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What drives smallholder farmers' crop production choices in Central Zambia? Lessons from the 2012/2013 agricultural season

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Abstract

The study, conducted in central Zambia was aimed at determining the major drivers of crop production choices among smallholder farmers. It utilized recent national crop production and utilization data; 200 semi-structured interview schedules, and key informant interviews conducted with smallholder farmers and experts from the agricultural sector in Zambia respectively. Results showed that despite being confronted by late on-set of rains and post germination crop attacks by army worms which made maize (*Zea mays*) production extremely precarious, 61.5% of the affected smallholder farmers replanted their cultivated land with maize. The farmers had a choice of whether to replant maize which had a ready market from the state agency, the Food Reserve Agency, or to plant a drought tolerant crop such as sorghum or millet which would have guaranteed them with household food security from own production. They mainly chose the former option. They increased production of other crops such as soya beans (*Glycine max*), sun flower *(Helianthus annuus)* and cotton (*Gossypium hirsutum*) when contract farming with private business entities became available. Markets determined smallholder farmers' crop production choices more than household food security from own production or availability of climate information forecasting poor rainfall distribution. The study concludes that (i) prior knowledge of climate information does not necessarily result in a change of smallholder farmers' crop production choices in response to a predicted climate anomaly, (ii) markets are a major determinant of crops cultivated by smallholder farmers, and hence adaptation measures involving crop diversification should be designed with market availability in mind.

Keywords: Climate information; conservation agriculture; food security; maize; markets

1. Introduction

Smallholder farmers in Zambia as in the rest of Sub Saharan Africa (SSA) face many challenges which contribute to their household food insecurity. For farmers in semi-arid areas of the region, major risks to agriculture involve water stress as a result of erratic, and insufficient or poorly distributed rainfall (Rosegrant et al., 2002). Agriculture for many of these farmers is rain-fed; hence they face a high risk of household food insecurity resulting from climate change and variability. While smallholder farmers might apply different methods to deal with climatic shocks and other risks, such as suitable crop and variety choice, application of fertilizer, planting density, and water harvesting (Aune and Bationo, 2008), they still contend with household food insecurity as their challenges involve a lot more than just extreme climatic events. For these smallholder farmers, it is not only floods or extreme droughts that are important to their sustainability. Such phenomena as intra-seasonal variability (Thomas et.al. 2007), the time at which the effective planting rains come, distribution of rainfall throughout the farming season (Mortimore and Adams, 2001), and how effective rainfall events are during each precipitation event (Usman and Reason, 2004), are more critical as they determine the yields for a particular season.

Adaptations in agricultural practices of smallholder farmers has been advanced in both popular and scientific literature as a major vehicle to achieving food security (Armitage et al., 2008; Câmpeanu and Fazey, 2014; Ericksen and Ingram, 2005; Gohari, 2013; Mubanga and Umar, 2014). To this end, the need for accurate climate information and efficient early warning might be seen as a means of ensuring smooth and effective farmer adaptation. Information about rainfall intensity and distribution within a particular season has been propagated as a major driver in changing farming methods or farming practices of smallholder farmers in rain fed systems (Mortimore and Adams, 2001; Vogel, 2000). The reactive adaptation measures expected to follow in cases of unfavourable climate information provision include; change in tillage practices, change in seed variety to be used or even change in crops cultivated by the affected farmers (Klein, 2003). These changes are all anticipated as efforts by smallholder farmers to ensure household food security and are expected to come about as a result of either farmer's access to seasonal rainfall forecasts or as a reactive adaptation measure to crop stresses observed early in the growing season. The crop stress might result from intra-seasonal droughts or floods to invading pests.

Although climatic factors influence the yields realized from a crop planted, they are not the only factors that dictate crop production choices and ultimately the household food security status of smallholder farming households. Crop production choices may also be influenced by farming households' desire to secure consumption from own production, market failures, and roles of state and non-state actors (Umar, 2011; 2013). This implies that although a well-chosen crop type with soil and climatic characteristics suitable for a particular region is more likely to produce higher yields as compared to a randomly chosen one, this in itself is not a sufficient reason for farming households to plant that crop. Other factors, which could be economic, socio-cultural or institutional, and equally likely to impinge on the household's food security status, may be at play. The factors and their salience, in influencing crop production choices vary across local, regional and national boundaries.

Understanding which factors influence smallholder farming households' crop choices is important as it can inform agricultural development interventions. Such information is important for development actors as they make decisions on the design and allocation of scarce resources to agricultural interventions that are more likely to have positive effects as they will be in line with the motivations of their targeted beneficiaries, smallholder farming households. This study, conducted in Shibuyunji district of central Zambia, was aimed at determining the drivers of crop choices by smallholder farmers in light of the available climate and local agriculture information during the 2012/2013 agricultural season. The purpose was to establish the major drivers of smallholder farmers' choice of crops cultivated in the district and derive some lessons for actors in the agriculture sector. The study finds that markets were the most important determinant of smallholder farmer crop choices as farmers dedicated disproportionate areas of land to the cultivation of crops whose market was guaranteed either by the state or by private firms.

2. Description of Study Area

Shibuyunji district is located in central Zambia about 70 km west of the capital city, Lusaka (Figure 1). It covers an estimated total area of 2087 km^2 and lies between latitudes 15° 20' 0" south of the equator and longitude 27° 56' 0" east. It receives average rainfall of between 800mm-1000mm which has a uni-modal seasonal distribution. The crop growing season ranges from 100 to 140 days (Saasa, 2003).

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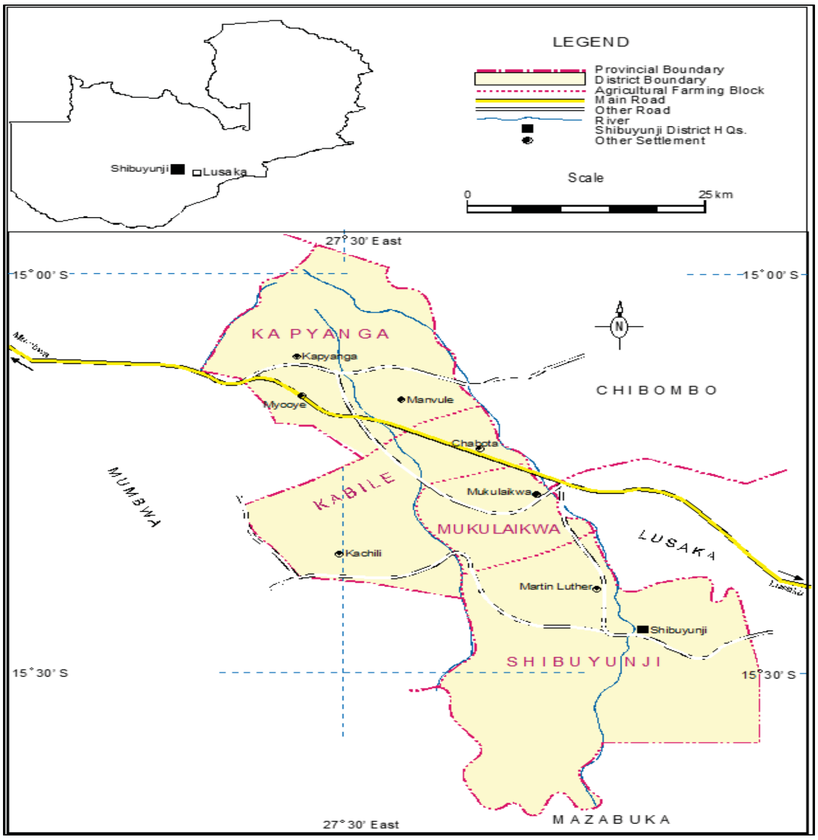

Figure 1. Shibuyunji District, Zambia

2.1 Rainfall Characteristics of the Study Area

The rainfall events in the area run from October to March with occasional rains in April. In the 2012/2013 season, Shibuyunji District started receiving rainfall in October. However, the effective planting rainfall was only received in the second week of December. This was the first opportunity for planting of most of the rain-fed crops and farmers took advantage of the opportunity. Ideally, planting ought to happen between 15th and 30th November (CFU, 2007) but the intra-seasonal drought experienced early in the season precluded any planting prior to mid-December. Most of the maize fields were attacked by an outbreak of army worms (*Pseudaletia unipuncta*) soon after germination. The affected farmers replanted their maize soon after the army worm infestation cleared. Consequently maize planting in the district continued up to late January.

Seasonal rainfall was below normal in magnitude and was poorly and differentially distributed in time and space among the districts' three agricultural blocks (Table 1). In the Zambian agricultural sector administration system, each district is subdivided into agricultural blocks, which are further divided into agricultural camps. A camp is the lowest level of agricultural administration and is ideally supposed to cover a radius of 15 km. Shibuyunji district has three agricultural blocks.

Table 1. Rainfall and temperature information for Shibuyunji district for 2012/2013 agricultural season

Agricultural Blocks in Shibuyunji	Average Rainfall (mm)	Mean Temperature (^{0}C)
Shibuyunji	812	21.5^{0}C (17-26^{0}C)
Mukulaikwa	507*	
Kapyanga	489*	

The information covers the period from November 2012 to March 2013.

*Below average rainfall.

2.2 Population Characteristics of the Study Area

Shibuyunji district has an estimated total population of 49 551 and 9764 households (CSO, 2011). Its population density of 24 persons per km^2 is higher than the national average of 17. It is an agricultural district with livestock rearing and crop production being the main activities. During the 2012/2013 agricultural season, 40 480 hectares of land was under cultivation while cattle population was at 32 030 (Ministry of Agriculture and Livestock, 2014: 6). The common types of livestock reared are cattle, goats, pigs, and a few donkeys while poultry consists mainly of free ranging chickens, guinea fowls and ducks. Livestock are important especially in times of hunger when through distress sales, most livestock owning households are able to purchase food (Tembo et al., 2014).

Shibuyunji District was created in 2011 and was hitherto a constituency under Mumbwa District in central Zambia. It was one of the districts severely hit by an army worm outbreak during the 2012/2013 agriculture season and hence provided a good case to study the behavior of smallholder farmers towards their crop production choices in light of the climatic and pest hurdles experienced.

3. Methods

Data for this study was collected during the 2012/ 2013 agricultural season over the period October 2012 to September 2013. The period covered a full crop growing cycle from land preparation, seed planting, weeding, to crop harvesting and marketing. The data was collected during two routine annual surveys conducted by the Ministry of Agriculture and Livestock (MAL), in collaboration with the Central Statistical Office. These two surveys are known as the Crop Forecast and Post-Harvest Surveys respectively. The crop forecast survey which has a national sample size of 13 600 agricultural households per year provides statistically representative estimates of crop production, area and yield at the national, provincial, and district levels from both smallholders and commercial farmers. The survey is conducted prior to crop harvest and records anticipated production and yield estimates based on the expert judgment of farmers. While it is understood that crop damage can occur after the survey is conducted, most crops in the country have already reached physiological maturity when the survey is conducted (IAPRI, 2014). The post-harvest survey is conducted in the same areas that are covered for the crop focus survey. The crop forecast data used in this study was collected between December 2012 and January 2013 while the post-harvest survey followed from July to

November 2013. The data pertaining to Shibuyunji district was extracted from the national datasets for both surveys.

Information on drivers of smallholder farmers' crop choices was obtained through a routine survey by MAL using a questionnaire administered to selected respondents who were purposively sampled on the basis of their having been farmers for a minimum of 5 years. A total of 200 farmers gave back their responses. Key informant interviews with officials from MAL as well as traditional leaders also formed part of the data collection package. A review of government agriculture reports related to provision of inputs, legislation, strategic plans beside literature on smallholder crop production was conducted in order to enhance the researchers' understanding of smallholder agriculture.

Analyses of the collected data were done using both qualitative and quantitative techniques. Quantitative analyses utilized statistical analyses software SPSS 22 and Microsoft Excel 10. Descriptive statistics including percentages, means, and graphs were derived using these software and formed tools for quantitative analysis. Qualitative data analysis was done using thematic analysis technique in which the responses were isolated into key emerging themes (Langdridge, 2004).

4. Results

Two of the three agricultural blocks in Shibuyunji district (Mukulaikwa and Kapyanga) had below expected rainfall while the other (Shibuyunji) recorded marginally normal rainfall during the 2012/2013 agricultural season. This was particularly worrisome for maize farmers most of whom planted the medium maturing hybrid maize varieties which required at least 800mm of well distributed rainfall. To compound the situation, army worms invaded maize fields soon after germination and farmers replanted their maize up to as late as January, 2013. The challenges to crop choices faced by the smallholder farmers in the district were compounded by the situation they found themselves in of planting maize in January considering the varieties available for planting required a growing period of 100-140 days while only 90 days of rainfall remained till the end of the season. Notwithstanding the challenges already highlighted, maize is naturally a sensitive crop and changes in weather conditions or intra-seasonal droughts occurring during seasons of high or low rainfall, can result in high yield loss particularly if the changes occur during germination or flowering (FAO, 2011; Umar and Nyanga, 2011). During the period under study both the amounts and distribution of rainfall for Shibuyunji were unsatisfactory for the optimum production of maize. This increased the precariousness of rain-fed maize agriculture.

4.1 Area under Cultivation for Major Crops in the 2012/2013 Agriculture Season

Farmers reserved 65% of their total cultivated land towards the growing of maize despite the seeming odds against a good maize harvest in the 2012/2013 growing season (Figure 2).The other crops cultivated included sunflower (*Helianthus annuus*), cotton (*Gossypium hirsutum*), groundnuts (*Arachis hypogaea*), cassava (*Manihot esculenta*) and soya beans(*Glycine max*).

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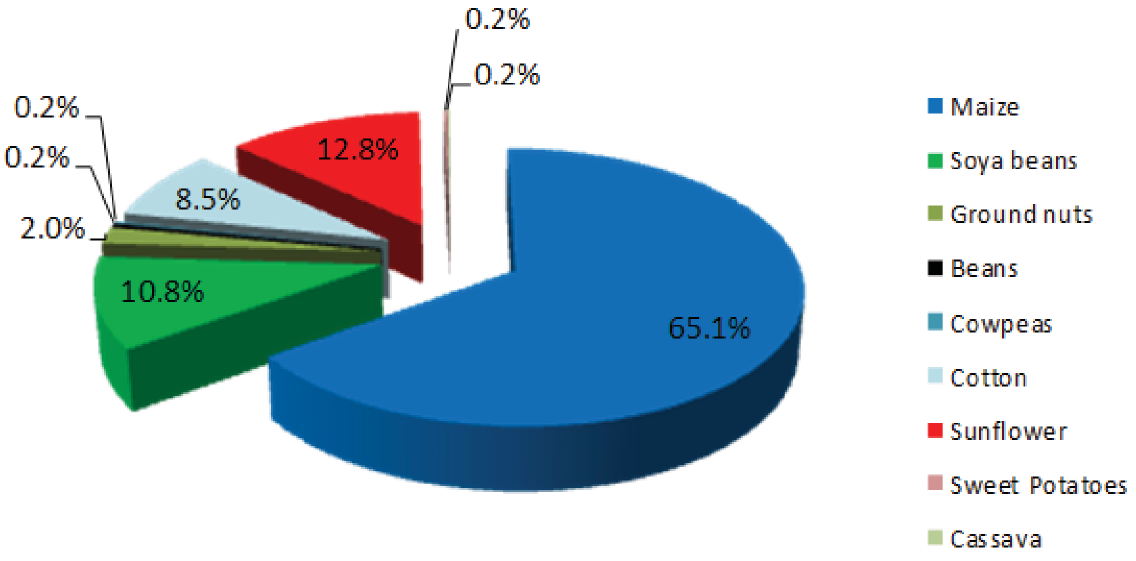

Figure 2. Area allocated towards cultivation of major crops in Shibuyunji district during the 2012/2013 agricultural season.

The relative importance of each of these crops to the farmers could be seen from the proportion of land they allocated to their cultivation (Figure 2). The dominance of maize production in Shibuyunji is clear but not unique. An aerial survey conducted in the southern province of the country in 1992 revealed that only 2% of smallholder lands were utilized for crops other than maize (Saasa, 2003:13). Commentators on Zambia's historical and current agricultural sector development have observed the sectors pre-occupation with maize production (Farringston and Saasa, 2002; Haggblade and Tembo, 2003; Sitko, 2011; Zulu et al., 2000). The dominance of maize production among smallholder farmers is attributable to several related factors. Since the country's independence in 1964, government agricultural policy has mainly focused on the provision of incentives for maize production and marketing (Tembo and Jayne, 2010).

The Farmer Input Support Programme (FISP) is a nationwide government subsidy programme through which smallholder farmers receive subsidized mineral fertilizer and free seed (Figure 3). Beneficiary farmers receive one pack of inputs which is sufficient for planting half (0.5) a hectare of land. Criteria for a smallholder farmer to benefit from FISP are that the farmer has to be a member of a registered farmer cooperative and should be cultivating between 1 and 5 hectares of land. The distribution of inputs was such that each beneficially farmer had a choice of their preferred input pack. During the period under review, a total of 7466 smallholder farmers benefited from FISP with 7180, 236 and 50 receiving maize, cotton and groundnut packs, respectively. The 7466 farmers represented 50% of the registered farmers in the district. The maize packs were selected by most farmers, showing the dominance of maize cultivation in the district.

Upon harvest, smallholder farmers have the opportunity to sell their maize to a government agency, the Food Reserve Agency (FRA) at floor prices that are announced at the beginning of the marketing season. The maize floor price is pan-territorial and pan-seasonal making it possible for smallholder maize producers in areas far from good roads and other communications infrastructure to be able to sell their maize at the same price as their counterparts in areas with more developed markets.

Typology of Input Subsidy Packages

i) **Maize pack:** 2 × 50kg basal dressing fertilizer, 2 × 50kg top dressing fertilizers and 1 ×10kg bag Maize seed

ii) **Sorghum pack:** 2 × 50kg basal dressing fertilizer, 1 × 50kg top dressing fertilizer and 1 × 5kg sorghum seed

iii) **Rice pack:** 1 × 50kg basal dressing fertilizer, 1 × 50kg top dressing fertilizer and 1 × 10kg bag rice seed

iv) **Groundnuts pack:** 1 × 50kg bag basal dressing fertilizer, 1 ×20kg bag groundnuts

v) **Cotton pack:** 2 × 50kg basal dressing fertilizer, 1 ×10kg cotton seed

Figure 3. Typology of input subsidy packages under the Fertilizer Input Support Programme. Basal fertilizer is (N: P_2O: $K^2 0$, 10:20:10) while top dressing fertilizer is 46% N.

Additionally, FRA sets up points at which farmers can deliver their maize to its agents in their locality. This is equivalent to a transport subsidy as these maize producers do not have to travel long distances to sell their maize. Analyses of the government set floor prices have revealed that these prices have been above market price levels (Mason and Myers, 2011) and have in effect encouraged hybrid maize adoption (Hamazakaza et al., 2013) and allocation of more land to maize and less to other crops (Umar, 2012). As of 2011/2012 agricultural season, over 1.2 million hectares of smallholder land was dedicated to maize production. This represents approximately 66 percent of the total smallholder land under cultivation in Zambia (Chamberlain et al., 2014: 1).

Also notable from Figure 2 is that farmers in Shibuyunji did not grow any cereal crops which could act as substitutes for maize, the staple crop in Zambia while the root crops, cassava and sweet potatoes (*Ipomoea batatas*) collectively contributed less than 1% of the total cultivated area. The low quantities could be explained by their low tradability as they are easily perishable crops.

Noteworthy from Figure 2 are the relatively high proportions of land allocated for sunflower, soya beans and cotton production. During the 2012/2013 agricultural season these crops also had a ready market from cooking oil manufacturing companies and cotton ginneries located within the area as they were under crop grower schemes. Despite their being perceived as unpopular, farmers in Shibuyunji area apportioned relatively large proportions of their land to the cultivation of sunflower, soya beans and cotton with a total of 4499, 3805, and 2978 hectares allocated to sunflower, soya beans and cotton respectively. This development was due to the existence of a ready market during the 2012/2013 agriculture season. This is explained in more detail in the next section.

4.2 Crops Produced Versus Crops Sold

By definition, smallholder farmers are partially engaged in input and output markets and are both producers and consumers (Ellis, 1993). They depend for their livelihoods on the production of food and other products that are provided by their own farms (Abebe, 2013). For crops such as maize, groundnuts, beans, and sweet potatoes, the farmers only sold part of the produce and retained the rest for household consumption while for crops such as soya beans, sunflower, and cotton, almost all the produce was sold (Table 2).

Cotton was produced under contract farming with cotton companies which provided inputs and extension services to the farmers (Chapoto et al., 2012). Three cotton companies-Dunavant, Alliance Ginneries, and Cargill- have a presence in the area. The farmers were legally obliged to sell the cotton to the cotton company that has provided the input loan at prices determined by the company after harvest. The farmers did not have to risk their own inputs for cotton production (Ibid). This seems to have positively influenced farmers' choices to grow cotton (Govereh et al., 2008).

Farmers also made the choice to grow crops traditionally considered unpopular in Shibuyunji due to incentives provided by oil and food processing companies; and Non- Governmental Organizations (NGOs). Unified Chemicals Zambia Ltd and Zambeef Products Plc. encouraged soya bean and sunflower production through contract farming arrangements which ensured ready markets for the two crops that smallholder farmers usually only produce under guaranteed market conditions.

Table 2. Crop production and sales in Shibuyunji District, 2012/2013 agricultural season

Crop	Quantity Produced (MT)	Quantity Sold (MT)	Percentage of crops sold
Maize	410.71	142.83	34.78
Soya beans	4.74	4.52	95.32
Ground nuts	0.60	0.38	63.94
Beans	0.06	0.03	54.94
Cowpeas	0.64	0.05	8.48
Cotton	2.03	1.95	96.15
Sunflower	2.88	2.86	99.20
Sweet Potatoes	0.40	0.22	54.88
Cassava	0.43	0.12	27.82

MT = metric tonnes. 1 MT = 1 000 Kilograms.

Concern Zambia and The International Institute of Tropical Agriculture (IITA) are two international NGOs operating in the study area on projects specifically aimed at encouraging crop diversification through the production of so called minor crops (Table 3).Through its RAIN (Realigning Agriculture to Improve Nutrition) Project, Concern Zambia has promoted legume production not only for protein provision to households but also for soil nitrogen fixation. IITAs MIRACLE (Making Agricultural Innovations Work for Smallholder Farmers Affected by HIV/AIDS in Southern Africa) project interventions include the production, consumption, and marketing of nutritious crop and livestock products. In Shibuyunji, the

MIRACLE project interventions included the promotion of legume production by giving out input packages to selected farmers who the project also trained in best agronomic practices for legume production. The input packages included cowpeas, soya beans and groundnuts. Up to 700 smallholder farming households were supported in this way.

Table 3. Organizations supporting smallholder arable agriculture in Shibuyunji district

No.	Name of organization	Activities involved in
1.	Harvest Plus	Promoting cultivation of vitamin A fortified maize, sweet potatoes, and groundnuts.
2	Dunavant/ Cargill/ Alliance Ginneries	Cotton production
3.	CFU	Conservation agriculture
4.	IITA (MIRACLE Project)	Promoting legume production e.g. soya beans, cow peas, groundnuts.
5.	Concern Zambia (RAIN Project)	Promoting crop diversification to unpopular crops e.g. soya beans and sugar beans
6.	Unified Chemicals Zambia/ Zambeef Products	Promoting growing of crops used for oil production e.g. soya beans and sunflower

The Conservation Farming Unit (CFU), a unit under the Zambia National Farmers Union has been promoting conservation agriculture in the area. One of the principles of conservation agriculture encouraged by CFU in the area is crop rotation using leguminous crops such as soya beans, velvet beans (*Mucuna pruriens*), and groundnuts. CFU encourages its farmers by *inter alia*, providing them with free legumes seeds. Following the introduction of conservation agriculture activities in the area during the 2009/2010 agricultural season, the district recorded an increase in production and productivity of crops with maize moving from an average yield of 2 tonnes to 2.2 tonnes per hectare for non-CA and 3.5 tonnes per hectare for CA smallholder farmers respectively (Department of Agriculture Official, personal communication.).

Other than maize; soya beans, cotton and sunflower were the only other crops to have over 1 MT produced during the 2012/2013 agricultural season. The rest of the crops-with no guaranteed market-were only cultivated in trace amounts as they were considered mainly as crops for household consumption only. For example, less than 10 % of the cowpeas produced were sold. This highlights the important role that activities of private business entities and NGOs play in influencing smallholder farming households' crop choices.

4.3 Vegetable Production

Smallholder vegetable production is engaged in during the dry season on fields close to perennial water bodies such as small rivers and streams. Small scale irrigation systems are employed. Vegetable production is thus the preserve of those smallholder farming households that have fields close to perennial water sources. During the 2012/ 2013 agricultural season, farmers in Shibuyunji allocated 54 hectares of land for vegetable production. The vegetables cultivated included rape (*Brassica napus*), onion (*Allium cepa*), *Kalembula* (leaves of *Ipomoea* *batatas*), African eggplant (*Solanumt orvum*), okra (*Abelmoschus esculentus*) and tomatoes (*Solanum lycopersicum*).

Table 4. Off-season vegetable crop production in Shibuyunji district, 2012/2013 agricultural season

Vegetable	Area planted (ha)	Quantity produced (MT)	No. of households engaged in production
Rape	2.5	17	48
Onion	1.5	0.23	39
Kalembula	8.0	172.5	42
African eggplant	15	100.8	109
Okra	24	100	69
Tomatoes	15	180	13
Total	54		

Most of the vegetables were transported to Lusaka for sale and formed the main source of income for farmers during the maize off-season. Vegetables are the second highest earner of smallholder farmers' income in the district after maize (Department of Agriculture Official personal communication).

4.4 Drivers of Smallholder Farmers' Crop Choices- Their Views

The results from the 200 farmers interviewed showed availability of markets as the most widely cited driver for their crop production choice (Table 5). In fact even household food security ranked second behind markets as a driver for smallholder farmers' choice of crop production. Climate information was ranked fourth. The low importance attached to climate information is contrary to results reported by Arimi (2014) who found that among smallholder farmers in Nigeria, access to early warning information was a major predictor of adaptation.

Table 4. Reasons for smallholder farmers' choice of crops for production

Reasons for cultivation of particular crops	Percentage of Farmers (%) n = 200
Availability of markets	100
Household food security	94
Availability of inputs	72
Does well under current weather	32
Less labour intensive	16

The findings in Table 5 agree with the conclusions from the analysis of the crop production data. Maize not only had guaranteed markets, but was important for household consumption and the availability of maize seed and fertilizer was enhanced through FISP. Soya beans, cotton and sunflower were cultivated more due to the markets and inputs provided by interested non state actors. The more the availability of markets, the higher the quantities of a crop produced. Smallholder farmers allocated most of their cultivated land to the production of maize. The markets attached to maize cultivation were arguably the biggest incentive for the dominance of maize. During the 2012/2013 agricultural season, the government through the Food Reserve

Agency (FRA) was buying a 50kg bag of maize for ZMW65 (~US $10) which was higher than the prices most private buyers were offering. FRA purchased the maize from depots conveniently located close to smallholder farmers' homes for easy transportation. This reduction in transport costs highly reduced costs attached to the sale of maize thereby increasing the income derived from it. This essentially made maize production more attractive to smallholder farmers compared to other crops. The incentives for maize production arguably made the risk of crop failure worth taking by the farmers.

The government policy of buying white maize from smallholder farmers annually at above market prices has to some extent encouraged the maize mono – cropping culture and over dependency on the commodity among this group. This is because the production of other crops has not been incentivized to such high levels by the both the state and non-state actors in the agricultural sector. Private buyers and/or companies are usually the market providers for other crops and do not offer similarly high price levels and farmers have complained about what they consider to be very unattractive prices. The maize-centric agricultural policy has been inimical to other government programmes aimed at encouraging crop diversification among smallholder farmers (GRZ, 2013).

The fact that the government only bought white grade maize hindered intra- crop diversification. Currently, farmers in Shibuyunji are reluctant to engage in the production of yellow or orange maize varieties despite their nutritional superiority as these varieties are not accepted for purchase by FRA. Harvest Plus, an NGO operating in Shibuyunji has been encouraging smallholder farmers' to cultivate orange maize which is fortified with Vitamin A. However, the adoption rate has been relatively low and farmers have complained of being unable to sale it to FRA. Only small quantities are cultivated for household consumption. This reasoning has also affected production of crops more agronomically suited to the district such as sorghum, millet, cassava and sweet potatoes.

4.5 Lessons Learnt

Five main lessons are drawn from this study of smallholder farmers' crop choices during the 2012/2013 agricultural season in Shibuyunji. Firstly, while advance knowledge of climate information by farmers is important, mere knowledge of when and how much rainfall or rainfall distribution an area will face will not result in farmers changing their agricultural practices in response to the predicted climate anomaly. This is despite the rainfall parameter being recognized as the most important climate parameter affecting smallholder farmers yields (Vogel, 2005) under rain fed agriculture. The study showed that not even late on-set of rainfall, pest occurrence or knowledge of increased risks involved in maize production was enough to change farmers from the maize dominance culture. Such information might be useful as a starting point in sensitizing farmers on the importance of newer and more successful agricultural practices, but it will not make farmers abandon their already established practices. Secondly, the availability of markets is a major determinant of crop production choices by smallholder farmers. Farmers in the study area considered it as the most important determinant of crop choice. Knowledge of this is important as markets may emerge as a catalyst towards promoting crop diversification. Crop production is currently seen as an important adaptation measure to impacts of climate change (Mubanga and Umar, 2014) as well as an adaptation pathway for response to changes and stressors (Câmpeanu and Fazey, 2014). Therefore, market information should not be looked at as a separate issue from smallholder agriculture but as an integral part of it, for purposes of ensuring household food security. Enhancing food security through agro-ecological specific crop varieties should proceed from establishment of tangible markets if farmers are going to adapt to the promoted varieties. Telling farmers to grow a particular crop variety will not result in household food security if the crop they are told to cultivate does not have a ready market. Hence adaptation measures involving agro-ecological specific crops and varieties should be attached to existing markets for them to be effective. Modern technologies involving crop diversification would be more effective if crops promoted for diversification had ready markets for produce.

Thirdly, achieving household food security is not always the main objective for smallholder farmers (Swift and Hamilton, 2001). If achieving food security was the goal, farmers in the study area would have converted from maize cultivation to a more drought tolerant crop such as sorghum or millet. However, farmers preferred the assured increased incomes associated with maize production which could enable them purchase their desired materials rather than the household food security assured by a drought tolerant crop with no guaranteed income returns. Fourthly, counterproductive policies may work against the same objectives other government programmes hope to achieve. Attaching markets to maize by the government through FRA works against an established agriculture adaptive pathway in crop diversification-one of the objectives of FISP. Furthermore, crop diversification is expected to play a very important role in achieving food security as well as sustainable food systems. The fifth lesson is on the role of non-state actors in affecting farmers' crop choices such as the roles of NGOs and private business entities. The ability of these institutions to enhance crop diversification was seen in the relatively high number of hectares apportioned to promoted crops such as soya beans, sunflower and cotton compared to the non-supported crops. The growth of the agriculture sector would be accelerated through inter-institutional cooperation and this should include both promotion and marketing of produce.

5. Conclusions

Smallholder agriculture in Shibuyunji district was confronted by several challenges during the 2012/2013 agricultural season. The late on-set of rains and crop attacks by army worms meant conditions for re-planting of maize only became possible in late January when it was late for farmers to plant the medium maturing maize varieties available to them. The farmers had a choice of whether to plant maize which had a ready market from the state or to plant a drought tolerant crop such as sorghum or millet which would guarantee them with household food security from own production. The allocation of 65.1% of their cultivatable land to maize production with no maize substitute planted entailed that farmers opted to risk with the maize which had ready market. The study concluded that availability of markets was the major determinant of crop choice for farmers even more than availability of climate information. Several lessons were drawn from this; (i) prior knowledge of climate information will not result in a change of smallholder farmers' agricultural practices in response to the predicted climate anomaly, (ii) markets are a major determinant of particular crops cultivated by smallholder farmers, hence adaptation measures involving crop diversification should be designed with market information in mind, (iii) food security is not always the objective of smallholder farmers' agriculture. Knowledge of this should influence the kind of help rendered to smallholder farmers by both state and non-state actors.

References

Abebe, T. (2013). Determinants of crop diversity and composition in enset-coffee agroforestry home gardens of Southern Ethiopia. *Journal of Agriculture and Rural Development in the Tropics and Subtropics, 114*(2013), 29-38.

Arimi, K. (2014). Determinants of climate change adaptation strategies used by rice farmers in Southwestern, Nigeria. *Journal of Agriculture and Rural Development in the Tropics and Subtropics, 115*(2014), 91-99.

Armitage, D. R., Plummer, R., Berkes, F., Arthur, R. I., Charles, A. T., Davidson-Hunt, I. J., Wollenberg, E. K. (2008). Adaptive co-management for social–ecological complexity. *Frontiers in Ecology and the Environment, 7*(2), 95-102. doi: 10.1890/070089

Aune, J. B., & Bationo, A. (2008). Agricultural intensification in the Sahel – The ladder approach. *Agricultural Systems, 98*(2), 119-125. doi: http://dx.doi.org/10.1016/j.agsy.2008.05.002

Câmpeanu, C. N., & Fazey, I. (2014). Adaptation and pathways of change and response: A case study from Eastern Europe. *Global Environmental Change*(0). doi: http://dx.doi.org/10.1016/j.gloenvcha.2014.04.010

CFU (2007). Conservation Farming and Conservation Agriculture: Handbook for Ox Farmers in Agro-Ecological Regions 1 and lla. Conservation Farming & Conservation Agriculture. Lusaka, Zambia, Conservation Farming Unit.

Chamberlin, J., Sitko, N.J., Kutega, A., Lubungu, M., & S. Tembo. . (2014). Maize Market Coordination in Zambia. An Analysis of the Incentives and Obstacles to Improved Vertical and Horizontal Marketing Arrangements *Technical Report No. 2* Lusaka: Indaba Agricultural Policy Research Institute.

Chapoto, A., Haggblade, S., Hichaambwa, M., Kabwe, S., Longabaugh, S., Sitko, N., & Tschirley, D. (2012). Agricultural Transformation in Zambia: Alternative Institutional Models for Accelerating Agricultural Productivity Growth and Commercialization *IAPRI Working Paper No. 64*. Lusaka: Indaba Agricultural Policy Research Institute (IAPRI).

Ellis, F. (1993). *Peasant Economics*. Cambridge: Cambridge University Press.

Ericksen, P. J., & Ingram, J. S. I (2005). Global Environmental Change and Food Systems (GECAFS). IHDP Annual Report 2004-5. pp. 45-46.

FAO. (2011). Climatic Risk Analysis in Conservation Agriculture in Varied Biophysical and Socio-economic Settings of Southern Africa. Johannesburg: Regional Emergency Office for Southern Africa (REOSA).

Farrington, J., & Saasa, O. (2002). Drivers for Change in Zambian Agriculture Defining What Shapes the Policy Environment', report for DFID.

Gohari, A., Eslamian, S., Abedi-Koupaei, J., Massah Bavani, A., Wang, D., & Madani, K. (2013). Climate change impacts on crop production in Iran's Zayandeh-Rud River Basin. *Science of The Total Environment 442 (0)*, 405-419.

Govereh, J., Jayne, T. S., & Chapoto, A. (2008). Assessment of alternative maize trade and market policy interventions in Zambia *FSRP Working Paper No. 33*. Lusaka: Food Security Research Project (FSRP).

GRZ. (2013). Ministry of Agriculture and Livestock: End of Year Report 2013. Choma: Department of Agriculture.

Haggblade, S., & Tembo, G. (2003). Conservation Farming in Zambia. EPTD Discussion Paper No. 108. Washington. D.C., International Food Research Policy Research Institute.

Hamazakaza, P., Smale, M., & H. Kasalu. . (2013). The Impact of Hybrid Maize on Smallholder Livelihoods in Zambia. Findings of a household Survey in Katete, Mkushi and Sinazongwe Districts *Working paper 73*. Lusaka: Indaba Agricultural Policy Research Institute.

Klein, J. T. R. (2003). Adaptation to Climate Variability and Change: What is Optimal and Appropriate? In E. E. C. Giupponi and M. Schechter (eds.) (Ed.), *In: Climate Change in the Mediterranean: Socio-Economic Perspectives of Impacts, Vulnerability and Adaptation* (pp. 32–50). Cheltenham, UK: Potsdam Institute for Climate Impact Research.

Langdridge, D. (2004). *Introduction to research methods and data analysis in Psychology*. England: Pearson Education Limited.

Mason, M. N., & Myers, J. R (2011). The Effects of the Food Reserve Agency on Maize Market Prices in Zambia: Are There Threshold Nonlinearities. Working Paper No. 60. Lusaka, Zambia, Food Security Research Project (FSRP).

Mortimore, M. J., & Adams, W. M. (2001). Farmer adaptation, change and 'crisis' in the Sahel. *Global Environmental Change, 11*(1), 49-57. doi: http://dx.doi.org/10.1016/S0959-3780(00)00044-3

Mubanga, K. H., & Umar, B. B. (2014). Smallholder Farmers' Responses to Rainfall Variability and Soil Fertility Problems by the Use of Indigenous Knowledge in Chipepo, Southern Zambia. *Journal of Agricultural Science 6*(6), 75-85.

Saasa, O. S. (2003). Agricultural intensification in Zambia. The role of policies and policy processes. On the project: Africa Food Crisis-The relevance of Asian models, Institute of Economics and Social Research. University of Zambia. Collaborative study between Lund University and The Institute of Economic and Social Research, University of Zambia.

Sitko, N. J., Chapoto, A., Kabwe, S., Tembo, S., Hichaambwa, M., Lubinda, R., Chiwawa, H., Mataa, M., Heck, S., & Nthani, D. (2011). Technical Compendium Descriptive Agricultural

Statistics and Analysis for Zambia in Support of the USAID Mission's Feed the Future Strategic Review. LUSAKA, ZAMBIA, FOOD SECURITY RESEARCH PROJECT, WORKING PAPER No. 52.

Swift, J., & Hamilton, K. (2001). Household food and livelihood security. In: Devereux, S., Maxwell, S. (Eds.), Food Security in Sub-Saharan Africa. ITDG, London.

Thomas, D. G., Twyman, C., Osbahr, H., & Hewitson, B. (2007). Adaptation to climate change and variability: farmer responses to intra-seasonal precipitation trends in South Africa. *Climatic Change, 83*(3), 301-322. http://dx.doi:10.1007/s10584-006-9205-4.

Tembo, G., and Jayne, S. T. (2010). "Increasing Returns to Marketing in Zambian Maize Markets." *Zambia Social Science Journal 1*(2), 140-157.

Tembo, G., Kapekele, E., Tembo, A., Goma, F. Y., & Sambo, J. (2014). Livestock trends and farmers' perceptions about their impacts in Southern Zambia. *Journal of Agricultural Studies. 2*(2), 11-20. http://dx.doi.org/10.5296/jas.v2i2.5397.

Umar, B. B. (2012). *From Maize Mono-cropping to Conservation Agriculture: A Multi-perspective Analysis of Smallholder Conservation Agriculture in Southern, Central and Eastern Zambia.* (PhD), Norwegian University of Life Sciences Norway.

Umar, B. B., & Nyanga, P.H. (2011). *Conservation agriculture and rainfall variability in Zambia: is CA a promising option for responding to droughts and floods?* Paper presented at the 5th World Conference on Conservation Agriculture, Brisbane Australia.

Usman, M. T., & Reason, C. J. C. (2004). Dry spell frequencies and their variability over southern Africa. *Climate Research, 26*(3), 199-211. http.//dx.doi: 10.3354/cr026199.

Vogel, C. (2000). Usable science: An assessment of long-term seasonal forecasts amongst farmers in rural areas of Sourth Africa. *South African Geographical Journal, 82*(2), 107-116. http://dx.doi.org/10.1080/03736245.2000.9713700.

Vogel, C. (2005). Seven Fat Years and Seven Lean Years"? Climate Change and Agriculture in Africa. *IDS Bulletin 36*(2), 30-35.

Zulu, B., Nijhoff, T. T., Jayne, T. S., & Negassa, A. (2000). Is the Glass Half-Empty or Half Full? An Analysis of Agricultural Production Trends in Zambia. FSRP Working Paper No.3. Lusaka, Food Security Research Project.

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Extending Postharvest Longevity and Improving Quality of Strawberry (*Fragaria Ananasa* Duch Cv. ‘Gaviota’) Fruit by Postharvest Salicylic Acid Treatment

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Abstract

Strawberries are an extremely perishable fruit mainly due to their soft texture and sensitivity to fungal infection. Postharvest application of conventional fungicides to fruits is prohibited. As an alternative to fungicides, salicylic acid has been found to enhance disease resistance of horticultural crops. In order to study the effect of salicylic acid as a phenolic compound on the postharvest durability and quality characteristics of strawberry fruit. ‘Gaviota’ strawberries were treated with SA at different concentrations (0, 25, 50 and 100 µlL^{-1}), then stored for 12 days at 4 ˚C and 75 % RH in darkness. Two different methods were applied (spray SA on fruits and paper disk method). Quality attributes such as weight loss, pH, TA, TSS, vitamin C, anthocyanin, calcium, pectin, CAT, POD, PG activity, decay percentage and sensory analyses evaluated every 3 days during storage. Results showed that, treated fruits with SA had lower weight loss, pH, TSS, POD, PG, decay and higher TA, vitamin C, anthocyanin, calcium, pectin, CAT and fruit quality compared with controls. Between two methods of treatment, paper disk method had higher effect on fruit decay and quality compared to spray method and as a general result, caused longer storability.

Keywords: Postharvest durability, Salicylic acid, Enzyme activity, Fruit quality.

1. Introduction

Strawberry fruit quality decrease rapidly after harvesting, due to the high metabolic activity (Lolaei *et al*., 2012). Because of the harmful effects of chemical fungicides on human health and the environment, developing safe and nonchemical compounds are highly needed (Mandal *et al*., 2009). Salicylic acid or ortho-hydroxybenzoic acid is one of the effective natural phenolic compounds has been extensively used for quality improvement in a number of crops and as a plant growth regulator can enhance disease resistance of plants (Pen and Jiang, 2006). SA is considered as generally recognized as safe (GRAS) (Hooper and Cassidy, 2006). Lolaei *et al*. (2012) were studied the effect of SA as postharvest treatment on the strawberry fruit quality. Treated fruits had higher TA, vitamin C and redness and less weight loss, decay than the control and delays the ripening of strawberry fruit. Application of SA at nontoxic concentrations to susceptible fruits and vegetables could enhance resistance to pathogens and control postharvest decay of crops (Asghari *et al*., 2009; Asghari *et al*., 2007; Babalar *et al*., 2007). Methyl salicylate (MeSA) vapor was significantly affected postharvest decay of Hayward kiwifruit during storage period (Soleimani Aghdam *et al*., 2009). Treatment of pear fruit in 1 mmol L^{-1} SA solution effectively controlled fruit decay during 5 months of storage (Asghari *et al*., 2007). Postharvest treatment of strawberry fruits with 1 and 2mmolL^{-1} significantly controlled fruit decay and increased shelf life of fruit (Babalar *et al*., 2007). Treatment of table grapes with SA before coating with chitosan effectively enhanced the efficacy of coating and decreased fruit total decay (Asghari *et al*., 2009). Postharvest treatment of grapes with SA had a positive effect on hardiness, appearance of fruit and controlled fungal infections compared with control (Duan *et al.,* 2007). The application of 2 mμ SA effectively increased antioxidant compounds, ascorbic acid content and TSS and prevented fungal infection of strawberries (Amborabe *et al.,* 2002) and softening of bananas and kiwifruits at maturity stage (Srivastava and Dwivedi, 2000; Wang and Zheng, 2001). SA significantly reduced the quality loss in peaches (Wang *et al*., 2006), tomato (Ding *et al*., 2001), sweet peppers (Fung *et al.,* 2004), and loquat fruits (Cai *et al*., 2005). The aim of the present study was to evaluate the effects of postharvest salicylic acid application on quality parameters during cold storage and storage life of strawberry fruit.

2. Materials and Methods

2.1 Plant Material

strawberries (*Fragaria ananassa* L.), cv. 'Gaviota' were harvested in the morning randomly from a commercial greenhouse located in Hashtgerd, Karaj, Iran at commercial maturity stage and transported to the laboratory where undamaged fruits at the same ripening stage (80% of the skin red) were selected. Samples were taken every 3 days up to the end of experiment (12 days) and fruits were evaluated at each sampling time after keeping them a day at room temperature.

2.2 SA Treatment

Treatments with SA were performed by dissolving the requisite amounts of SA (0, 25, 50 and

100 μlL^{-1}) in ethanol. Two different methods were applied (spray SA on fruits and paper disk method). SA sprayed on fruits and spotted onto filter paper at the final concentration of control, 25, 50 and 100 μlL^{-1} then air dried. Each treatment was replicated three times with 150 g fruits per replicate. All packages were stored at 4 ˚C and 75 % RH in darkness for 12 days. Measurements were made at room temperature every 3 days. Quality attributes such as weight loss, pH, TA, TSS, vitamin C, anthocyanin, calcium, pectin, CAT, POD, PG activity, decay percentage and sensory analyses evaluated during storage.

2.3 Weight Loss Percentage

The effect of SA exposure on fruit weight loss was also investigated. Weight of individual fruits was recorded at the beginning of harvest and different sampling times and expressed as percentage of original weight (Saini *et al*., 2006).

2.4 pH

pH was measured using a pH meter Metrohm Lab 827 (Saini *et al*., 2006).

2.5 Titratable Acidity (TA)

Titrable acidity was measured using titration method. To do that, 5 mL fruit juice was added to 25 mL distilled water plus two drops of phenolphthalein and titrated with 0.1N NaOH up to pH 8.1. The results were expressed as gram of citric acid per 100 g fresh weight (AOAC, 1990).

2.6 Total Soluble Solids (TSS)

TSS was determined using ATAGO-ATC-20E (Japan) refractometer at 20 ºC and expressed as ºBrix.

2.7 Vitamin C Assay

The content of vitamin C was determined using indophenol procedure. 10 ml of samples were filtrated and titrated against sodium 2, 6-dichlorophenol indophenol dye to a faint pink color which persisted for 5-10 seconds. It was expressed as mg vitamin C/100g fruit weight (Titer × dye equiv. × dilution ×100/ Wt. of sample) (Saini *et al.*, 2006).

2.8 Anthocyanin Assay

Total anthocyanin content of strawberry extract was measured using the pH differential method. Absorbance was measured at 510 and 700 nm, respectively, in different buffers at pH 1.0 and 4.5, using A = [(A510-A700) pH1.0 (A510-A700) pH 4.5] with a molar extinction coefficient for cyanidin-3-glucoside of 29600. Results were expressed as milligrams of cyanidin-3-glucoside (C3G) equivalents per 100 g of fresh weight (Cheng & Breen, 1991).

2.9 Calcium Content

Calcium was precipitated as calcium oxalate. The precipitate was dissolved in hot dilute sulfuric acid and titrated with standard potassium permanganate. 1ml.0.1N $KMnO_4$=0.002 gm. Calcium (Ruck, 1969).

2.10 Pectin Content

Pectin was precipitated as calcium pectate from an acid solution by the addition of calcium chloride. The calcium pectate precipitate was washed with water until chloride-free, then dried and weighed. Ca pectate (%) = wt. of Ca pectate× 100 / wt. of sample (Ruck, 1969).

2.11 Peroxidase Activity

POD activity was assayed Spectrophotometrically with guaiacol by measuring an increase in absorbance at 470 nm (ε= 26.6 mM-1cm-1) according to Maehly and Chance (1954). The mixture of 0.5 cm3 of the enzyme extract, 0.5 cm3 of 50 mM acetate buffer (pH 5.6), 0.5 cm3 of 20 Mm guaiacol and 0.5 cm3 of 60 mM H_2O_2 was used. The enzyme activity was expressed in units (mmol tetraguaiacol min-1) per g fresh weight.

2.12 Catalase Activity

CAT activity was determined at 25 °C according to Aebi (Aebi, 1984). The reaction mixture contained 40 mM phosphate buffer pH 7.0 and 0.1 ml pure enzyme in a total volume of 3ml. CAT activity was estimated by decreased in absorbance of H_2O_2 at 240nm.

2.13 Polygalacturonase Activity

PG activity was determined by measuring reducing groups released from sodium polypectate, using D-galacturonic acid as the standard. The assay medium reagents were 0.2 M acetate buffer, pH 4.5 to the amount 0.2 ml, and 1% polygalacturonic acid in 0.05 M acetate buffer solution pH 4.5 to the amount 0.3 ml. One ml of enzyme solution and distilled water was added. The reaction started by adding the enzyme, and it was then left for 30 min at 37° C, after which the reaction was stopped by adding 3, 5 – dinitrosalicylic acid (DNS). The solution was then boiled in water for 5 min, after which it was diluted and absorbance measured at a wavelength of 520 nm, using galacturonic acid (0–1mg/ml) as the standard solution (Miller, 1959). One unit of polygalacturonase activity (U/g) was defined as the amount of enzyme which released one mol of galacturonic acid per minute per gram of substrate.

2.14 Decay Percentage

Percent of decay was scored on a 1-5 scale, where: 1= intact fruit, 2= more than 5 % Decay, 3= between 5-20 % decay, 4= between 20-50 % decay, 5= more than 50% decay (Ayala-Zavala *et al*., 2005).

2.15 Sensory Evaluation

Sensory analyses to compare the quality of treated and control fruits were carried out by a 10 trained adults aged 25-40 years. It was about aroma, taste, firmness, appearance and texture. Panelists scored fruits between1-10. Ten being the best total quality and 1 being the worst (Hernandez-Munoz *et al*., 2008). Samples were scored for overall quality by using an interval hedonic scale. Assessments were continued until fruits condition were considered unacceptable.

2.16 Statistical Analysis

Statistical analysis of the data obtained in the present study was carried out using split factorial method in a completely randomized design layout with 3 replications. Data obtained were subjected to analysis of variance (ANOVA).

3. Results and Discussion

3.1 Weight Loss

No significant differences in weight loss were observed among all of the SA treatment concentrations. SA treatment decreased weight loss of strawberries during storage for 12 days compared with controls. Between two methods of treatments fruits that treated with paper disk method (Figure 1) had more weight loss than spray method (Figure 2). SA can also decrease the respiration rate and fruit weight loss (Zheng and Zhang, 2004). Lolaei *et al.* (2012) reported that strawberry fruits dipped by SA had less weight loss and the greatest fruit weight loss was calculated in plants treated with 7mM. Besides, our results are in agreement with Garcia *et al.* (1995) who found similar results in strawberry fruits cv. 'Tudla' and Soleimani Aghdam *et al*. (2011) who stated that weight loss of the kiwifruit was significantly decreased when they were treated by methyl salicylate (MeSA). Weight loss in fruit decreased with increasing of MeSA concentration. Decrease in fruit metabolic activities results to decrease in fruit water content, weight loss, carbohydrate depletion rate and delay fruit senescence process (Wills *et al.,* 1998). Kazemi *et al*. (2011) reported that maximum weight loss occurred in control apples while lowest loss was recorded in 3 mM SA treatment. SA also decreases in respiration rate and fruit weight losses by closing stoma (Zheng & Zhang, 2004).

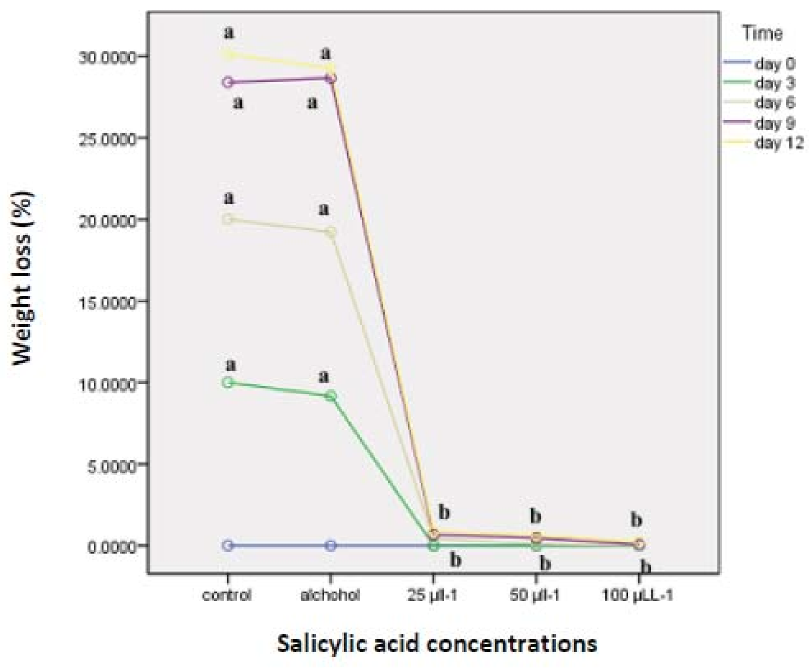

Figure 1. The effect of salicylic acid treatment on weight loss of strawberry fruit in paper disk method.

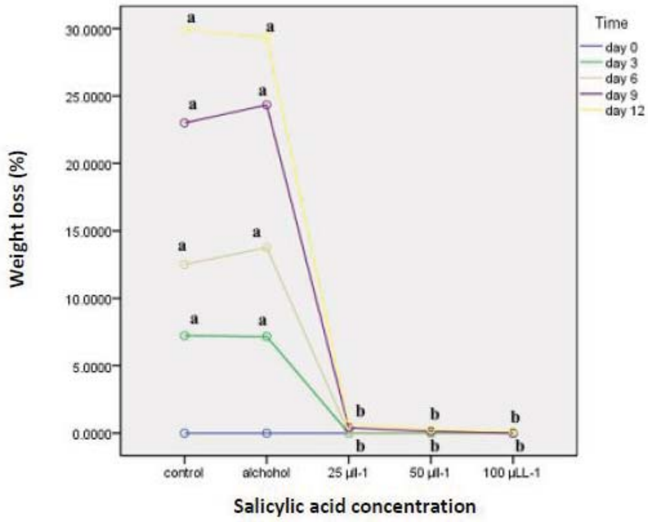

Figure 2. The effect of salicylic acid treatment on weight loss of strawberry fruit in spray method.

3.2 pH

The pH value of strawberry fruit increased slightly, corresponding to a decrease in TA during storage. Little difference in pH value was observed among all of the treatments. Control fruits had the most pH value and 100 µlL^{-1} concentration of SA had the least pH value (Figure 3). No significant differences were observed between methods of treatments application. Our results are in agreement with Soleimani Aghdam *et al*. (2011) who found that MeSA treatment significantly affected pH and pH of kiwifruit fruit juice increased after 3 months of storage but then decreased to end of storage. The fluctuations of pH might be due to the variations in TA or temperature of storage and the decline of acidity is attributed due to increased activity of citric acid content may be due to their conversion into sugars and further utilization in metabolic process during storage (Rathore *et al*., 2007).

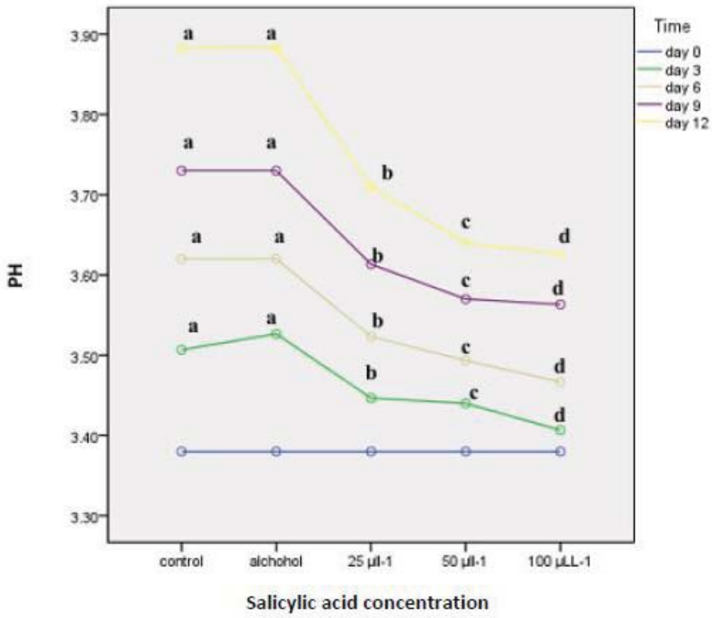

Figure 3. The effect of salicylic acid treatment on pH of strawberry fruit.

3.3 TA and TSS Content

SA treatment increased TA content and decreased TSS content in strawberries compared to controls. TA decreased gradually during storage. TA of 100 µlL^{-1} concentration of SA was the highest among all SA concentrations (Figures 4 and 5). TSS of fruits increased during storage. Among all concentrations of SA 25 µlL^{-1} had the lowest TSS amount (Figure 6). Fruits that treated with spray method had more TA content compared with paper disk method (Figures 4 and 5). Lolaei et al. (2012) found that postharvest SA treatments induced higher TA values than the control that was in agreement with our results. Lu et al. (2011) reported that postharvest treatment of strawberry with SA resulted in an increased TA of fruit. Also, Bal and Celik (2010) stated that TA content was lower in controls than other treated kiwifruits. TA is directly related to the concentration of organic acid present in the fruit which are an important parameter in maintaining the quality of fruits (Kazemi et al., 2011). Study of Lu et al. (2011) on pineapple fruit showed that the application of SA as postharvest treatment resulted in a decreased TSS. Shafiee et al. (2010) reported that postharvest treatment of strawberry with ASA resulted in a lower TSS than the control. Asghari (2006) reported that SA decreased TSS in strawberry cv. Selva and Lolaei et al. (2012) showed that treatment of kiwifruits with 32 mlL^{-1} MeSA maintained a lower TSS content than the control fruits at the end of cold storage. These results are in agreement with our results. TSS content of fruits during storage is considered an index of fruit ripening and an increase in TSS of control fruits corresponds to a conversion of starch to soluble sugars.

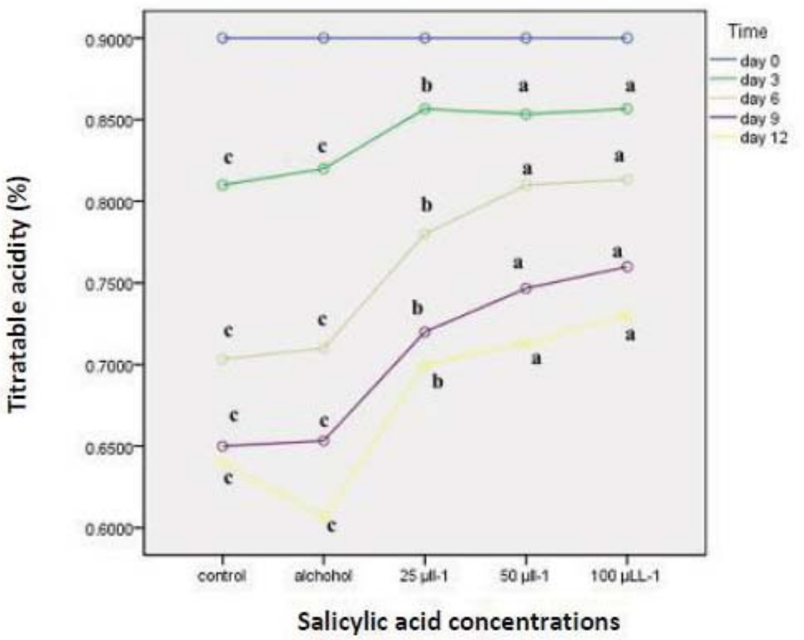

Figure 4. The effect of salicylic acid treatment on titratable acidity of strawberry fruit in paper disk method.

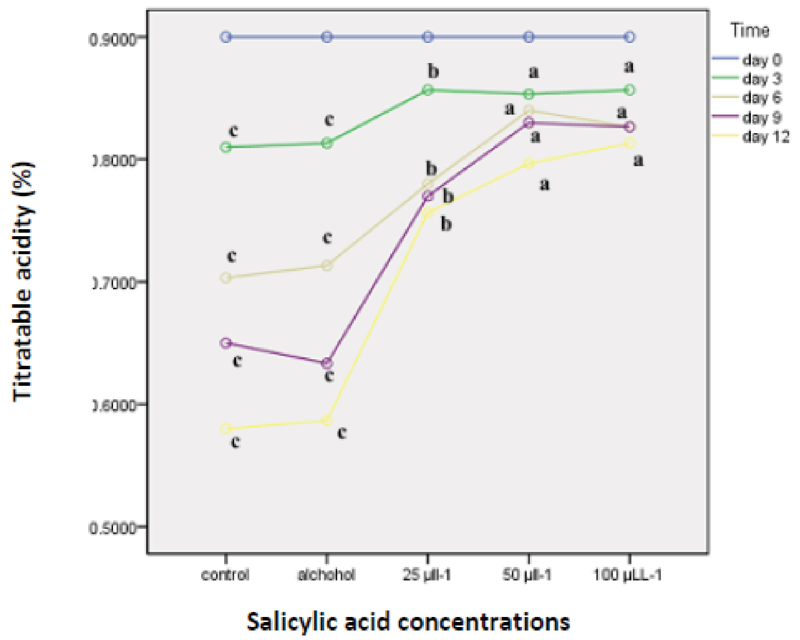

Figure 5. The effect of salicylic acid treatment on titratable acidity of strawberry fruit in spray method.

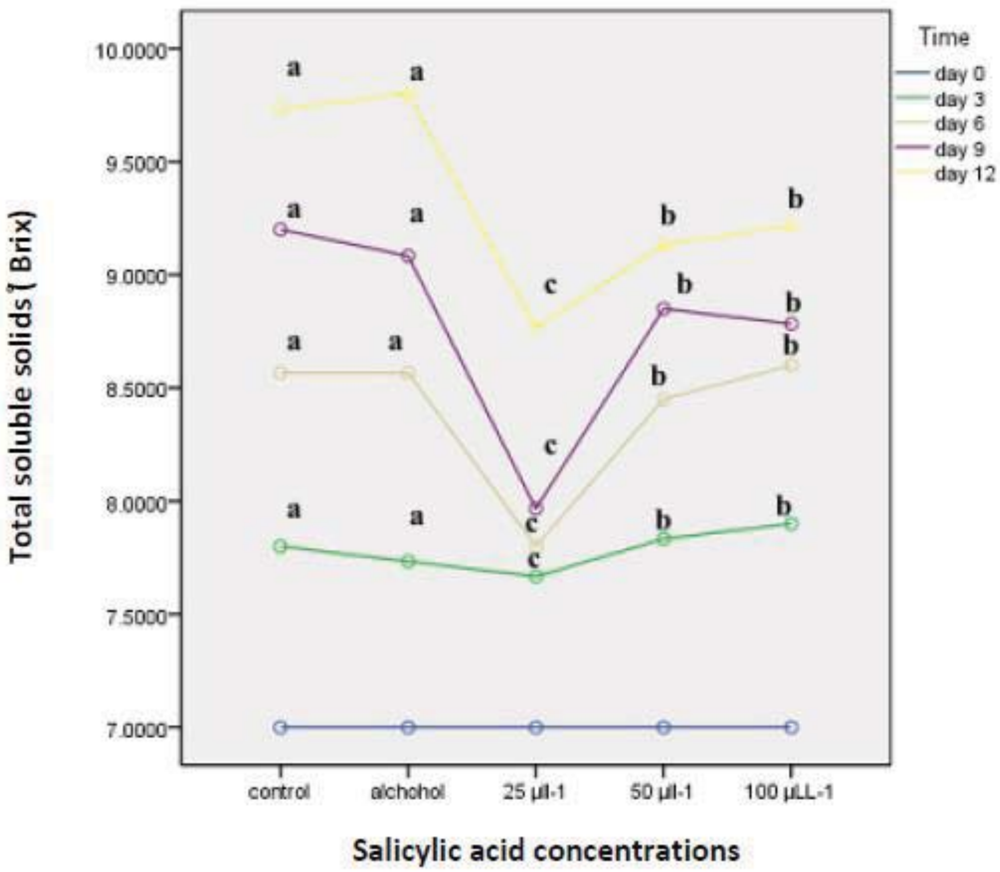

Figure 6. The effect of salicylic acid treatment on total soluble solids of strawberry fruit.

3.4 Vitamin C

Vitamin C content of fruits was markedly affected by SA treatment, whereas high concentrations of SA (50 or 100 µlL^{-1}) had the highest amount of vitamin C (Figure 7). The levels of vitamin C were higher in SA-treated fruits than in control samples. The content of strawberry vitamin C did not show changes in response to SA (Lolaei et al., 2012). The application of SA can increase vitamin C content and then decrease antioxidant in strawberry fruit (Jing-Hua et al., 2008). Soleimani Aghdam et al. (2011) found that MeSA treatment maintained significantly ascorbic acid content of the kiwifruit during storage and there was a positive correlation between MeSA concentration and fruit ascorbic acid content that are in agreement with our results. Hung et al. (2007) suggested that high ascorbate (AA) contents in the pulp of pretreated fruit with SA may result from an acceleration of biosynthetic pathways or a decrease in catabolism through an accumulation of dehydroascorbate (DHAA).

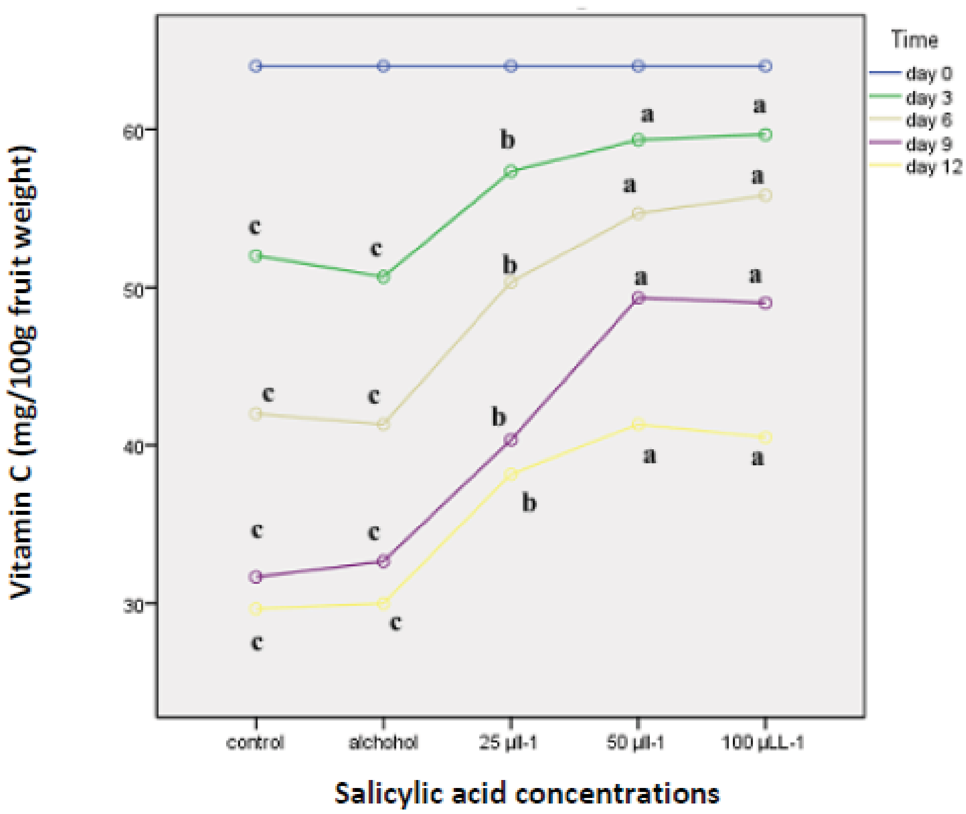

Figure 7. The effect of salicylic acid treatment on vitamin C of strawberry fruit.

3.5 Anthocyanin content

Anthocyanin content decreased during storage period. As shown in Figure 8, the levels of anthocyanin were higher in SA-treated fruits than in control samples; whereas the higher concentration of SA (100 and 50 µlL^{-1}) treated fruits had the most amount of anthocyanin. There were not significant differences between two methods of SA application. Anthocyanins are a group of phenolic compounds responsible for the red-blue color of many fruits. Javaheri et al. (2012) stated that application of SA increased the fruit lycopene content also they showed that SA activated the synthesis of carotenoids and xanthophylls. In accordance with our results Tareen et al. (2012) reported that SA treatments significantly affected skin color of peach fruits during 5 weeks of storage period.

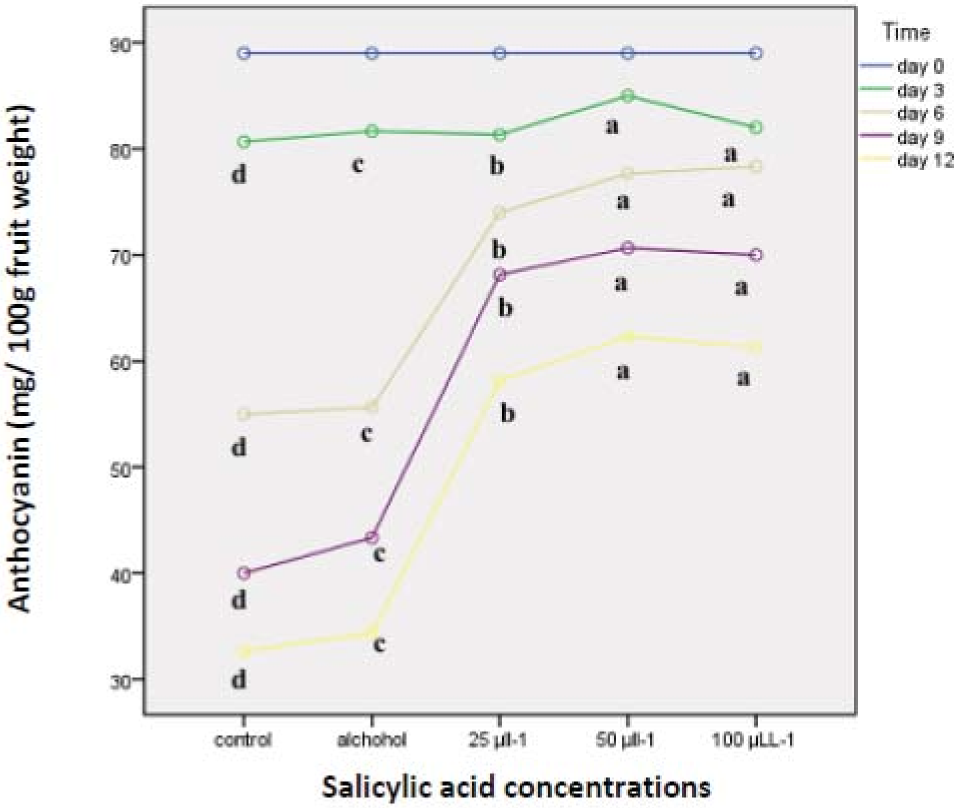

Figure 8. The effect of salicylic acid treatment on anthocyanin of strawberry fruit.

3.6 Calcium and Pectin Contents

Calcium and pectin contents decreased gradually during storage period. SA-treated fruits had more calcium and pectin content compared to controls. There was no significant difference in pectin and calcium between methods of SA application. The effect of SA treatment on fruit calcium and pectin significant varied with the concentrations applied. As shown in Figure 9 and 10 treatment with 50 μlL^{-1} had the highest amount of calcium and pectin and the lowest concentration of SA (25 μlL^{-1}) had the lowest amount of calcium and pectin. Pectins are likely to be the key substances involved in the mechanical strength of the primary cell wall which are important to the physical structure of the plant (Sirisomboon *et al*., 2000). Ca^{+2} appears to be necessary because it induces the cross-linking of polygalacturonan chains into a structure that can be recognized by its isoperoxidase (Penel *et al*., 1999). Coway *et al*. (1987) stated that the loss of firmness due to call wall carbohydrate metabolism during storage has been associated with increased susceptibility to infection by fungal pathogens.

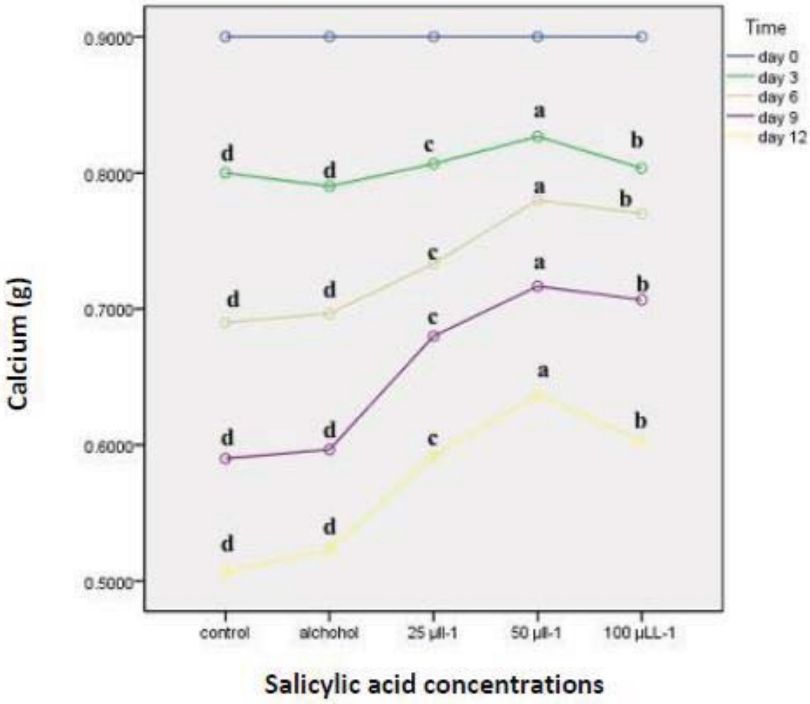

Figure 9. The effect of salicylic acid treatment on calcium of strawberry fruit.

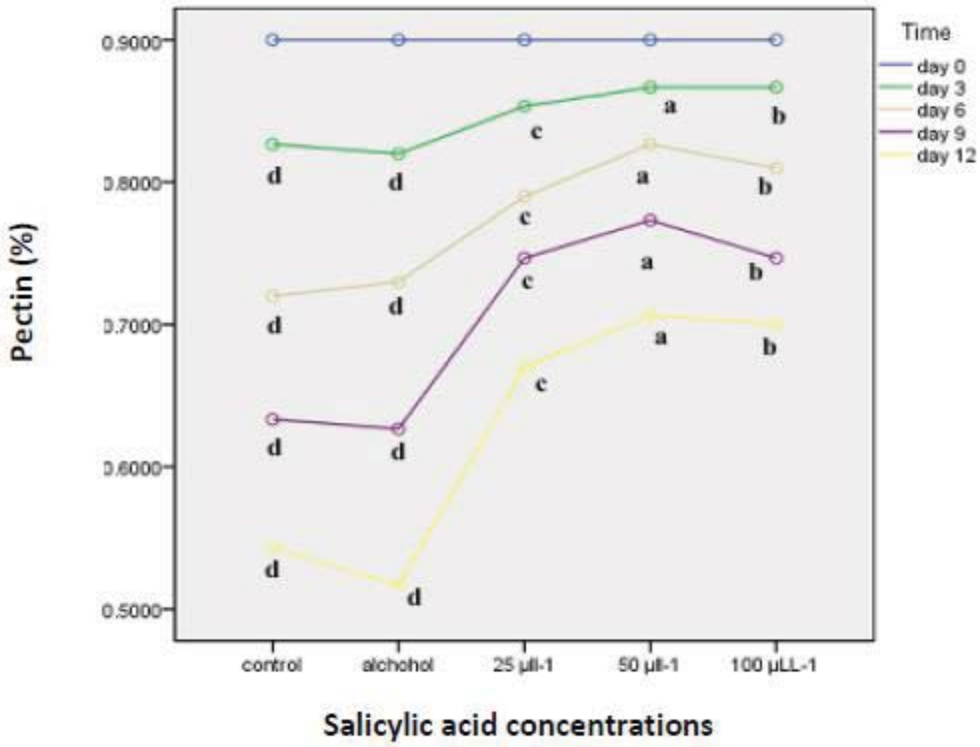

Figure10. The effect of salicylic acid treatment on pectin of strawberry fruit.

3.7 CAT Activity

Result showed that the catalase activity decreased at the end of the storage period. The samples which were subjected to SA with 50 and 100 µlL^{-1} concentrations had the highest catalase activity (Figure 11). Catalase eliminates H_2O_2 by breaking it down directly to form water and oxygen. In consistent of our results, Soleimani Aghdam *et al*. (2011) stated that the lowest CAT activity observed when 32 µlL^{-1} MeSA applied at all determination times, while the highest CAT activity was related to control fruits. SA interaction with CAT leads to high levels of H_2O_2 accumulation in cells, which induces fruit resistance against pathogens via activating protective enzymes and pathogenesis related (PR) proteins (Klessig and Malamy, 1994; Malamy and Klessig, 1992).

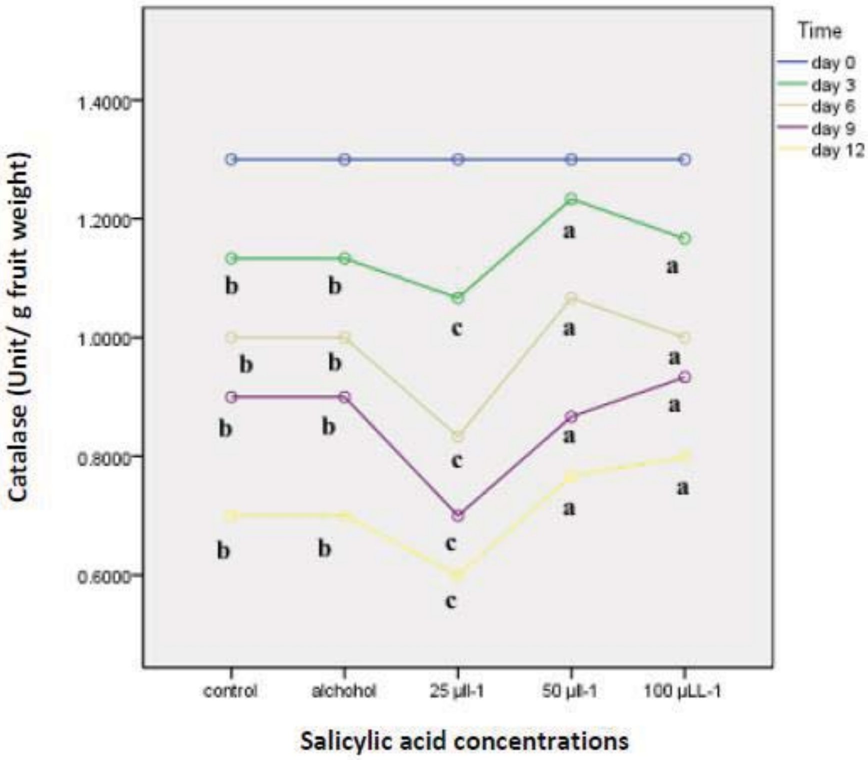

Figure 11. The effect of salicylic acid treatment on catalase activity of strawberry fruit.

3.8 POD Activity

Peroxidase activity increased along the storage. The samples treated with SA concentrations 50 and 100 µll^{-1} showed a significant decreased in POD rate (Figure 12). Peroxidase (POD) activity plays an important role in the oxidative degradation of phenolic compounds, which can lead to the production of brown polymers (Tomás-Barberán and Espín, 2001). Srivastava and Dwivedi (2000) stated that SA treatment decreased levels of POD, than their respective controls, in a concentration dependent manner, during the ripening of banana fruits. In consistent with our results Kazemi et al. (2011) indicated that maximum POD activity was observed in 3 mM SA in the storage duration.

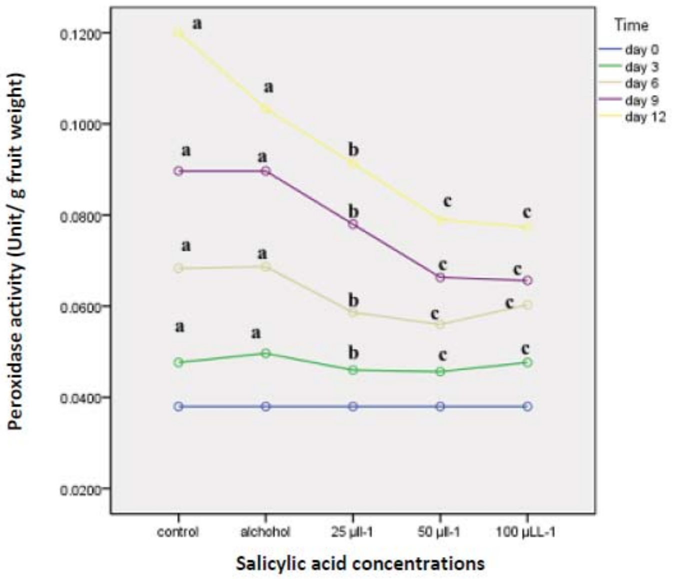

Figure 12. The effect of salicylic acid treatment on peroxidase activity of strawberry fruit.

3.9 PG Activity

PG content of fruits increased significantly along the storage period. The controls had the highest PG activity and the samples which were subjected to SA had less PG activity compared to controls (Figure 13). The samples which were treated with 100µlL^{-1} SA had the lowest PG activity. Treatment of banana with SA resulted in decreased level of cell wall degrading enzyme in a concentration dependent manner, during the ripening of fruit (Srivastava and Dwivedi, 2000). PG is reported to be primarily responsible for ripening associated pectin degradation and fruit softening (Huber, 1983). Physical and chemical treatments which suppress ripening inhibit PG gene expression (Ogura et al., 1975; Picton et al., 1993).

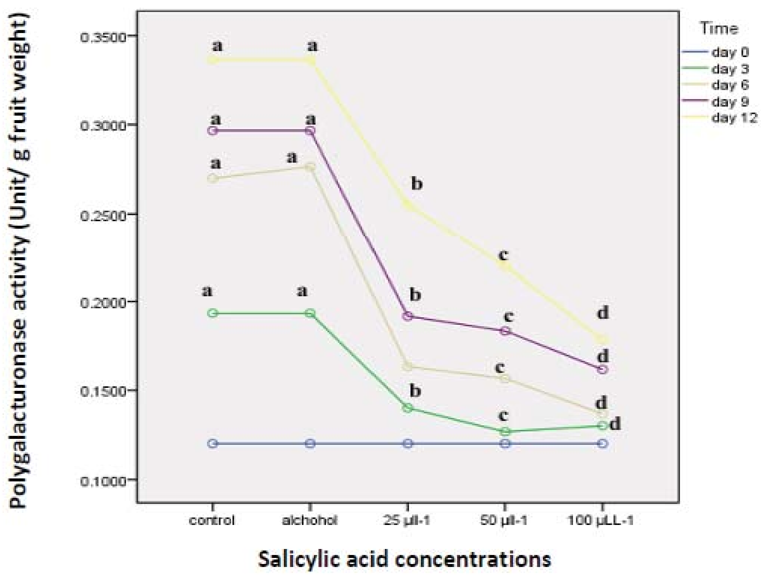

Figure 13. The effect of salicylic acid treatment on polygalacturonase of strawberry fruit.

3.10 Fruit Decay

The effect of SA treatment on fruit decay significant varied with the concentrations applied and storage time. Treatment with 100µLL^{-1} SA significantly inhibited fruit decay throughout the storage period, whereas control samples had the least effect. Paper disk method inhibited fruit decay more than spray method (Figures 14 and 15). SA is also involved in local and systemic resistance to fungal pathogens (Meena *et al*., 2001). It is known that SA can enhance disease resistance of detached plant organs (Meena *et al.,* 2001; Qin *et al.,* 2003). SA can induced disease resistance by coordinate activation of a specific set of PR-genes many of which encode for proteins with antimicrobial activity (Durrant and Dong, 2004; Van Loon *et al*., 2006). Duan *et al*. (2007) stated that SA treatment of grapes decreased fungal infections which showed significant differences with control. Soleimani Aghdam *et al*. (2011) showed that kiwifruit fungal decay was significantly affected by MeSA vapor in the end of shelf life period compared with control fruits. Application of SA in a concentration dependent manner from 1 to 2mmolL^{-1} effectively reduced fungal decay in 'Selva' strawberry fruit (Babalar *et al.,* 2007). Asghari *et al*. (2007) found that dipping of pear fruit in 1 mmolL^{-1} SA solution effectively controlled fruit decay during cold storage period. These results are in agreement with our results.

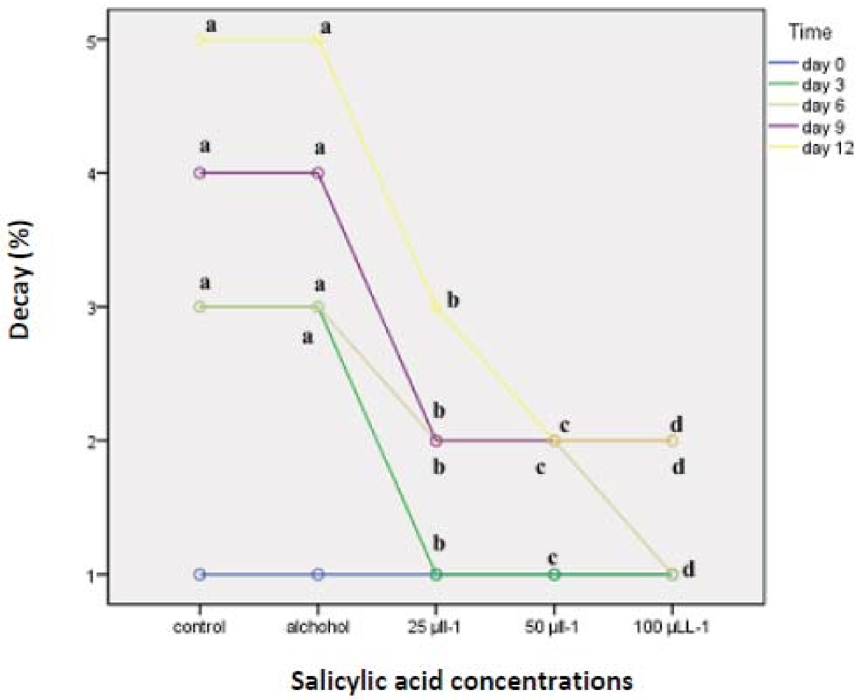

Figure 14. The effect of salicylic acid treatment on decay percentage of strawberry fruit in paper disk method.

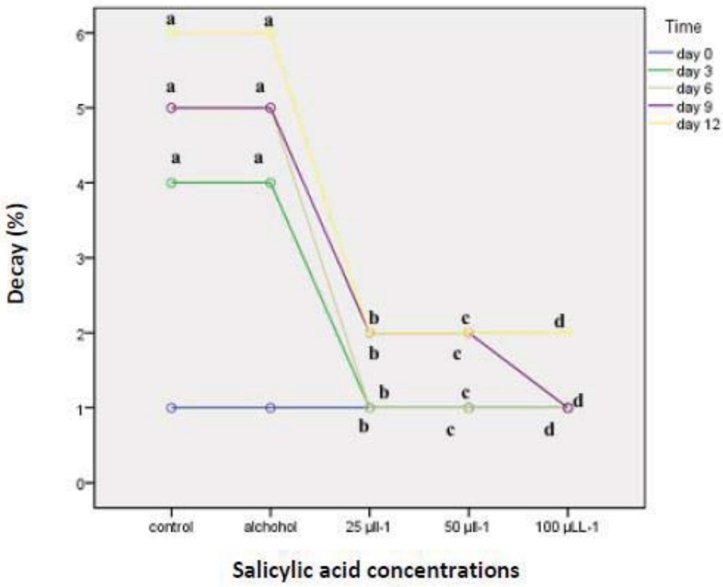

Figure 15. The effect of salicylic acid treatment on decay percentage of strawberry fruit in spray method.

3.11 Sensory analyses

Overall quality decreased continuously during storage at higher rate in untreated fruits compared with those treated with SA. Treatment with 100µlL^{-1} SA had the highest effect on fruit quality among all of concentrations. Fruits that treated with paper disk method had better fruit quality compared with spray method (Figures 16 and 17). These results showed that SA treatment had a significant effect on retaining quality parameters in strawberry fruit. Our results are in accordance with Kazemi *et al.* (2011) about apple fruit.

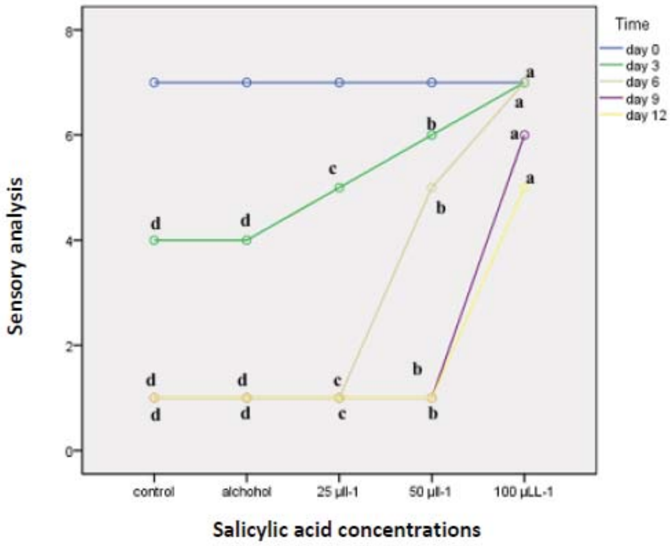

Figure 16. The effect of salicylic acid treatment on sensory analysis of strawberry fruit in paper disk method.

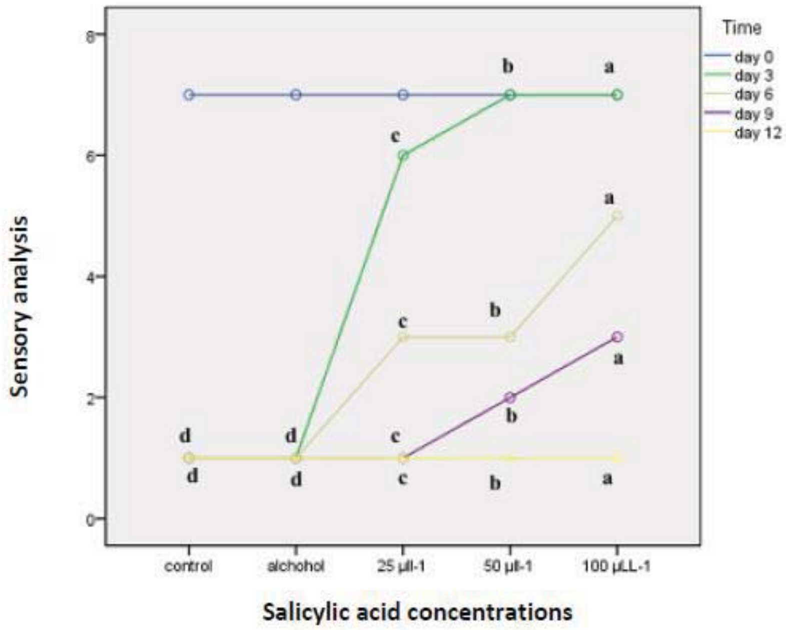

Figure 17. The effect of salicylic acid treatment on sensory analysis of strawberry fruit in spray method.

References

Aebi, H. (1984). Catalase. In: L. Packer (Ed), methods in enzymology, Academic Press, Orland, *105,* 121-126.

Amborabe, B.E., Lessard, P., Chollet, J.F. & Roblin, G. (2002). Antifungal effects of salicylic acid and other benzoic acid derivatives towards Eutypalata: structure-activity relationship. *Plant Physiology and Biochemistry, 40,* 1051-1060. http://dx.doi.org/10.1016/S0981-9428(02)01470-5

AOAC, (1990). Official methods of analysis of the Association of Official Analytical Chemists. 15th ed., Association of Official Analytical Chemists, Arlington V A 1058-1059.

Asghari, M.R., Hajitagilo, R. & Jalil Marandi, R. (2009). Postharvest application of salicylic acid before coating with chitosan affects the pattern of quality changes in table grape during cold storage. In 6th International Postharvest Symposium, Antalya, Turkey.

Asghari, M.R., Hajitagilo, R. & Shirzad, H. (2007). Postharvest treatment of salicylic acid effectively controls pear fruit diseases and disorders during cold storage. In: Proceedings of the international congress on Novel approaches for the control of postharvest diseases and disorders COST action, *924,* 355-360.

Asghari, M. (2006). Effects of salicylic acid on Selva strawberry fruit, antioxidant activity, ethylene production and senescence, fungal contamination and some other quality attributes. Ph.D. Thesis, University of Tehran.

Ayala-Zavala, J. F., Wang, S. Y., Wang, C. Y., & Gonzalez-Aguilar, G. A. (2005). Methyl jasmonate in conjunction with ethanol treatment increases antioxidant capacity, volatile compounds and postharvest life of strawberry fruit. *European Food Research Technology, 221,* 731-738. http://dx.doi.org/10.1007/s00217-005-0069-z

Babalar, M., Asghari, M., Talaei, A. & Khosroshahi, A. (2007). Effect of pre and postharvest salicylic acid treatment on ethylene production, fungal decay and overall quality of Selva strawberry fruit. *Food Chemistry, 105,* 449-453. http://dx.doi.org/10.1016/j.foodchem.2007.03.021

Bal, E., & Celik, S. (2010). The effects of postharvest treatments of salicylic acid and potassium permanganate on the storage of kiwifruit. *Bulgarian Journal of Agricultural Science, 16(5),* 576-584.

Cai, C., Li, X. & Chen, K. S. (2005). Acetylsalicylic acid alleviates chilling injury of postharvest loquat fruit. *European Food Research Technology, 223,* 533-539. http://dx.doi.org/10.1007/s00217-005-0233-5

Cheng, G.W. & Breen, P.J. (1991). Activity of phenylalanine ammonia lyase (PAL) and concentrations of anthocyanins and phenolics in developing strawberry fruit. *Journal of American Society Horticultural Sciences, 116,* 865-869.

Conway, W. S., Gross, K. C., & Sams, C. E. (1987). Relationship of bound calcium and inoculums concentration to the effect of postharvest calcium treatment on decay of apples by *Penicillium expansum*. *Plant Disease, 71,* 78-80. http://dx.doi.org/10.1094/PD-71-0078

Ding, C. K., Wang, C. Y., Gross, K. C., & Smith, D. L. (2001). Reduction of chilling injury and transcript accumulation of heat shock protein genes in tomatoes by MeJA and MeSA. *Plant Science, 161,* 1153-1159. http://dx.doi.org/10.1016/S0168-9452(01)00521-0

Duan, X., Su, X., You, Y., Qu, H., Li, Y., & Jiang, Y. (2007). Effect of nitric oxide on pericarp browning of harvested longan fruit in relation to phenolic metabolism. *Food Chemistry, 104,* 571-576. http://dx.doi.org/10.1016/j.foodchem.2006.12.007

Durrant, W. E., & Dong, X. (2004). Systemic acquired resistance. *Annual and Plant Pathology, 31,* 139-145. http://dx.doi.org/10.1146/annurev.phyto.42.040803.140421

Fung, R., Wang, C., Smith, D., Gross, K., & Tian, M. (2004). MeSA and MeJA increase steady-state transcript levels of alternative oxidase and resistance against chilling injury in sweet peppers. *Plant Science, 166,* 711-719. http://dx.doi.org/10.1016/j.plantsci.2003.11.009

Garcia, J. M., Aguilera, C. & Albi, M. A. (1995). Postharvest heat treatment on Spanish strawberry. *Journal of Agriculture Food Chemistry, 43,* 1489-1492. http://dx.doi.org/10.1021/jf00054a014

Hooper, L. & Cassidy, A. (2006). A review of the health care potential of bioactive compounds. *Journal of Science Food Agriculture, 86,* 1805-1813. http://dx.doi.org/10.1002/jsfa.2599

Hernandez-Munoz, P., ALmenar, E., Del Valle, V., Velez, D. & Gavara, R. (2008). Effect of chitosan coating combined with postharvest calcium treatment on strawberry quality during refrigerated storage. *Food Chemistry, 110,* 428-435. http://dx.doi.org/10.1016/j.foodchem.2008.02.020

Hung, R. H., Liu, J. H., Lu, Y. M., & Xia, R. X. (2007). Effect of salicylic acid on the antioxidant system in the pulp of Cara Cara navel orange at different storage temperatures. *Postharvest Biology and Technology, 47,* 168-175. http://dx.doi.org/10.1016/j.postharvbio.2007.06.018

Huber, D. (1983). Role of cell wall hydrolases in fruit softening. *Horticultural Review, 5,* 169-219.

Javaheri, M., Mashayekhi, K., Dadkhah, A., & Zaker Tavallaee, F. (2012). Effects of salicylic acid on yield and quality characters of tomato fruit (*Lycopersicum esculentum* Mill*.). International Journal of Agriculture and Crop Sciences, 4(16),* 1184-1187. http://dx.doi.org/10.1002/9781118060728.ch4

Jing-Hua, Y., Yuan, G., Yan-Man, L., Xiao-Hua, Q. & Ming-Fang, Z. (2008). Salicylic acid induced enhancement of cold tolerance through activation of antioxidative capacity in watermelon. *Science Horticulture, 118,* 200-205. http://dx.doi.org/10.1016/j.scienta.2008.06.015

Kazemi, M., Aran, M., & Zamani, S. (2011). Effect of salicylic acid treatments on quality characteristics of apple fruits during storage. *American Journal of Plant Physiology, 6*(2), 113-119. http://dx.doi.org/10.3923/ajpp.2011.113.119

Klessig, D. F., & Malamy, J. (1994). The salicylic acid signal in plants. *Plant Molecular Biology, 26*, 1439-1458.http://dx.doi.org/10.1007/BF00016484

Lolaei, A., Kaviani, B., Rezai, M. A., Khorrami Rad, M., & Mohammadipour, R. (2012). Effect of pre and postharvest treatment of salicylic acid on ripening of fruit and overall quality of strawberry fruit. *Annals of Biological Research, 3*(10), 4680-4684.

Lu, X., Sun, D., Li, Y., Shi, W., & Sun, G. (2011). Pre and postharvest salicylic acid treatments alleviate internal browning and maintain quality of winter pineapple fruit. *Scientia Horticulturae, 130*, 97-101. http://dx.doi.org/10.1016/j.scienta.2011.06.017

Mandal, S., Mallick, N., & Mitra, A. (2009). Salicylic acid acid-induced resistance to Fusarium oxysporum f. sp. Lycopersici in tomato. *Plant Physiology Biotechnology, 47*, 642-649. http://dx.doi.org/10.1016/j.plaphy.2009.03.001

Miller, G. L. (1959). Use of DNS reagent for determination of reducing sugars. *Analytical Chemistry, 31*, 426-428. http://dx.doi.org/10.1021/ac60147a030

Malamy, J., & Klessig, D. F. (1992). Salicylic acid and plant disease resistance. *Plant Journal, 2*, 643-654. http://dx.doi.org/10.1111/j.1365-313X.1992.tb00133.x

Meena, B., Marimuthu, T., & Velazhahan, R. (2001). Salicylic acid induces systemic resistance in groundnut against late leaf spot caused by Cercosporidium personatum. *Journal* *of Mycology and Plant Pathology, 31*, 139-145.

Ogura, N., Nakagawa, H., & Takenhana, H. (1975). Effect of storage temperature of tomato fruits on changes of their polygalacturonase and pectinesterase activities accompanied with ripening. *Journal of Agricultural Chemistry Society Japan, 49*, 271-274. http://dx.doi.org/10.1271/nogeikagaku1924.49.271

Penel, C., Van Custem, P., & Greppin, H. (1999). Interactions of a plant peroxidase with oligogalacturonides in the presence of calcium ions. *Phytochemistry, 51*, 193-198.http://dx.doi.org/10.1016/S0031-9422(98)00741-9

Peng, L., & Jiang, Y. (2006). Exogenous salicylic acid inhibits browning of fresh-cut Chinese water chestnut. *Food Chemistry, 94*, 535-540.http://dx.doi.org/10.1016/j.foodchem.2004.11.047

Picton, S., Barton, S. L., Bouzayen, M., Hamilton, A. J., & Grierson, D. (1993). Altered fruit ripening and leaf senescence in tomatoes expressing an antisense ethylene forming enzyme transgene. *Plant Journal, 3*, 469-481.http://dx.doi.org/10.1111/j.1365-313X.1993.tb00167.x

Qin, Q. Z., Tian, S. P., Xu, Y., & Wan, Y. K. (2003). Enhancement of biocontrol efficacy of antagonistic yeasts by salicylic acid in sweet cherry fruit. *Physiology and Molecular Plant Pathology, 62*, 147-154. http://dx.doi.org/10.1016/S0885-5765(03)00046-8

Ruck, J.A. (1969). Chemical method of analysis of fruit and vegetable products. Res. Station, Summerland, B.C. 14-16.

Rathore, H. A., Masud, T., Sammi, S. & Soomro, A. H. (2007). Effect of storage on physio-chemical composition and sensory properties of mango variety Dosehari. *Pakistan Journal of Nutrition, 6*(2), 143-148. http://dx.doi.org/10.3923/pjn.2007.143.148

Saini, R. S., Sharma, K. D., Kaushik, R. A., & Dhankhar, O. P. (2006). Laboratory Manual Analytical Techniques in Horticulture. Agrobios (India). IST Edition, pp 12-26.

Shafiee, M., Taghavi, T. S., & Babalar, M. (2010). Addition of salicylic acid to nutrient solution combined with postharvest treatment (hot water, salicylic acid and calcium dipping) improved postharvest fruit quality of strawberry. *Scientia Horticulturae, 124*, 40-45. http://dx.doi.org/10.1016/j.scienta.2009.12.004

Sirisomboon, P., Tanaka, M., Fujitha, S., & Kojima, T. (2000). Relationship between the texture and pectin constituents of Japanese pear. *Journal of Text Studies, 31*, 679-690. http://dx.doi.org/10.1111/j.1745-4603.2000.tb01028.x

Soleimani Aghdam, M., Motallebiazar, A., Mostofi, Y., Fattahi Moghaddam, J., & Ghasemnezhad, M. (2011). Methyl salicylate affects the quality of Hayward kiwifruits during storage at low temperature. *Journal of Agricultural Science, 3*(2), 149-156. http://dx.doi.org/10.5539/jas.v3n2p149

Srivastava, M. K., & Dwivedi, U. N. (2000). Delayed ripening of banana fruit by salicylic acid. *Plant Science, 158*(2), 87-96. http://dx.doi.org/10.1016/S0168-9452(00)00304-6

Tareen, M. J., Abbasi, N. & Hafiz, A. (2012). Effect of salicylic acid treatments on storage life of peach fruits cv. 'Flordaking'. *Pakistan Journal of Botany, 44*(1), 119-124.

Tomás, B. F. A., & Espin, J. C. (2001). Phenolic compounds and related enzymes as determinants of quality in fruits and vegetables. *Journal of Science Food and Agriculture, 81*, 853-876. http://dx.doi.org/10.1002/jsfa.885

Van Loon, L. C., Rep, M., & Pieterse, C. M. J. (2006). Significance of inducible defense-related proteins in infected plants. *Annual Review of Phytopathology, 44*, 135-162. http://dx.doi.org/10.1146/annurev.phyto.44.070505.143425

Wang, S. Y., & Zheng, W. (2001). Effects of plant growth temperature and antioxidant capacity in strawberry. *Journal of Agricultural and Food Chemistry, 49*, 4977-4982. http://dx.doi.org/10.1021/jf0106244

Wang, L., Chena, S., Kong, W., Li, S., & Archbold, D. D. (2006). Salicylic acid pretreatment alleviates chilling injury and affects the antioxidant system and heat shock proteins of peaches during cold storage. *Postharvest Biology and Technology, 41*, 244-251. http://dx.doi.org/10.1016/j.postharvbio.2006.04.010

Wills, R., McGlasson, B., Graham, D., & Joyce, D. (1998). Postharvest, an introduction to the physiology and handling of fruit and vegetables and ornamentals. Sydney 2052, Australia, University of New South Wales Press Ltd., *University of New South Wales,* 125-156.

Zheng, Y., & Zhang, Q. (2004). Effects of polyamines and salicylic acid postharvest storage of 'Ponkan' mandarin. *Acta Hort, 632,* 317-320.

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Volatility Analysis and Volatility Spillover Analysis of Indonesia's Coffee Price Using Arch/Garch, and Egarch Model

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Abstract

This study aims to analyze the best model to expect volatility of Indonesia's coffee price using ARCH/GARCH model and to measure the coffee price volatility spillover of International market for Indonesia's coffee price using EGARCH model. These models use different conditional variance specifications to catch up the asymmetry. The empirical results show that GARCH (1.1) model seems to better describe the Indonesia's coffee price volatility. From the EGARCH analysis known that International coffee price has an asymmetric effect on Indonesia's return coffee price and indicate that domestic coffee market is not efficient.

Keywords: Indonesian, Coffee, Price, Volatility, Spillover, ARCH/GARCH, EGARCH

1. Introduction

The role of plantation commodities for Indonesia's economy is very large, when the global economic crisis in 1998 and 2008, the manufacturing sector in Indonesia converting the vulnerability, but the plantation sector emerged as the savior of the Indonesia's economy through its contribution to domestic income, foreign exchange gains, employment, as well as the economic development of the region.

Coffee is one of the leading commodity in the Indonesia's agricultural sector, Indonesia's coffee production has reached 600 thousand tons per year and more than 80 percent comes from public forest. In addition, Indonesia's coffee is one of the commodities that have quite important contribute as the third largest foreign exchange earner after wood and rubber. Foreign exchange earned from coffee exports could reach Rp 7,784 billion (2009), involving 1.97 million households that supports 5 million peasant family life. Coffee as a plantation crop is one commodity that is attractive to many countries, especially developing countries because coffee plantations provide employment opportunities are quite high and can generate much needed foreign exchange for national development (Spillane, 1990).

Approximately 63% of Indonesia's coffee are for export, it makes the stability of Indonesia's coffee economy is highly depend on world market conditions. In other words, the price of coffee in Indonesia depends on coffee production from other exporting countries, such as Brazil, Colombia and Vietnam. World coffee crisis in 2000 that occurred because of the success of Vietnam's coffee production and the increasing success of Brazil to minimize disruption caused frost coffee's role in the Indonesia's economy is fading. Coffee prices fell because of flooding the world's coffee production and continued to fall until it reaches its lowest price in 30 years in early 2002 (FAO, 2002). These conditions have a direct impact on the movement of the Indonesia's producers, coffee price, because the price of coffee in Indonesia is very depend on the international market. The unstable movement of coffee prices in the international market will affect the domestic coffee prices, Indonesia's foreign exchange earnings and also will affect both coffee farmers and exporters decision. When the international coffee prices are higher than domestic prices, exporters prefer to sell their coffee to the international market. So that, these decisions will ultimately affect the coffee price in the domestic market.

The coffee price movements are irregular showed varying price changes or volatility, called a swing irregularity of the data. This volatility also describes the coffee price transmission *(spillover)* which reflects the price transmission from the international market to the farmer's domestic market level or vice versa and creating instability in global commodity markets (Stigler, 2011).

The Auto regressive Conditional Heteroscedasticity (ARCH), Generalized Auto regressive conditional heteroscedasticity (GARCH) family is widely used in the measurement of price volatility in agricultural commodities (Yang et al, 2003; Hernandez et al, 2009; Fakari et al, 2013) because ARCH/GARCH family are suitable for use in studies using time series data. This model allows the heterocedasticity of data that are usually happening the time series commodity price, this model also can investigate time different attributes expected price and price volatility. Exponential Generalized Autoregressive conditional heteroscedasticity

(EGARCH) model, check volatility spillover and provided evidence of volatility spillovers in agricultural markets (Buguk et al, 2013). EGARCH models are one form of development of ARCH/GARCH models that can identify the presence of symmetric effects among the variables used in the study, so that the EGARCH models can be used to determine the level of volatility spillover between the International coffee prices and the price of coffee in Indonesia.

Based on the study above, this research is greatly important with the aim to:

1. Estimate the best model of Indonesia's coffee price volatility using ARCH/GARCH Model.
2. Measuring the coffee price volatility spillover of the international market for Indonesia's coffee price using EGARCH Model.

2. Literature Review

Historical volatility, also called realized volatility, is based on the observed movements of prices over the long term, and indicates how volatile an asset or commodity price has been in the past (Bernardina, 2012). It showed the volatility level observed in the past on the basis of fluctuations in the price of the commodity. Historical volatility is determined by using a statistical tool known as standard deviation. Implied volatility derives from market forecasts of future variations in the commodity price. Evaluation of the premium for an option is based on market fundamentals, the option exercise price, numbers of days until expiration and volatility. The only unknown component is volatility, or so-called implied volatility. A number of mathematical and econometric methods have been developed to estimate this volatility component on the basis of the Black-Scholes model. Measurements of historical and future volatilities have an impact on evaluations and profits of a number of financial products. Volatility measurements are regarded as a barometer of investor sentiment. A high volatility level generally indicates an extremely nervous market while a low volatility level indicates a low-risk market and a consequent tendency for risk-taking. (International Coffee Council, 2009).

Volatility modeling is popular in financial economics. Financial variables such as stock price, interest rate and exchange rates are being modeled frequently by using financial econometric models, especially ARCH classes of models (Engel, 2001; Gee, 2010; Grobys 2010; Diebold et al, 2012; Ezzaty, 2013). However, volatility and volatility spillover analysis can also be performed to see the volatility of food price (Kuwornu, 2011; Kane, 2013) a wide variety of agricultural commodities (Jordaan, 2007; Benavides, 2009; Shiferaw, 2012; Sembiring, 2013), plantations (Malan, 2013), livestock (Buguk, 2013) even for the oil price (Salisu, 2012; Dhaoui, 2014).

3. Methods

3.1 Data Description

The data that used in this research is annual data from 1980-2011. This data collected from many resources, such as Indonesia's Bureau of Statistic online database, Indonesia's Ministry of Agriculture online database and Food and Agriculture (FAO) online database. Variables in this research are producer Coffee price from 1980-2011.

3.2 Unit Root Test

A series is *stationary* (weakly or covariance) if the mean and autocovariances of the series do not depend on time. Any series that is not stationary is said to be *nonstationary*. A common example of a nonstationary series is the *random walk*:

$$y_t = y_{t-1} + \varepsilon_t y_t = y_{t-1} + \varepsilon_t \tag{1}$$

where ε is a stationary random disturbance term. The series has a constant forecast value, conditional on, and the variance is increasing over time.

3.3 ARCH-LM-Test

The ARCH-LM test is a Lagrange multiplier (LM) test for autoregressive conditional heteroscedasticity (ARCH) in the residuals (Engle, 1982). This particular specification of heteroscedasticity was motivated by the observation that in many financial time series, the magnitude of residuals appeared to be related to the magnitude of recent residuals. ARCH in itself does not invalidate standard LS inference. However, ignoring ARCH effects may result in loss of efficiency.

The ARCH-LM test statistic is computed from an auxiliary test regression. To test the null hypothesis that there is no ARCH up to order q in the residuals, we run the regression:

$$e_t^2 = \beta_0 + \left(\sum_{s=1}^{q} \beta_s e_{t-s}^2\right) + v_t \tag{2}$$

Where e is residuals. This is a regression of the squared residuals on a constant on lagged squared residuals up to order q.

3.4 ARCH Model

Autoregressive Conditionally Heteroskedasticity (ARCH) model is a particular nonlinear model. In particular ARCH models assume the variance of the current error term or innovation to be a function of the actual sizes of the previous time periods' error terms: often the variance is related to the squares of the previous innovations (Brook, 2008).

The model of ARCH is written as:

$$\sigma_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 \tag{3}$$

3.5 GARCH Model

The GARCH Model was developed independently by Bollerslev and Taylor (1986). The GARCH model allows the conditional variance to be dependent upon previous own legs, so that the conditional variance equation of GARCH is:

$$\sigma_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + \beta \sigma_{t-1}^2 \sigma_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + \beta \sigma_{t-1}^2 \quad (4)$$

3.6 EGARCH Model

The exponential GARCH model was proposed by Nelson (1991).

$$\ln \sigma_t^2 = \alpha_0 + \alpha_{1a} \frac{\varepsilon_{t-1}}{\sigma_{t-1}} + \alpha_{1b} \left(\frac{\varepsilon_{t-1}}{\sigma_{t-1}} - E\left[\frac{\varepsilon_{t-1}}{\sigma_{t-1}} \right] \right) + \beta_1 \ln \sigma_t^2 \quad (5)$$

For $\varepsilon_t \sim N(0, \sigma_t^2) \varepsilon_t \sim N(0, \sigma_t^2)$ the standardized variable $\frac{\varepsilon_t \varepsilon_t}{\sigma_t \sigma_t}$ follows a standard normal distribution and consequently $E\left[\frac{\varepsilon_t}{\sigma_t}\right] = \sqrt{\frac{2}{\pi}} E\left[\frac{\varepsilon_t}{\sigma_t}\right] = \sqrt{\frac{2}{\pi}}$. The parameter $\alpha_{1a}\alpha_{1a}$ captures the leverage effect. For "good news" ($\frac{\varepsilon_{t-1}}{\sigma_{t-1}} \frac{\varepsilon_{t-1}}{\sigma_{t-1}} > 0$) the impact of the innovation $\varepsilon_{t-1}\varepsilon_{t-1}$ is $(\alpha_{1b} + \alpha_{1a})\alpha_{1b} + \alpha_{1a})$ and for "bad news" ($\frac{\varepsilon_{t-1}}{\sigma_{t-1}} < \frac{\varepsilon_{t-1}}{\sigma_{t-1}} <$ *0)* it is $(\alpha_{1b} - \alpha_{1a})\alpha_{1b} - \alpha_{1a})$

If $\alpha_{1a}\alpha_{1a} = 0$, In $\sigma_t^2 \sigma_t^2$ responds symmetrically to $\frac{\varepsilon_{t-1}\varepsilon_{t-1}}{\sigma_{t-1}\sigma_{t-1}}$. To produce a leverage effect, $\alpha_{1a}\alpha_{1a}$ must be negative. The fact that the EGARCH process is specified in terms of log-volatility implies that $\sigma_t^2 \sigma_t^2$ is always positive and, consequently, there are no restrictions on the sign of the model parameters.

4. Result and Discussion

4.1 Data Analysis

Data used in this study are rate of producer coffee price from 1980 through 2011, the time series data collected from various sources such as the Food and Agriculture (FAO) online database, Indonesia's Ministry of Agriculture online database, Association of Indonesia's Coffee Exporters and Producers (AICE) online database and some related papers. The data are analyzed the volatility of the coffee price in Indonesia, Brazil, Colombia and Vietnam is the return value of the producer coffee price, this is done because the volatility is the variance of the return value. Indonesia's coffee price data is used to analyze the Indonesia's coffee price, and Brazilia's, Colombia's and Vietnam's coffee price data as International coffee market, are used to measure the volatility spillover of International coffee price to Indonesia's coffee price.

Table 1. Descriptive statistic, return value of Indonesia's, Brazilian, Colombian and Vietnamese Coffee Price

	Indonesia (percent)	Brazil (percent)	Colombia (percent)	Vietnam (percent)
Mean	0.038701	0.042325	0.043266	0.045930
Median	0.046782	0.077283	0.051636	0.029725
Maximum	1.028347	1.057496	0.959134	1.142783
Minimum	-1.079214	-1.141771	-1.230161	-1.015751
Std. Dev.	0.321664	0.336271	0.331190	0.328117

The descriptive statistic of data is included mean, median, maximum, minimum, standard deviation, is shown in Table 1. Mean is the average value of 31 observed data in this research, the mean value of Indonesia's return coffee price is 3.8 percent, Brazil is 4.2 percent, Colombia is 4.3 percent and Vietnam is 4.6 percent. The mean value of each country is less than their median value, except Vietnamese return coffee price. It is mean that the distribution of observed data is concentrated at low, value, but for the Vietnamese return coffee price the observed data is concentrated at high value. This is because the difference between the mean value and the median value is big.

4.2 Unit Root Test

The unit root test is used to test the notion that a time series data are not stationary, the data is said to be stationary that data is flat, does not contain a trend component, with constant diversity, and there are no periodic fluctuations. Commonly used to test the data stationarity is the augmented Dickey–Fuller (ADF) test, this test is indicate the presence of a unit root null hypothesis.

The augmented Dickey–Fuller tests are shown a variable follow a unit-root process. The null hypothesis is that the variable contains a unit root, and the alternative is that the variable was generated by a stationary process. The result of unit root test from real return coffee price, first difference form of return coffee and second difference of return coffee price is shown in Table 5.2. The return coffee price value for Indonesia, Brazil, Colombia and Vietnam are already significant at level, so all results of each form (level, first difference, second difference) return coffee price are significant, or less than is a critical value of 1%, 5% and 10%. Meaning that all forms of return coffee price data are stationer, so the data used to predict the volatility of Indonesia's, Brazilian, Colombian and Vietnamese coffee price is the real return value of coffee price or the return coffee price of each country at level.

Table 2. Unit-root test of Indonesia's, Brazilian, Colombian, and Vietnamese return coffee price

Series	Level	First Difference	Second Difference
Indonesia	-7.68 ***	-7.88 ***	-10.19 ***
Brazil	-7.33 ***	-7.69 ***	-9.89 ***
Colombia	-8.16 ***	-8.68 ***	-12.07 ***

Vietnam	-7.19 ***	-7.46 ***	-10.68 ***
Test critical values for Indonesia	1% level		-3.670170
	5% level		-2.963972
	10% level		-2.621007
Test critical values for Brazil	1% level		-3.699871
	5% level		-2.976263
	10% level		-2.627420
Test critical values for Colombia	1% level		-3.670170
	5% level		-2.963972
	10% level		-2.621007
Test critical values for Vietnam	1% level		-3.670170
	5% level		-2.963972
	10% level		-2.621007

Note: statistical significance at 1% (***), 5% (**), and 10% (*)

4.3 Heteroscedasticity Test (ARCH effect)

Heteroscedasticity test is used to prove that the data are heteroscedastic and has an ARCH effect. The result of heteroscedasticity tests is shown in table 3 below.

Table 3. Heteroscedasticity Test: ARCH

	Indonesia	Brazil	Colombia	Vietnam
F-statistic	5.864229 **	6.652265 **	3.599933 *	7.044679 **
Obs*R-squared	5.195065 **	5.759160 **	3.417665 *	6.030598 **

Note: statistical significance at 1% (***), 5% (**), and 10% (*)

The result of heteroscedasticity tests of return coffee price for Indonesia, Brazil, Colombia and Vietnam shows that the heteroscedasticity or ARCH effect are significant at 5% for Indonesia's, Brazilian, Vietnamese return coffee price and significant at 10% for Colombian return coffee price. Meaning that the appropriate model for measuring return coffee price volatility of Indonesia's, Brazilian, Colombian and Vietnamese are ARCH/ GARCH family.

4.4 Indonesia's Coffee Price Volatility

ARCH and GARCH models are used to expect the return of Indonesia's coffee price and the volatility of Indonesia's return coffee price equation. As the result, the expected for Indonesia's return coffee price can be present as follows:

$$CP_t^e = d_0 + d_1 CP_{t-1} + d_2 CP_{t-2} + \varepsilon_{2t} \quad (6)$$

Where:

$CP_t^e CP_t^e$: expected return coffee price

$CP_{t-1}CP_{t-1}$: return of producer coffee price in time t-1

$CP_{t-2}CP_{t-2}$: return of producer coffee price in time t-2

The expected variance of return coffee price gets from the variance equation as follow:

$$\sigma_t^2 = \alpha_0 + \alpha \varepsilon_{2t-1}^2 + \beta h_{t-1} \quad (7)$$

The variance equation is called GARCH conditional variance equation, this equation is also known as the volatility of Indonesia's return coffee price equation. According to the equation, $\sigma_t^2\sigma_t^2$ is specified as a linear function of *p* lagged-square residuals and its own *q* lagged conditional variance. The result of GARCH-typed estimation of Indonesia's return coffee price to the expected price equation are presented in table 4.

The table 4 shows the analytical result of ARCH and GARCH model of the price equation. The Akaike info criterion and Schwarz information criterion is used to rank the three models of Indonesia's return coffee price, because it allows a degree of freedom comparison of the models' performance. A comparison of AIC and SIC values shows that GARCH (1,1) model is the most appropriate to describe the expected price equation system.

Table 4. Result of Indonesia's return coffee price volatility

	ARCH (1)	GARCH (1,1)	GARCH (0,1)
Mean Price Equation			
d_0	0.197***	0.079***	0.089
CP_{t-1}	-0.587	0.017	-0.381*
CP_{t-2}	-0.277**	0.055***	-0.212
Variance Equation			
α_0	0.010	0.001	0.003
α	1.669**	-0.200***	
β		1.239***	1.038***
α + β	1.669	1.039	1.038
Akaike info criterion	0.434	-0.089	0.533
Schwarz criterion	0.669	0.193	0.769

Note: statistical significance at 1% (***), 5% (**), and 10% (*)

$\alpha + \beta < 1$ (low volatility), $\alpha + \beta = 1$ (high volatility), $\alpha + \beta >$ (extreme volatility)

The equation for expected of Indonesia's return coffee price is:

$$CP_t^e = 0.079 + 0.017CP_{t-1} + 0.055CP_{t-2} + \varepsilon_{2t} \quad (7)$$

The equation means that the increasing of 1% of Indonesia's producer returns coffee price at time t-1 will increase 1.7% of the expected Indonesia's return producer coffee price and increasing 1% of Indonesia's producer return coffee price at time t-2 will increase 5.5% of the expected Indonesia's return producer coffee price. With GARCH (1,1), also obtained an equation for the return volatility of Indonesia's coffee price. The equation shows as follows:

$$h_t = 0.001 - 0.200\varepsilon_{2t-1}^2 + 1.239h_{t-1}h_t = 0.001 - 0.200\varepsilon_{2t-1}^2 + 1.239h_{t-1} \quad (8)$$

From the equation above, shows that the total value of α + β is equal to 1. This result indicates that the return price volatility of Indonesia's producers coffee is high.

4.5 Indonesia's Coffee Price Volatility Spillover

Table 5 presents the empirical results of the estimated EGARCH between Indonesia's return coffee prices and the return coffee price of the world's largest coffee exporter countries, Brazil, Colombia and Vietnam. The results of the average equation of Indonesia return coffee price are positively affected by the return of Brazilian coffee prices at 1% significance level, which is implies that as the world's largest coffee producer, Brazil plays an important role on the world coffee price volatility. This is evidenced when the world coffee crisis in 2000 which occur due to Brazil's success in minimizing disruption frost that causing coffee prices fell because of flooding the world's coffee production, world coffee prices continue to fall until it reaches its lowest point in 30 years in early 2002 (FAO, 2002).

Like Brazil, Vietnam's returns coffee prices also have a positive effect on returns and significant at the level of 1% for Indonesia's return coffee prices. This happens because Vietnam is an Indonesia's major competitor as a coffee exporter, both countries produce the same type, IE robusta coffee. While the Colombian coffee prices return a negative effect, but no significant effect on the Indonesia's return coffee price.

Table 5. Volatilities Spillover of Brazilian, Colombian and Vietnamese Coffee Price to Indonesia's Return Coffee Price.

Variable	Coefficient
Price Spillover	
C	-0.016515**
Brazil	0.470787***
Colombia	-0.013669
Vietnam	0.505254***
Volatility Spillover	
ω	-4.592419*
α	-1.827363*
γ	-0.348790
β	-0.002515
BRAZIL	-3.533541
COLOMBIA	-1.126942
VIETNAM	3.730985

Note: statistical significance at 1% (***), 5% (**), and 10% (*)

α' stands for the symmetric effect of the model, from table 5 it is known that α value of Indonesia's return coffee price is significant at 1%. This indicates that Indonesia's returns coffee price is asymmetric, and indicate that the return coffee price volatility of Brazil, Colombia and Vietnam are not significant or has no significant effect of Indonesia's return coffee price volatility.

5. Conclusion

This study has investigated the return price volatility of Indonesia's coffee price and volatility spillover of Brazilian, Colombian and Vietnamese return coffee price to Indonesia's Coffee price, the expected equation was examined with ARCH, GARCH and EGARCH model. The empirical results of the expected price show that, GARCH (1,1) model conforms as the most appropriate model to describe the expected return price of Indonesia's coffee. From the variance equation GARCH (1,1) or Indonesia's coffee price volatility, shows that the Indonesia's return coffee price volatility is high. This is because the Indonesia's coffee is exported product which is depend on the international coffee market. But from the average return price spillover analysis, it is known that Brazil and Vietnam have a positive and significant effect to the average equation of Indonesia's Return Coffee Price. For volatility spillover analysis, known that Indonesia's returns coffee price is asymmetric, and the return coffee price volatility of Brazil, Colombia and Vietnam has no significant effect of Indonesia's return coffee price volatility. Indonesian domestic coffee prices are controlled by middlemen traders, this leads to an asymmetric effect between international coffee prices to Indonesian coffee price. The game price by middlemen is causing the coffee price at farm level is low, and lower the welfare of Indonesian coffee farmers.

Government should provide a policaes to improve and stabilize the Indonesia's domestic coffee price to suppress the role of middleman in domestic coffee price play, so the welfare level of Indonesia coffee farmers can be assured, because based on the results of analysis show that the level Indonesia's coffee price volatility is significantly influenced by the coffee price of the previous year, this suggests that the Indonesia's coffee price is more influenced by the Indonesia's domestic market conditions than the international coffee market condition.

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References

Bernardina, Algieri. (2012). Price Volatility, Speculation and Excessive Speculation in Commodity Markets: sheep or shepherd behaviour?. ZEF- Discussion Papers on Development Policy No. 166, Center for Development Research, Bonn, May 2012, pp. 37.

FAO. (2002). Commodity Market Review 2001-02. Commodities And Trade Division Food And Agriculture Organization Of The United Nations. *Food and Agriculture Organization of The United Nations*. Rome. Avaiable at ftp://ftp.fao.org/docrep/fao/004/y3007e/y3007e00.pdf

Stigler, Matthieu. (2011). Safeguarding Food Security in Volatile Global Markets, ch. 2. *Food* *and Agriculture Organization of The United Nations*. Rome. Available at http://www.fao.org/docrep/013/i2107e/i2107e27.pdf

Gee, Chan Sok et al. (2010). Volatility Spillovers of the Major Stock Markets in ASEAN-5 with the U.S. and Japanese Stock Markets. *International Research Journal of Finance and Economics.* Available at: http://repository.um.edu.my/6874/1/irjfe_44_12.pdf

Grobys, Klaus. (2010). Have Volatility Spillover Effects Of Cointegrated European Stock Markets Increased Over Time?. *The Review of Finance and Banking Volume 02*, Issue 2, Year 2010. Available at: http://www.rfb.ase.ro/articole/paper3.pdf

Ezzati, Parinaz. (2013). Analysis Of Volatility Spillover Effects: Two-Stage Procedure Based On A Modified GARCH-M. *The University of Western Australia.* Available at: http://www.business.uwa.edu.au/__data/assets/pdf_file/0006/2385780/13-29-Analysis-of-Volatility-Spillover-Effects-Two-Stage-Procedure-Based-on-a-Modified-GARCH-M.pdf

Diebold et al, (2012). Measuring Financial Asset Return and Volatility Spillovers, With Application to Global Equity Markets. *University of Pennsylvania*

Engle, Robert. (2001). GARCH 101: The Use of ARCH/GARCH Models in Applied Econometrics. *Journal of Economic Perspectives—Volume 15*, Number 4—Fall 2001—Pages 157-168. Available at: http://dx.doi.org/10.1257/jep.15.4.157

Jordaan et al. (2007). Measuring the Price Volatility of Certain Field Crops in South Africa using the ARCH/GARCH Approach. *Agrekon, Vol 46*, No 3 (September 2007). Available at: http://dx.doi.org/10.1080/03031853.2007.9523774

Kane, Gilles Quentin. (2013). Food Price Volatility In Cameroon: Causes, Transmission And Consequences. *African Economic Research Consortium (AERC)*. Available at: http://aercafricaevents.org/papers/GroupE/CPPE1-KANE.pdf

Kuwornu et al. (2011). Analysis of Food Stuff Price Volatility in Ghana: Implications for Food Security. *European Journal of Business and Management*. Vol 3, No.4, 2011. Available at: http://www.iiste.org/Journals/index.php/EJBM/article/view/299/186

Benavides Guillermo. (2009). Price Volatility Forecasts For Agricultural Commodities: An Application of Volatility Models, Option Implieds and Composite Approaches for Futures Prices of Corn and Wheat. *Journal of Management, Finance and Economics*, vol. 3, n´um. 2 (2009), pp. 40-59. Available at: http://dx.doi.org/10.2139/ssrn.611062

Buguk, Cumhur. Darren Hudson, and Terry Hanson. (2013). Price Volatility Spillover in Agricultural Markets: An Examination of U.S. Catfish Markets. *Journal of Agricultural and Resource Economics 28*(1), *86-99*. Copyright 2003 Western Agricultural Economics Association. Available at: http://ageconsearch.umn.edu/bitstream/30716/1/28010086.pdf

Sembiring, Elsa. 2013. Analysis of Price Volatility Spillover of Soyabean (Glycine max (L.) Merrill) in East Java. *Greener Journal of Agricultural Sciences. 3*(9), 656-662, September 2013. Available at: http://www.gjournals.org/GJAS/GJAS%20Pdf/2013/September/071513732%20Sembiring.pd

f

Shiferaw, Yegnanew Alemu. (2012). Modeling Volatility of Price of Some Selected Agricultural Products in Ethiopia: ARIMA/GARCH Applications. *Hawassa University, Ethiopia.* http://dx.doi.org/10.2139/ssrn.2125712

Yang, Jian. Jin Zhang. David J. Leatham. (2003). Price and Volatility Transmission in International Wheat Futures Markets. *Analysis Of Economics And Finance 4*, 37-50 (2003). Available at: http://down.aefweb.net/AefArticles/aef040103.pdf

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Analysis of Effects of Agriculture Intervention Using Propensity Score Matching

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Abstract

Nowadays, the agriculture extension programmes are practiced in many parts of the world. There is a mixture of results about the effects of agriculture intervention programmes. The literature shows that the interventions are ineffective and have limited diffusion. On the other side, it shows that interventions are effective. Following different arguments about the effects of agriculture extension, this paper adopted Propensity Score Matching (PSM) to analyze the effects of District Agricultural Sector Investment Project (DASIP) using agriculture data.

The study was conducted in rural Tanzania areas. It covered five regions namely Kagera, Mwanza, Mara, Simiyu and Kigoma. The study focused on agro-ecological zone where corn is cultivated. Two methods which are questionnaire administration and direct oral interview were used to collect primary data. The collection of data using the questionnaire was done from both participants (359) and non-participants (519). Before running the independent t test, the estimation of propensity score was done using Logistic regression. Thirteen confounding variables were used to estimate propensity scores.

The effects of the intervention were analysed by considering four items namely the earnings from corn production, value of livestock owned, value of household assets owned, and value of farm assets owned. The results show that none of the four factors had significant result as the p values are greater than 0.05. This implies that the earning between farmers participating in DASIP are not significant different from those who do not participate in the programme. The study recommends that the group activities should last longer rather than changing them from time to time.

Keywords: Agriculture Extension programme, DASIP, Farmer Field School, Intervention, Propensity Score Matching (PSM)

1. Introduction

The agriculture plays a major role in economic development (Yeshwanth, 2008). Nowadays, agriculture extension programmes are practiced in many parts of the world. Such programmes are implemented because farmers lack direct linkage with advanced agricultural technology. It is through extensions where farmers are given knowledge, skills and motivation for farming. These are done through Farmer Field Schools (FFS) also called Participatory Group Farmers (PGFs) model.

The FFS started in Tanzania in the 1997 (Braun et al., 2006). The approach has been engineered by both government and non-governmental organizations. The government of Tanzania adopted the FFS approach in one of its project called District Agricultural Sector Investment Project (DASIP) in which this paper is focused. The DASIP is a six year project aimed at increasing the productivity and incomes of rural households in the project area within the overall framework of the Agricultural Sector Development Strategy (ASDS). The DASIP started in the 2006.

One of the main challenges that the extension and research is currently confronted with is the transfer of agricultural technology from the research stations to the farm lands (Dinpanah et al., 2010). There is a mixture of results about the effects of agriculture intervention programmes. The literature shows that the interventions are ineffective and have limited diffusion (see Quizon et al., 2001; Feder et al., 2003; and Rola et al., 2002). On the other side, the literature shows that FFS are effective (see Godtland et al., 2004; Van den Berg., 2004; Feder et al., 2003; Tripp et al, 2005; Erickson, 2003; and Ooi et al, 2005).

There is less common rigorous impact evaluations of agricultural extension interventions despite the vast literature dealing with issues related to agricultural extension (Waddington et al., 2010). Heinrich et al. (2010) argue that this is a result of several problems accompanied by the evaluation of the programmes. The problems include: establishing the counterfactual; need for an adequate comparison group; selection bias; and role of randomization (Duflo and Kremer, 2003). These problems can be solved by the use of statistical methods depending on the nature of the intervention programmes. Unfortunately, the data used in the past impact analyses did not define well the counterfactual factors. The comparison is done by just looking at two observation points that is, before and after.

The intervention programmes can either be random or non-random. The randomized design occurs when the inclusion of the units or subjects in the intervention is random while non-random implies that the inclusion of the units is not by chance but depends on other factors. The randomized design programmes are very limited in literature because many intervention programmes have specific objectives and target something which makes non-random inclusion of the units. Because of this, non-experimental methods are adopted.

The Propensity Score Matching (PSM) is among the vibrant non-experimental methods. It is the most used method because it overcomes the fundamental evaluation problem and addresses the possible occurrence of selection bias. One of the advantages of this method is that it is used even if there are no baseline data. This was argued by Caliendo and Kopeinig (2005) in their working paper about guidance for the implementation of PSM.

Following different arguments about the effects of agriculture extension, this paper adopted PSM to analyse effects of DASIP using agriculture data.

2. Material and Methods

2.1 Study Area

The study was conducted in rural Tanzania particularly in the areas where DASIP operates. This covers five regions namely Kagera, Mwanza, Mara, Simiyu and Kigoma. Within these regions, the study focused on agro-ecological zone where corn is cultivated. The rationale of choosing DASIP area was that there was limited statistical survey on the impact evaluation of the programme conducted.

2.2 Population and Sample Size

The target population of this study was corn farmers found in DASIP intervention areas. Both DASIP participants (242,000 farmers) and non-participants were included in the study. A sampling unit was individual farmer.

Basing on the sample selection formula by Yamane (1967), out of 242,000 participant farmers, only 399 participant farmers with the precision level (margin of error) of 5% were targeted in the sample but the study was able to include only 359 (89.97%) participant farmers. In order to control the confounding factors, the study involved the sample of 275 (96.2%) out of 286 non-participant farmers who were located in the villages with DASIP intervention and sample of 244 (85.3%) out of targeted 286 non-participant farmers located in the villages far from villages where DASIP operates (See Table 1).

Table 1. Sample Distribution

Corn farmer category	Targeted sample size	Actual sample size
FFS participant farmers from villages with FFS programme	399	359
Non-participant farmers from villages with FFS programme	286	275
Non-participant farmers from villages without FFS programme	286	244
Total	971	878

There was a need to have a large sample size of non-participant farmers in evaluating the impact of a programme especially PSM (Bryson et al., 2002). The PSM requires large data in both the number of variables and sample size. It is termed as a data hungry method. When data are scarce, the appropriateness of this technique should be carefully analysed (Heinrich et al., 2010). For instance, the sample size used by Lalonde (1986) consisted of 297 treatment group observation and 425 control group (Smith and Todd, 2005). Actually, the large sample makes fewer margins of error and increases confident in results.

The systematic sampling with non-equal selection probabilities was involved in the study to select the respondents. The technique was applied because the population under study was not homogenous something which restricted the use of systematic sampling with equal selection probabilities.

2.3 Data Collection and Analysis

The two methods namely the questionnaire administration and direct oral interview were used to collect primary data. The collection of data using the questionnaire was done from both participant (359) and non-participant farmers (519). The use of the questionnaire was preferred in this study because it is very cost-effective and it gives a greater response rate rather than adopting inadequate mailing method and/or time consuming direct oral interview in such a large sample and large geographical area. This study adopted a pre-test structured questions form of interview for safe basis generalization. The structured interview method was applied to DASIP officers.

The analysis of the effects of extension was done using an independent t test. The effects of the intervention is analysed by considering four items namely the earnings from corn production, value of livestock owned, value of household assets owned, and value of farm assets owned. The earning from corn production refers the money obtained after selling corns. The value of the livestock such as chicken, guinea fowl, duck, etc. owned by the farmer comprised of the total value of all livestock. . The household assets include the total value of things such as house, mobile phone, television, radio, bicycle, etc. The farm assets include assets such as hand hoe, farm (ha), cart/barrow, plough, etc.

Before running the t test, the estimation of propensity score was done using Logistic regression. Thirteen confounding variables involved in estimation included: sex, age, type of farmer, marital status, level of education, household size, land owned, distance from home to corn farm (km), distance from the village to district headquarters (km), distance to tarmac road (km), weather, soil type and membership of other participatory farmer groups.

3. Results and Discussion

3.1 Propensity Score Matching

Before the PSM was performed, the data were scrutinized to ensure that they are clean. The variables with outlier were cleaned. The estimated propensity score were matched using simple 1:1 nearest neighbour matching. The calliper of 0.15 of the standard deviation of the logit of the propensity score was used to exclude bad matches as recommended by Thoemmes (2012).

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In order to assess the balance achieved after matching, both univariate and multivariate balance statistics are used. For multivariate, chi square and $\mathcal{L}_1$ were used while for univariate standardized mean difference $|d|$ and plots were used.

The output shows that the overall chi square balance test was not significant as $\chi^2(13) = 14.878, p = 0.315$. Multivariate imbalance measure $\mathcal{L}_1$ for unmatched solution (before matching) was 0.998 while after matching was 0.996. Both Chi square test and multivariate imbalances show that there is no imbalance after matching. The $\mathcal{L}_1$ indicates that there is no imbalance because the value for matched sample is small (0.996) than unmatched sample (0.998).

For the case of univariate balance test, the standardized mean difference shows that all covariates were balanced as $|d| \leq 0.25$. The distribution of propensity scores is shown in Figure 1. The graph is visualized to examine the similarity of the propensity score distributions after matching and to assess the area of common support (Thoemmes, 2012). From Figure 1, it can be seen that there is overlapping distribution of the propensity scores in treatment and control groups as tails of histograms are overlapping.

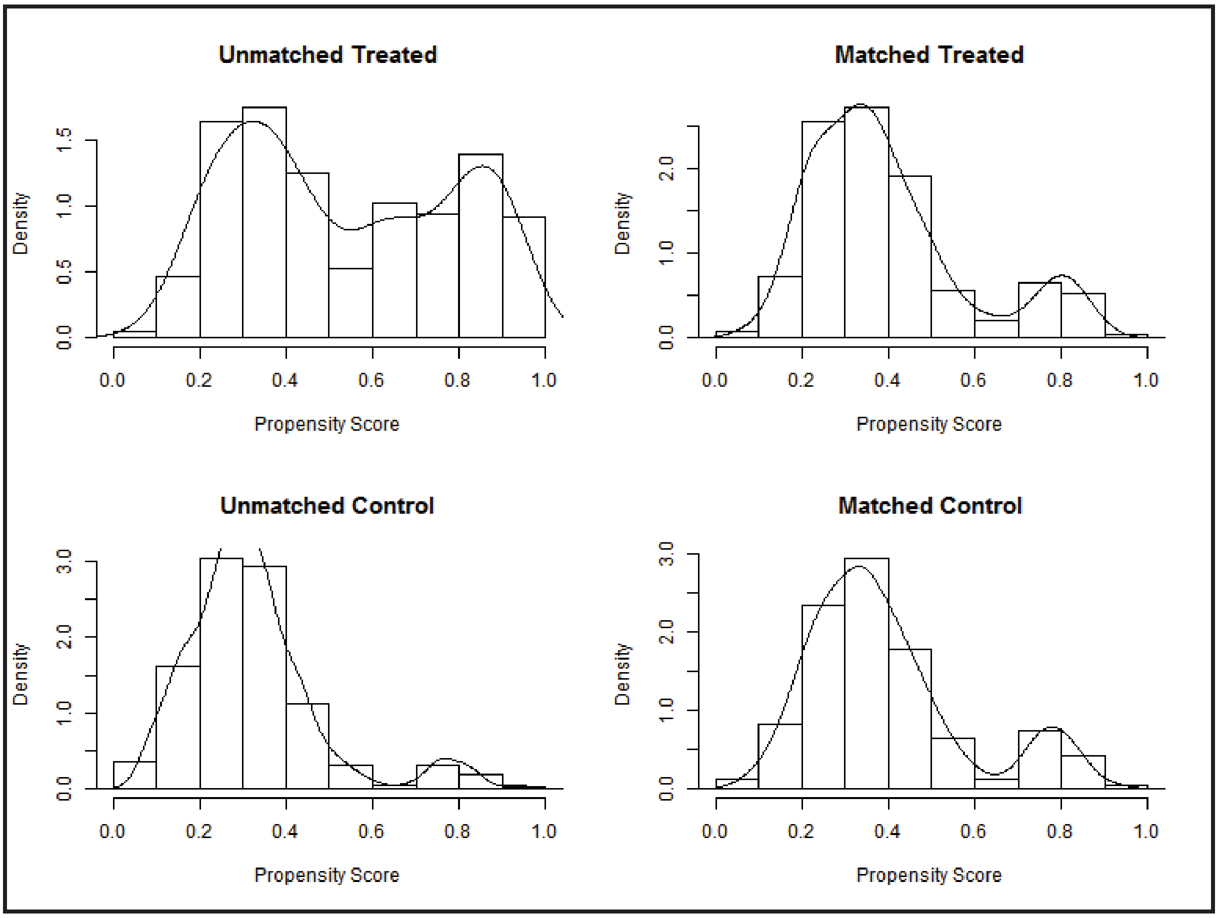

Figure 1. Distribution of Propensity Scores of Treatment and Control Groups

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In Figure 2, the plot showing individual propensity scores is presented. Unlike plot in Figure 1, Figure 2 provides information of plots of individual units. It can be easily seen that the two groups (treatment and control) are comparable.

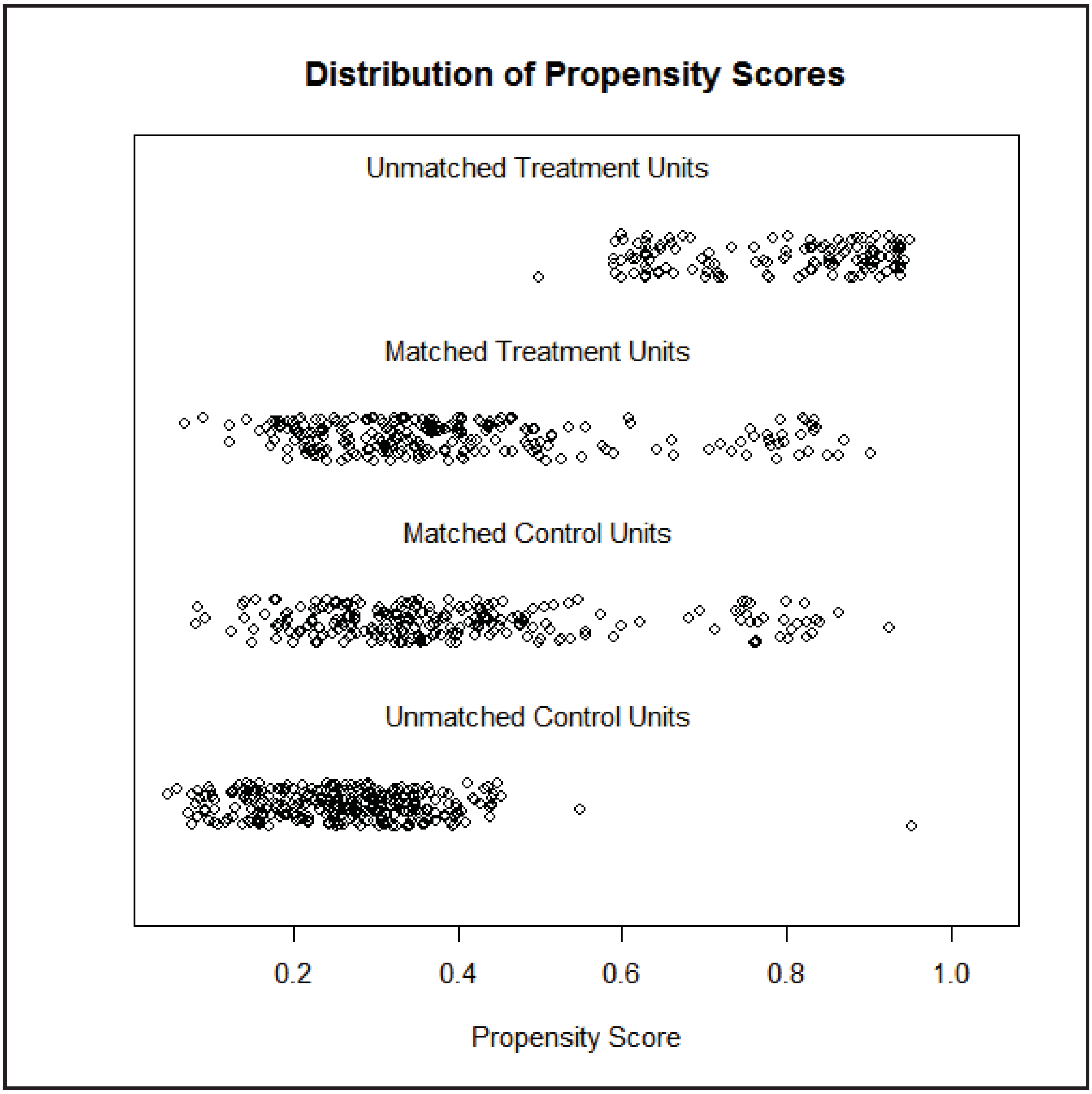

Figure 2. Dot plot of Individual Propensity Scores

The standardized difference is presented in Figure 3. From the figure, it can be seen that the standardized differences after matching are centred on zero and that no systematic difference still exist after matching.

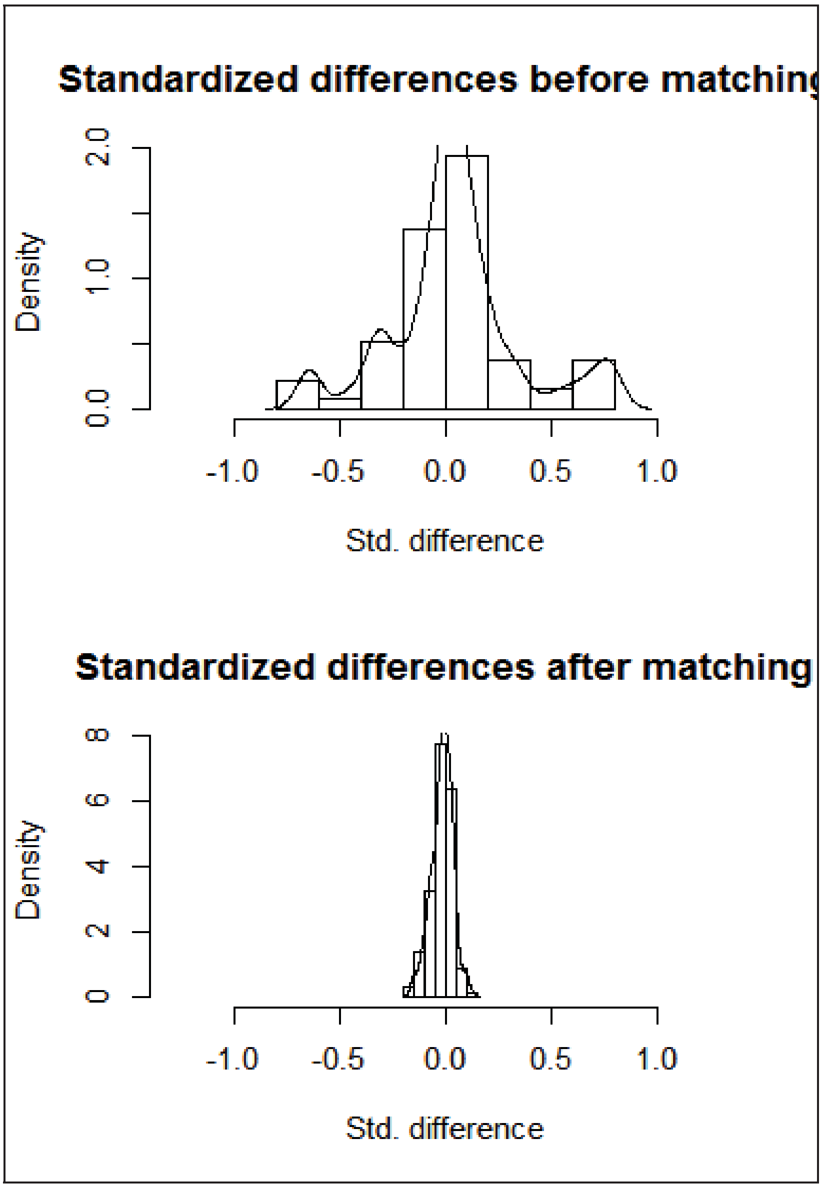

Figure 3. Histogram of Standardized Differences

The magnitude of standardized differences before and after matching for each covariate is presented in Figure 4. It can be seen from the figure that there is an improvement of scores after matching compared to before matching.

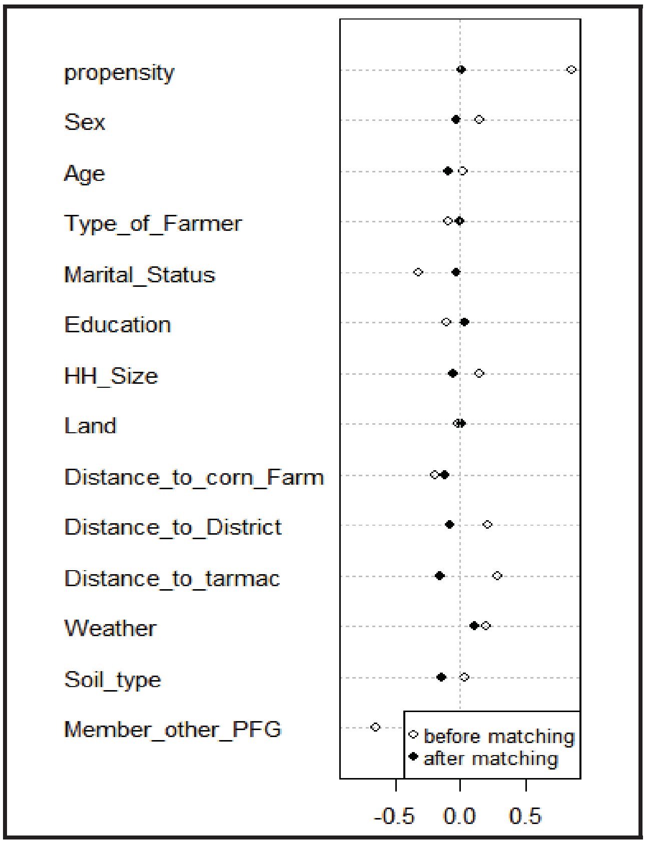

Figure 4. Dot plot of Standardized Mean Differences

In Figure 5, the standardized mean difference before and after matching are presented. The bolded lines are standardized differences that increase after matching.

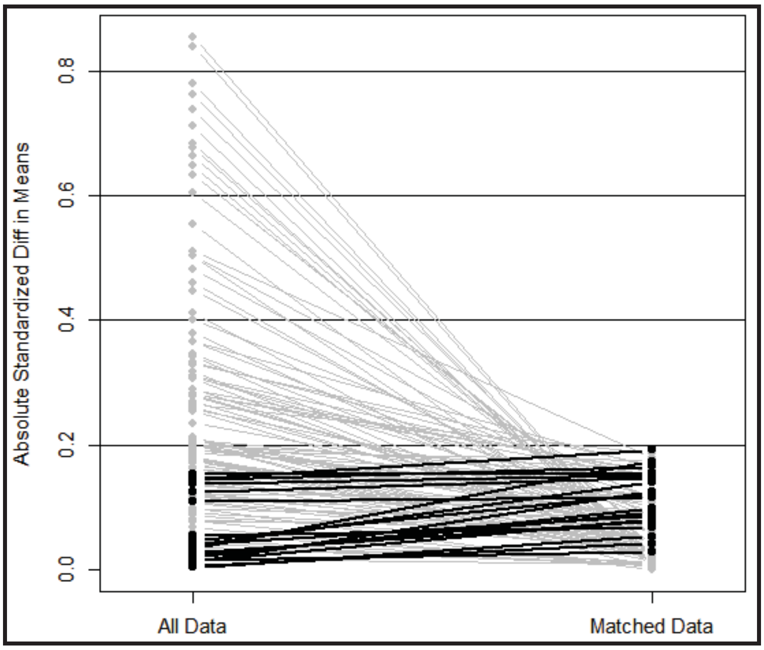

Figure 5. Line plot of Standardized Differences before and after Matching

All the univariate and multivariate indicate that there are no imbalances after matching. Out of 878, the matched samples were 252 for both control and treated farmers. From the control group, about 265 were unmatched and 94 for treated farmers were unmatched. About 15 samples (2 control and 13 treated) were discarded because they were outside the common support.

3.2 Effects of Intervention

The t test was adopted so as to compare the means of two groups (control and treatment). The test is used when the subjects are randomly assigned to two groups. Although the subjects were not randomly assigned into two groups, the adoption of PSM to some extent controls selection bias and make the difference between the groups to be due to treatment and not to other factors. The test results of the four items are presented in Table 2.

Table 2. Comparison of welfare of farmers

Welfare measure	***t***	***df***	***p-value***
Earnings from corn production	-1.697	460	0.090
Value of livestock owned	0.824	460	0.410
Value of household assets owned	0.366	460	0.715
Value of farm assets owned	-1.484	460	0.139

None of the four factors had significant result as the *p values* are greater than 0.05. This implies that the earning between farmers participating in DASIP are not significant different from those who do not participate in the programme. The same applies to the other three welfare measures. Looking at the sign of t values, it was found that farmers who do not participate in DASIP had high earnings from corn production compared to those participating in the programme. Also, the values of farm assets of non-participating farmers are higher than those of participant farmers. The participant farmers had higher values of livestock and household assets compared to non-participant farmers.

The findings show that DASIP has not contributed much to the welfare of farmers. This result is contrary to that obtained by Okorley et al. (2004) when studied the effects of FFS in Cocoa intervention. They find that capital assets of the farmers improved. Davis et al. (2010) find that the value of crops produced per acre, livestock value gain per capita, and agricultural income per capita increased significantly for FFS participants. The vast of the majority in literature find that FFS has improved the status of participants than non-participants. The nature and way the data were analysed is quite different to this paper. In literature, many authors focused on assessing knowledge and skills.

The results of this paper could be the results of most DASIP groups not to practice what they have acquired from DASIP. During the data collection, it was observed that groups have a tendency of changing group activities often. A group can cultivate corn this year but after just a year it can turn to be livestock keeper. There are limited groups which stick on the activities since the formation of the groups. The data were collected in rural area and average distance to district headquarter is 20 km.

The insignificant contribution of DASIP could be also contributed by unsatisfactory monitoring of the activities. Sometimes, the projects and activities which were performed by groups are not monitored and evaluated by the DASIP officials because of the scarcity of funds. Most of the farmers require maximum supervision in order to benefit from activities engaged. So, if there is a limited follow-up, there will be limited knowledge diffusion. Other factors such as different cultures, lack of commitment among group members, mistrust among group members, lack of water and land degradation affect both productivity and income of the farmers. A combination of all factors affects the outcome based of the four items.

4. Conclusion

Basing on the findings, the welfare of the farmers participating in DASIP is almost the same as that for those who do not participate in DASIP. These findings suggest that, still there is much to do with agriculture intervention in order to increase productivity. The study recommends that agriculture intervention should include a component of irrigation as one of the objectives. Also, activities performed by a group should last longer rather than changing the activities from time to time. Furthermore, there should be close monitoring and evaluation of group activities, sensitization and awareness of intervention should be advocated.

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References

Braun, A., Jiggins, J., Röling, N., Berg, H. and Snijders, P. (2006). A Global Survey and Review of Farmer Field School Experiences. [Online] Available: http://www.ifad.org/rpr2011/background/1.pdf (August 24, 2011).

Bryson, A., Dorsett, R., & Purdon, S. (2002). The Use of Propensity Score Matching in the Evaluation of Active Labour Market Policies. Crown.

Davis, K., Nkonya, E., Kato, E., Mekonnen, D. A., Odendo, M., Miiro, R., & Nkuba, J. (2010). Impact of farmer field schools on agricultural productivity and poverty in East Africa. International Food Policy Research Institute (IFPRI).

Dinpanah, G., Mirdamadi, M., Badragheh, A., Sinaki, J. M., & Aboeye, F. (2010). Analysis of Effect of Farmer Field School Approach on Adoption of Biological Control on Rice Producer' Producer' Characteristics in Iran. *American-Eurasian J. Agric. & Environ. Sci., 7* (3), 247-254.

Duflo, E., & Kremer, M. (2003). Use of randomization in the evaluation of development effectiveness. Aper Prepared for the World Bank Operations Evaluation Development (OED) Conference on Evaluation and Development Effectiveness in Washington, DC.

Erickson, R. (2003). Review and Evaluation Technical Assistance No. 3383-PAK: Integrated

Pest Management. Asian Development Bank. Philippines.

Feder, G., Murgai, R., & Quizon, J. (2003). Sending farmers back to school: The impact of farmer field schools in Indonesia. *Rev. Agric. Econ.*, *26*, 1-18. http://dx.doi.org/10.1596/1813-9450-3022.

Godtland, E. M., Sadoulet, E., Janvry, A. D., & Murgai, R. (2004), The Impact of Farmer Field Schools on Knowledge and Productivity: A study of Potato Farmers in the Perivian Andes, The Univesrty of Chicago.

Heinrich, C. Maffioli, A., & Vázquez, G. (2010). A Primer for Applying Propensity-Score Matching: Impact-Evaluation Guidelines. Inter-American Development Bank.

LaLonde, R. J. (1986), Evaluating the Econometric Evaluations of Training Programs with Experimental Data, *The American Economic Review*, *76*(4), 604-620.

Okorley, E. L., Adjargo G., & Bosompem, M. (2004). The Potential of Farmer Field School in Cocoa Extension Delivery: A Ghanaian Case Study. *Journal of International Agricultural and Extension Education,* Volume 21, Issue 2. http://doi: 10.5191/jiaee.2014.20203.

Ooi, P. A., & Kenmore, P. E. (2005). Impact of Educating Farmers about Biological Control in Farmer Field Schools. Second International Symposium on Biological Control of Arthropods.

Quizon, J., Feder, G., & Murgai, R. (2001). Fiscal Sustainability of Agricultural Extension: The Case of the Farmer Field School Approach. *Journal of International Agricultural and Extension Education* *8*(1), 13-24. http://citeseerx.ist.psu.edu/viewdoc/summa ry ?doi=10.1.1.473.3519.

Rola, A. C., S. B. Jamias, & J. B. Quizon (2002). Do farmer field school graduates retain and share what they learn: an investigation in Iloilo, Philippines. *Journal of International Agricultural and Extension Education* 9: http://doi: 10.5191/jiaee.2002.09108.

Smith, J. A., & Todd, P. E. (2005). Does matching overcome LaLonde's Critique of Non-experimental estimators? *Journal of Econometrics,* *125*, 305-353. http://dx.doi.org/10.2139/ssrn.286297.

Thoemmes, F. (2012). Propensity score matching in SPSS. [Online] Available: http://sourceforge.net/projects/psmspss/files/ (September 12, 2014).

Tripp, R., Wijeratne, M., & Piyadasa, V. H. (2005). What should we expect from farmer field schools? A Sri Lanka case study. *World Development - Volume* 33, no. 10, pp. 1705-1720. http://dx.doi.org/10.1016/j.worlddev.2005.04.012

Van den Berg, H. (2004). IPM Farmer Field Schools: A synthesis of 25 impact evaluations. Wageningen University, Report prepared for the FAO Global IPM Facility, Rome.

Waddington, H., Snilstveit, B., White, H., & Anderson, J. (2010). The Impact of Agricultural Extension Services. *International Initiative for Impact Evaluation*. http://dx.doi.org/10.4102/aej.v1i1.19.

Yeshwanth K. N. L. G. (2008). A Study on Knowledge and Adoption of Integrated Crop Management (ICM) Practices by the Participants of Farmers Field School (FFS) in Bellary District. Masters Dissertation, University of Agricultural Sciences, Dharwad.

Yamane, Taro. (1967). Statistics: An Introductory Analysis, 2nd Edition, New York: Harper and Row.

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Response of Tomato Variety (Roma F) Yield to Different Mulch Materials and Staking in Kabba, Kogi State, Nigeria

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Abstract

This experiment was carried out at student's experimental field, Kabba College of Agriculture, Horticultural Section to investigate the response of tomato variety (Roma F) yield to different mulch materials and staking. A split plot experiment was laid out in a randomized complete block design (RCBD) with three replications to randomize the staking levels and mulch materials in the main and sub-plots, respectively. The experiment comprised of two staking levels, i.e. stick staking (SST) and no- stick staking (NST) and six mulch materials, i.e. black polyethylene, white polyethylene, maize straw, palm fronts, grasses and no mulch. The parameters taken on soil physical and chemical properties are soil moisture content (%), soil temperature (^{O} C), soil pH, total nitrogen, available phosphorus and soil organic matter. Growth and yield parameters taken are as follows: average plant height, number of leaves, and number of fruits, stem girth, number of fruit per plant, fruit length, fruit diameter and yield per land area. Weeds were identified and their dry weights were measured. Data were collected from ten randomly selected plants in each plot. The data were statistically analyzed using GENSTAT. The analysis of variance (ANOVA) was performed to find out the significance of variation among the treatments while the significant difference between mean treatments were separated using Duncan's multiple range test (DMRT) at 5% level of probability. The result obtained from this study indicated that mulch materials and stick staking affect significantly growth parameters of tomato, yield per plant and yield per land area. The result also, indicated that plot mulch with black polythene performance best in terms of growth and yield and also improved soil physical properties better than either white polythene or organic mulch in the study area. It is therefore recommended that black polyethylene should be used as mulch materials for tomato production. However, better and stable fruit yield of tomato could be obtained with the practice of mulching in combination with staking. It is recommended that mulching should be carried out together with staking for higher fruit yield and black polyethylene should be use as mulch material in the study area.

Keywords: Mulch Material, Properties, Tomato, Growth, Yield, Soil and organic

1. Introduction

Tomato *(Lycopersicon esculentum* Mill.*)* is the most important and popular vegetable crop grown commercially throughout the country. In spite of its wide cultivation in Nigeria, the average yield is still very low. In southern guinea savanna agro-ecology, inadequate soil moisture is the main hindrance for tomato production in the dry season. Use of mulches offer great hope because of its moisture conserving ability and also, its moderate soil temperature (Bhella, 1988, Kwon *et al.,* 1988; Chakarborthy and Sadhu 1994 and Hooda, *et al.,* 1999). Polyethylene mulches are widely used in vegetable production and have contributed significantly to reduction of losses due to weed competition [Uguajio and Ernest, 2004]. Film color may affect effective weed seed germination, growth, and development under the plastic (Brault *et al*. 2002). Black polyethylene plastic mulch is the standard plastic mulch used in vegetable production (Gordon *et al*., 2010). Researchers using black plastic instead of bare soil have recorded higher yields (Mirshekari *et al*. 2012); Ragablarigani amd Aghaalikhani, (2011), earlier harvests Ihara *et al*. (2010), Lamont (1993). Earlier, Sweeney *et al.* (1987) and Bhella (1988) have also reported the moisture-conserving property of polyethylene mulches. Ability of organic mulch to conserve soil moisture was appreciably lower than that of the polyethylene mulch (Chakraborty and Sadhu, 1994). The natural mulching (paddy-straw or sugarcane trash) also stimulated vegetative growth compared to un-mulched but to a lesser extent than polyethylene mulch. Different mulch materials influenced flowering and fruiting in tomato (Decoteau *et al.,* 1986). The natural mulching materials such as paddy-straw or sugarcane trash retarded the weed growth considerably compared to control (Kwon *et aI.,* 1988). Staking is a means of providing supports to ensure clean and unblemished fruits which kept fruits off from the ground, minimizing diseases and rotting of fruits thereby increasing marketable yield (Hanna and Adams, 1982). Marketable yield of tomato under wet condition was significantly increased by staking of tomato plants (Quinn, 1973). Therefore the objective of the study was to assess the influence of staking and mulching on growth and yield of tomato (Roma f) in Southern Guinea Savannah Agro- ecology of Nigeria.

2. Materials and Methods

2.1 Experimental Site

The experiment was carried out for two consecutive growing seasons (2012 and 2013) at the

Research Site of Horticultural Section, Kabba College of Agriculture, Kabba. The site is located at latitude of 07° 35' N and longitude of 06° 08' E and is 1000 m above sea level, in Southern Guinea Savanna Agro Ecological Zone of Nigeria, where the dry seasons are dry and hot while, wet seasons are cool. The rainfall spans between April to November with peak in June. The dry season extends from December to March. The mean annual rainfall is 1570mm per annum with an annual temperature range of 18°C - 32°C. The mean relative humidity (RH) is 60% (Meterological data, 2011). The major soil order within the experimental site is Gleysol (Higgins, 1957; Babalola, 2010).

2.2 Determination of Soil Physical Properties

Soil moisture content was taken at 30 and 60 days after transplanting. Five undisturbed samples were collected at 0-15cm depth from each plot using core samplers and were used for the determination of gravitational moisture contents after oven dried at 100^0C for 24 hours. Soil temperature was determined at 15.00 hours (3pm) with a soil thermometer inserted to 5cm depth. Five readings were made per plot at each weekly determination.

2.3 Soil Sampling and Analysis

In order to determine some chemical properties of the soil on per plot basis, soil samples were collected from each plot at 30 and 60days after transplanting. Soil sample was analyzed in the laboratory for N, P, K, pH, organic carbon. Total N (%) was determined by the macro-Kjeldahl method (Bremner, 1982). Available P (ppm) was found using Bray I method according to Olsen (1982). Soil pH values were obtained by using a HI9813-5 portable pH/EC/TDS/°C meter (HANNA instruments, Romania, 2002). Soil organic carbon was determined by Walkley-Black procedure (Nelson and Sommers, 1982).

2.4 Field Methods

A split plot experiment was laid out in a randomized complete block design (RCBD) with three replications to randomize the staking levels and mulch methods in the main and sub-plots, respectively. The experiment comprised of two staking levels, i.e. staking (ST) and no-staking (NST) and six mulch materials, i.e. black polythene, white polythene, maize straw, palm fronts, grasses and no mulch. The treatments were carried out on the same plots in 2012 and 2013 growing seasons. The size of each plot was 5.0 m long and 3.0 m wide. A buffer zone of 2.0 m spacing was provided between plots. In both growing seasons, one of the most commercial varieties of tomato cv. ROMA F was transplanted manually at a spacing of 60cm on a raised bed at both sides. Before transplanting, half the recommended levels of N (150 kg ha^{-1}) and recommended levels of P (100 kg ha^{-1}) and K (50 kg ha^{-1}) were used as Urea, TSP (triple super phosphate) and MOP (muriate of potassium), respectively. The remaining half recommended level of N was applied at flowering. pedimethalin (1.5L ha^{-1}) was also applied for weeds control before transplanting. Tomato was transplanted on 25^{th} August when the soil was well watered in all treatments. Both black and white plastic-film measuring 5 m long × 3 cm wide and 0.25 mm thick was used to cover the experimental beds (raised beds, 25 cm high) of appropriate plots and was held down with forked sticks and pegs to prevent it from been blown away by the wind. Organic mulch was also spread on plots at rate of 10kg per 45m^2. This was done one week before transplanting. Tomato plants were staked with stick measuring 65cm, 5cm base of which was inserted to the soil. During the growing season, the insecticides and fungicides were applied according to general local practices and recommendations. All other necessary operations except those under study were kept normal and uniform for all the treatments.

2.5 Weeds Characters

At 30 and 60 DAT (days after transplanting), weed samples were collected from two 50 cm × 50 cm quadrates randomly laid per plot. The weeds were identified up to species level and were clipped at soil surface, oven-dried at 80°C for 48 hours and weighed to determine the dry matter (DM).

3. Results and Discussion

Effect of different mulch materials and staking on soil temperature and moisture content are presented in Table 1. Temperatures of plots mulched with black and white polythene were higher than plots with organic mulch and the control in this experiment. The plots mulched with maize straw, palm fronts and grasses are slightly higher than control (no much) (Table 1). Hooda et al. (1999) and Rajbir, (2005) reported higher temperatures with the use of different mulches. Mulch regulates soil temperature, creates suitable condition for germination, improve soil moisture (Patil and Basad, 1972). Improves soil physical conditions by enhancing biological activity of soil fauna and thus increases soil fertility (Lal, 1989). Plots with stick staking had higher soil temperature compared with no stick staking plots. The higher temperature observed could be due to ease of sun rays interception by the soil created by staking.

Table 1. Effect of Different Mulching Materials and staking on Soil Physical Properties (2013 and 2014).

Mulching methods	Soil moisture		Soil temperature	
	2013	2014	2013	2014
Black polyethylene	14.3a	16.2a	27.4a	32.6a
White polyethylene	13.6a	16.0a	29.7a	33.2a
Maize straw	11’9bc	11.6b	24.1ab	28.7b
Palm fronds	12.6ab	11.0b	23.0b	28.3b
grasses	10.8c	12.4b	23.3ab	29.9ab
No mulch	8.3d	10.1b	22.8b	28.4b
Staking methods				
Stick staking	12.6a	13.4a	26.3b	27.4b
No staking	09.3b	11.2b	29.6a	31.3a

In a column, figures bearing same letter(s) do not differ significantly at 5% level of probability by DMRT.

Higher soil moisture was observed in plot with polyethylene mulch when compared with plots with organic mulch and the control (Table 1), the result is in line with the finding of Sweeney *et al.* (1987), they reported the moisture conserving property of polyethylene mulches. Organic mulches (maize straw, palm fronts and grasses) recorded slightly higher soil moisture than the control. Chakraborty and sadhu (1994) and Singh (2005) also reported the ability of organic mulch to conserve soil moisture was appreciably lower than that of the polyethylene mulch. Plot with no mulch recorded least moisture content in this experiment. The result is in line with the finding of Bhella (1988). No stick staking plots had higher soil moisture content than stick staking plots. The observed higher moisture recorded in no stick staking plots could be due to the foliage of tomato that spread on the soil and acted like cover crop, thereby reduces the rate of soil evaporation, Agble (1975).

Table 2. Effect of Different Mulch Materials and staking on Soil chemical Properties (mean of 2013 and 2014).

Mulching materials	Soil pH	Nitrogen	Phosphorus	Organic matter
Black polyethylene	6.3a	1.63ab	2.62c	1.98b
White polyethylene	6.3a	1.54b	2.44c	2.12b
Maize straw	6,3a	1.69ab	4.11a	3.43a
Palm fronds	6.3a	1.90a	3.98a	2.91a
grasses	6.3a	1.87a	3.86a	2.74a
No mulch	6.4a	1.68ab	2.93bc	2.01b
Staking methods				
Stick staking	6.3a	1.87a	3.56a	2.67a
No staking	6.3a	1.74a	3.47a	2.56a

In a column, figures bearing same letter(s) do not differ significantly at 5% level of probability by DMRT.

Effect of different mulch materials and staking on soil pH, nitrogen, and phosphorus and soil organic matter are presented in Table 2. There was no significant difference in soil pH as result of treatments imposed. Effect of different mulch materials was significant on nitrogen, phosphorus and soil organic matter. Plots with organic mulch (maize straw, palm fronds and grasses) had similar effect on nitrogen, phosphorus and soil organic matter. These were significantly higher than plots with polyethylene mulch irrespective of their colour and no mulch plots. The highest values of nitrogen, phosphorus and soil organic matter occurred in plots treated with maize straw. Plots treated with white polyethylene recorded least values of these parameters. Effect of staking was not profound on soil pH, nitrogen, phosphorus and organic matter.

Effect of different mulch materials and staking on growth components of tomato are presented in Table 3**.** The result shows significant difference in growth parameters considered. Polyethylene mulch had significant beneficial effect on vegetative growth of tomato plants (Table 3). Gordon *et al*. (2010) reported that plastic mulch produced higher plant height, fresh weight, early and total yield when compared with other mulches. Though, organic mulches (maize straw, palm front and grasses) also stimulated vegetative growth compared to un-mulched plots but to a lesser extent than the polyethylene mulches. Among the polyethylene mulch used, black polyethylene recorded better performance in term of plant height, number of branches, number of leaves and stem girth with mean values of 77.2cm, 6.65, 26.8 and 0.92cm respectively. Awodoyin *et al*. (2007) reported that mulched tomato plants had more branches than the un- mulched plants, which supported the present results. Hamid *et al*. (2012) opined that plants grown over plastic mulches considerably produced the most number of leaves relative to control treatment. The microclimate condition improved by the mulches might have provided a suitable condition for producing higher number of leaves in the plants. Franquere, (2011) reported that lettuce grown on red mulch had most number of leaves compared to the other coloured mulch treatment. Table (3) also presented the influenced of different mulching materials on days to 50% flowering in tomato. In general, different mulch materials influenced flowering in tomato. Flowering was earlier in all the mulch plots compared to the control. The earliest advanced flowering was observed in plots with black polyethylene (44 days). The result corroborated the findings Decoteal *et al*., (1986) and Singh (2005). All the growth characters considered were significantly influenced by staking, tomato staked with stick had higher plant height, number of branches, number of leaves and stem girth than no staked plants. Flowering was earlier in all the staked plants compared to the no staked plants (Table 3). This could be due to better photosynthetic activity created by good arrangement of the leaves.

Table 3: Effect of Different Mulch Materials and staking on growth components of tomato (mean of 2013 and 2014).

Mulching materials	Plant height(cm)	Branches per plant	No of leaves	Stem girth (cm)	Dry weight (cm)	Day to 50% flowering
Black polyethylene	77.2a	6.65	26.8a	0.92a	265.3^{a}	44^{a}
White polyethylene	74.6a	4.98	23.4a	0.84a	256.4^{a}	46^{a}
Maize straw	62.8b	3.75	21.0ab	0.71ab	198.3^{ab}	53^{ab}
Palm fronds	63.4b	3.96	18.9b	0.62b	202.4^{ab}	53^{ab}
grasses	61.8b	3.74	19.6b	0.76ab	196.5^{ab}	54^{ab}
No mulch	44.6c	2.89	18.4b	0.56b	146.2^{b}	57^{b}
Staking methods						
Stick staking	78.6^{a}	7.4^{a}	26.5^{a}	0.98^{a}	284.0^{a}	47^{a}
No staking	56.4^{b}	4.6^{b}	19.3^{b}	0.61^{b}	166.4^{b}	55^{b}

In a column, figures bearing same letter(s) do not differ significantly at 5% level of probability by DMRT.

Number of weeds identified and dry weight of the weed are presented in (Table 4). Weeds did not grow at all, in plots mulched with black polyethylene, while other mulches allowed weeds growth even white polyethylene. Dry weight of weeds on white polyethylene, maize straw, palm fronts and grasses are 114.2, 98.4, 116.3 and 198.4 g/m^2 respectively. The result indicated that colour of polyethylene dictated the light intensity reaching the soil surface; white polyethylene did not restrict the light intensity and hence, failed to reduce the photosynthetic activity of the weeds. Organic mulch retarded weed growth compared to control. The result confirmed with the earlier observation of Kwon *et al*. (1988) and Sadhu (1994) and Singh (2000). Effect of staking was not profound on weeds characters observed.

Table 4. Effect of Different Mulch Materials and staking on identified weed and its dry weight (mean of 2013 and 2014)

Mulching methods	Identified weeds		Dry weight of weeds identified	
	2013	2014	2013	2014
Black polyethylene	0	0	0	0
White polyethylene	5b	6b	104.2b	123.6b
Maize straw	5b	8b	98.4b	106.1b
Palm fronds	7b	11b	116.3b	187.9b
Grasses	5b	9b	198.4b	201.0b
No mulch	14a	21a	470.6a	632.8a
Staking methods				
Stick staking	8a	13a	116.0a	108.3a
No staking	6a	10a	134.2a	126.4a

In a column, figures bearing same letter(s) do not differ significantly at 5% level of probability by DMRT.

Table 5. Effect of Different Mulch Materials and staking on yield components of tomato (mean of 2013 and 2014)

Mulching methods	Fruits per plant	Fruit weight(g)	Fruit length(mm)	Fruit diameter(mm)	Yield per plant(kg)
Black polyethylene	29.6a	69.3a	58.3ab	42.1a	2.05a
White polyethylene	24.4ab	68.7a	61.8a	46.3a	1.81a
Maize straw	21.4b	64.8a	66.4a	38.6	1.39b
Palm fronds	22.8b	63.6a	60.3a	43.4a	1.45ab
grasses	21.3b	59.8ab	63.4a	37.1ab	1.27b
No mulch	16.1c	46.2b	49.3b	26.4c	0.74c
Staking methods					
Stick staking	26.7a	74.8a	62.4a	45.5a	2.16a
No staking	14.3b	41.3b	46.2b	34.6b	1.04b

In a column, figures bearing same letter(s) do not differ significantly at 5% level of probability by DMRT.

Table 5 presented the effect of different mulch materials on yield and yield components of tomato. Significant differences were observed in number of fruits per plant, fruit weight (g) fruit length (mm), fruit diameter (mm) and fruit yield per plant (kg) as influenced by different mulch materials. Black polyethylene mulch treatment gave the highest number of fruit per plant, individual fruit weight, fruit length (mm), fruit diameter (mm) and fruit yield per plant.

However, these were statistically higher than plots with organic mulches (maize straw, palm fronts and grasses) and the control (Table 5). The greatest yield was observed in plots mulch with black polyethylene and may be due to complete elimination of weeds, high soil moisture availability and moderates soil temperature during cropping seasons. The result is in agreement with observations of Ashworth and Harrison (1983) and Singh (2005) they reported higher yield under black polyethylene mulch and ascribed this to reduced nutrients losses due to weed control and improved hydrothermal regimes of soil. Similarly, white polythene produced significantly higher yield compared to the organic mulches and control. The increase is due to greater number of fruits per plant as well as their larger size. Lower yield in white polyethylene mulch compare to black polyethylene may be due to poor weed control. Among the organic mulches, palm fronts was found better for increase fruits number and fruit yield per plant (Table 5). However, fruit yield was significantly higher under organic mulches than the control. The observed results confirm the findings of Chakraborty and Sadhu (1994); Hooda *et al*., (1999) and Singh (2005). Staking significantly affect all yield characters observed, plot with stick staking recorded greater values of number of fruits per plant, fruit weight (g) fruit length(mm), fruit diameter(mm) and fruit yield per plant (kg). The result confirmed the work of Quinn (1973b) who reported that marketable yield of tomato under wet condition was significantly increased by staking of tomato plants.

4. Conclusions

Mulch moderates soil physical condition, creates suitable condition for germination, and stimulates vegetative growth, thereby increased tomato fruits which resulted in higher fruit yield of the tomato. However, better and stable fruit yield of tomato could be obtained with the practice of mulching in combination with staking.

Recommendations

It recommended that mulching should be carried out together with staking for higher fruit yield and black polyethylene should be use as mulch material in the study area. There is the need to carry out further studies especially cost benefit analysis and multi-locational trials in future studies.

References

Agble, F. (1976). Effects of Pruning and Spacing on Tomato Productivity. *Ghana Journal of Science, 15*, 175-179.

Awodoyin, R. O. Ogbeide, F. I., & Oluwole, O. (2007). Effects of Three Mulch Types on the Growth and Yield of Tomato (*Lycopersicon esculentum* Mill.) and Weed Suppression in Ibadan, Rainforest-savanna Transi-tion Zone of Nigeria, *Tropical Agricultural Research & Extension, 10*, 53-60, 2007.

Ashworth S, & Harrison H. (1983). Evaluation of Mulches for Use in the Home Garden. *Hort. Sci. 18* (2), 180-182.

Babalola, T. S. (2010). Land Evaluation Studies of Two Wetland Soils in Nigeria. An MSc Thesis Submitted to the Department of Crop, Soil and Environmental Sciences, University of

Ado –Ekiti. Pp 141.

Bhella, H. S. (1988). Tomato Response of Trickle Irrigation and Black Polyethylene Mulch. J. Amer. *Soc. Hort. Sci. 113*(4), 543-546.

Bremner J. M. (1982). Total nitrogen. In: Page A.L. Miller R.H. and Keeny D.R. (Eds.). Methods of Soil Analysis. Part-2, 2nd Ed. Agronomy Monograph No. 9. ASA and SSSA, Madison, WI. pp. 915-928.

Brault, D., Stewart, K. A., & Jenni, S. (2002). Optical Properties of Paper and Polyethylene Mulches Used for Weed Control in Lettuce, *HortScience*, *37*, 87-91, 2002.

Chakraborty, R. C., & Sadhu, M. K. (1994). Effect of Mulch Type and Colour on Growth and Yield of Tomato *(Lycopersicon esculentum* Miller). *Indian J. Agric. Sci. 64*, 608-612.

Decoteau, D. R., Daniel, D. D., Kasperbauer, N. J., & Hunt, P. G. (1986). Coloured Plastic Mulches and Tomato Morphogenesis. *Proc. Natl. Agr.Plastic Congr. 19*, 240 -248.

Franquera, E. D. (2011). Influence of Different Colored Plastic Mulch on the Growth of Lettuce (Lactuca sativa), *Journal of Ornamental and Horticultural Plants, 1*(2), 97-104, September.

Gordon, G. G. Foshee, G. W., Reed, S. T., Brown, J. E., & Vinson, E. L. (2010). The Effects of Colored Plastic Mulches and Row Covers on the Growth and Yield of Okra, *HortTechnology, 20*(1), 224-233.

Ham, J. M., Kluitenberg, G, & Lamont, W. (1993). Optical Properties of Plastic Mulches Affect the Field Temperature Regime, *Journal of the American Society for Horticultural Science, 118*, 188-188.

Hamid R. R. Farzad, H., & Ramin, R. (2011). Effect of Colored Plastic Mulches on Yield of Tomato and Weed Biomass. *International Journal of Environmental Science and Development, 3*(6).

Hanna, H. Y., & Adams, A. J. (1982). Increased Yield in Slicing Cucumbers with Vertical Training of Plants and Reduced Plant Spacing, *Horticulture, 22*, 32-34.

Higgins, G. M. (1957). Preliminary Report on the Detailed Land, Soil and Contours Survey of River Rine Area of School of Agriculture, Kabba. Soil Survey Bulletin No 31: 28p.

Hooda RS, Singh J, Malik VS & Batra VK (1999). Influence of Direct Seeding, Transplanting Time and Mulching on Tomato Yield. *Veg. Sci. 26*(2), 140-142.

Iharra, L., Flores, J., & Diaz-Pérez, J. C. (2001). Grow and Yield of Muskmelon in Response to Plastic Mulch and Row Covers" *Scicntia Hort*, *87*, 139-145. http://dx.doi.org/10.1016/S0304-4238(00)00172-2

Kwon YS, Leo YS, Park SK & Ko KD (1998). Effect of Different Mulch Material on the Soil Environment, Growth and Yield of Red Pepper *(Capsicum annum* L.). *Research* Reports of

Rural Development Administration, *Horticulture, Republic of Korea, 30*, 9-17.

Lamont, W. J. (1993). Plastic Mulches for Production of Vegetable Crops, *HortTechnology, 3*(1), 35-39.

Lal, R. (1989). Conservation Tillage for Sustainable Agriculture: Tropic versus Temperate Environments. *Adv. Agron. 42*, 147-151.

Mirshekari, B. Rajablarijani, H. R. AghaAlikhani, M. Farahvash, F., & Rashidi, V. (2002). Evaluation of Biodegradable and Polyethylene Mulches in Sweet Corn Production, *International Journal of Agriculture and Crop Sciences*, *4*(20), 1540-1545.

Nelson, D. W., & Sommers, L. E. (1982). Total Carbon, Organic Carbon and Organic Matter. In: Page A.L. Miller R.H. and Keeny D.R. (Eds.). Methods of Soil Analysis. Part-2, 2nd Ed. Agronomy Monograph No. 9. ASA and SSSA, Madison, WI. pp. 539-579.

Ngouajio, M., & Ernest, J. (2004). Light Transmission through Colored Polyethylene Mulches affected Weed Population. *Hort Science, 39*(6), 1302-1304.

Olsen S. R. (1982). Phosphorus. In: Page A.L. Miller R.H. and Keeny D.R. (Eds.). Methods of Soil Analysis. Part-2, 2nd Ed. Agronomy Monograph No. 9. ASA and SSSA, Madison, WI. pp. 403-430.

Patil, A. V., & Basad, A. D. (1972). Effect of Mulching Treatments on Soil Properties Growth and Yield of Tomato. *Indian J. Hort, 29*(2), 177-205.

Quinn, J. G. (1973b). An Evaluation of Methods of Mulching and Staking Tomatoes Grown During the Rains at Samaru, *Nigeria Horticulture Research Journal, 13*, 97-104.

Rajablarijani, H. R., & Aghaalikhani, M. (2011). Non-Chemical Weed Control in Winter Canola (*Brassica napus* L.), in *Proc. 2nd International Conference on Agricultural and Animal Science. IPCBEE, 22,* 30-34.

Singh, R. (2005). Influence of Mulching on Growth and Yield of Tomato (*Solanum lycopersicum* l.) in North Indian Plains. *Veg. Sci. 32*(1), 55-58.

Sweeney DW, Gratz DA, Bottcher AB, Locascio SJ & Campbell KL (1987). Tomato Yield and Nitrogen Recovery as Influenced by Irrigation Method, Nitrogen Source and Mulch. *Hort. Sci. 22*, 27-29.

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Operations Scheduling of Sugarcane Production Using Classical GERT Method (Part I: Land Preparation, Planting and Preserve Operations)

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Abstract

Analysis and evaluation of agricultural systems use these criteria: energy, economic, agronomy, environmental conservation and time. Because of time importance indicator for reducing timeliness cost, project scheduling techniques are used. Graphical Evaluation and Review Technique (GERT) is widely used as a tool for managing projects. In this research GERT Networks were used and operations scheduling of sugarcane production (land preparation, planting and preserve operations) in Khuzestan province of Iran as a case study was analysed, by using WinQsb software. Critical activities, events and path were determined. The earliest project completion time is 214.03 days. The results show a high potential for operations scheduling of sugarcane production.

Keywords: Scheduling, GERT network, Agricultural Mechanization, Sugarcane

1. Introduction

Analysis and evaluation of agricultural systems use these criteria: energy, economic, agronomy, environmental conservation and time. Because of time importance indicator for reducing timeliness cost and work breakdown, project scheduling techniques and work study especially network models are used. Such a network would as a powerful tool available a farm manager to plan, schedule, monitor, and control a project (Monjezi et al, 2012a). Since GERT (Graphical Evaluation and Review Technique) Networks have most of the advantages associated with networks and enables system analyst in exact evaluation of certain types of networks, in this research GERT Networks were used and operations scheduling of sugarcane production in Khuzestan province of Iran as a case study was analysed. Manju and Pooja (2007) GERT technique was applied to model and analyse the reliability of the above system. One of the strengths of the GERT network is the graphical representation, which is intuitive and easy to understand (Manju & Pooja, 2007). Abdi et al. performed Modeling and Analysis of Mechanization Projects of Wheat Production by GERT Networks. Results showed that the network model was able to answer any statistic questions concerning with the project (Abdi et al, 2010 and Abdi et al, 2009).

2. Materials and Methods

The study was carried out in Khuzestan province of Iran in 2015. Data were collected from variety sources such as reports and statistics of meteorological synoptic stations, opinions and comments of Khuzestan Sugarcane and by-Product Research and Training Institute experts and reports and statistics of Sugarcane Agro-Industry. All activity times are given in day. Having known perform once probability (p_{ij}) and three time estimates for an activity: optimistic time (t_o), most likely time (t_m) and pessimistic time (t_p), then expected time (t_e) and variance (v_{te}) was calculated for an activity from formulas (1) and (2):

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$$t_e = \mu = \frac{t_o + 4t_m + t_p}{6} \tag{1}$$

$$v_{t_e} = \left(\frac{t_p - t_o}{6}\right)^2 \tag{2}$$

The leading route calculation (the first node of the last node in the network starts to go) as soon as the expected (mean) and its variance of the occurrence of any event, relations (3) and (4) are calculated, respectively.

$$\mu^j_{T_E} = \max\left\{\mu^j_{T_E} + t^{ij}_e, \ldots\right\} \tag{3}$$

$$\delta^{2j}_{T_E} = \delta^{2i}_{T_E} + v^{ij}_{t_e} \tag{4}$$

Where:

$\mu^j_{T_E}$: Expected earliest occurrence time

T_E: Earliest time of occurrence of a random variable

$\delta^{2j}_{T_E}$: Earliest time the event variance

And in computing the backward direction (from the last node to the first node in the network has begun and will continue) latest times the expected (mean) and variance of the occurrence of any event that the relations (5) and (6) are obtained.

$$\mu^i_{T_L} = \min\left\{\mu^j_{T_L} - t^{ij}_e, \ldots\right\} \tag{5}$$

$$\delta^{2i}_{T_L} = \delta^{2j}_{T_L} + v^{ij}_{t_e} \tag{6}$$

Where:

$\mu^i_{T_L}$: Expected latest occurrence time

T_L: Latest time of occurrence of a random variable

$\delta^{2i}_{T_L}$: Latest time the event variance

Events in GERT slack for calculating network, since the slack for the event is the general latest time minus the earliest time of occurrence of the event and also the network and the earliest time of occurrence of GERT latest both random variables are defined, So the slack (S) is also a random variable from equation (7) is calculated.

$$S = T_L - T_E \tag{7}$$

The slack is obtained by subtracting two independent random variables with a normal distribution and to calculate the mean and variance of the relations (8) and (9) are used, respectively.

$$\mu_S = E(S) = \mu_{T_L} - \mu_{T_E} \tag{8}$$

$$\delta^2_S = var(S) = \delta^2_{T_L} + \delta^2_{T_E} \tag{9}$$

All calculations were performed using the software Win QSB (Windows Quantitative System for Business).

3. Results and Discussion

Time estimates (optimistic time, most likely time and pessimistic time), probability and Variance for each activity of sugarcane production (land preparation, planting and preserve operations) were calculated (Table 1). The results of Activity Analysis for project scheduling (project completion time, critical activities, earliest and latest start time, earliest and latest finish time and slack time) of sugarcane production, by using WinQsb software, have been shown in Table 1. The Table 1 shows that the earliest project completion time is 214.03 days. Some activities have a positive slack and some may have zero slack. Positive slack for each activity, showing the progress of the project ahead of schedule. In fact, there are many sources for that activity. Zero slack means being critical of the activity, the activity must occur at a specific time; otherwise they will schedule the project. Zero slack in progress, indicates the progress of the project schedule and resources are appropriately allocated. Critical activities, events (event, the result of completing one or more activities), or paths, if they delayed, will delay completion of the project. A project's critical path is understood to mean that sequence of critical activities (and critical events) which connects the project's start event to its end event cannot be delayed without delaying the project [5]. In other words, a critical path defines a chain of critical activities which connects start and end events of the directed network. The method of determining such a path includes two phases: The first phase is called the forward pass where calculations begin from the 'start' node to the 'end' node. The objective of this phase is computation of the earliest start time (T_E) of all events. The second phase called the backward pass begins calculation from the 'end' node and moves to the 'start' node. The objective of this phase is computation of the latest completion time (T_L) for all events. Slack times is the difference between the latest completion time and the earliest start time (Si=T_Li-T_Ei). S,T_L and T_E for each event and the results of computations are presented in Table 1:

(1) T_EEND= 214.03 (day) is the earliest completion time for event END and whole project;

(2) T_LEND=214.03 (day) is the latest completion time for event END and whole project (The researcher assumed that T_L of project equal to T_E one);

(3) S=0 presents that this activity is critical. Project's progress is according to the scheduling and the resource allocation is proper;

(4) S = n, n > 0. Project progress is foregoing than scheduling and resources are surplus;

(5) S=m, m<0. Project progress is lag behind than scheduling and resources are lack;

(6) Critical path, events and activities are known. The critical path is of great interest for project managers. The activities on the critical path are ones which absolutely must be done on time in order to complete the whole project on time. If any activity on the critical

(7) Given the critical path, the earliest expected time for completion of the first part of sugarcane production operations shall be to:

$$\begin{aligned}\mu_{T_E}^{118} = 0 + 3.16 + 0.1 + 0.1 + 5 + 0 + 8.16 + 0 + 1 + 4 + 1 + 4 + 1.83 + 8 + 1 + 8 \\ + 1.83 + 8 + 1 + 7 + 4 + 1 + 4 + 1.83 + 4 + 1.83 + 2 + 1.83 + 1 + 9 \\ + 1 + 9 + 1.83 + 2.08 + 1 + 4.25 + 3 + 4.25 + 1 + 0 + 1.83 + 4.16 + 0 \\ + 4.25 + 1 + 0 + 2 + 7.16 + 0 + 4.25 + 1.83 + 4 + 4.25 + 5 + 1 + 7.17 \\ + 1 + 1 + 0 + 1.83 + 3 + 0 + 4.25 + 1 + 0 + 1.83 + 2.08 + 0 + 4.25 \\ + 1.83 + 1 + 13.83 + 2 + 0 + 1.83 + 4.25 + 0 = 214.03\end{aligned}$$

And also taking into consideration the critical path, the variance of the end activity will be as follows:

$$\delta^{2^{118}}_{T_E} = 0.250 + 0 + 0 + 0.111 + 0 + 0.250 + 0 + 0 + 0.111 + 0 + 0.111 + 0.027 + 0.111 + 0 + 0.111 + 0.027 + 0.111 + 0 + 0.111 + 0.111 + 0 + 0.111 + 0.027 + 0.111 + 0.027 + 0.111 + 0.027 + 0 + 0.111 + 0 + 0.111 + 0.027 + 0.062 + 0 + 0.174 + 0.111 + 0.174 + 0 + 0 + 0.027 + 0.694 + 0 + 0.174 + 0 + 0 + 0.111 + 0.694 + 0 + 0.174 + 0.027 + 0.111 + 0.174 + 0.444 + 0 + 0694 + 0 + 0 + 0 + 0.027 + 0.111 + 0 + 0.174 + 0 + 0 + 0.027 + 0.062 + 0 + 0.174 + 0.027 + 0 + 4.694 + 0 + 0 + 0.027 + 0.174 + 0 = 11.41$$

This course may be taken with respect to the probability of finding the directories in the path that is provided in Table 1, as follows:

$$P_{critical\,path} = 0.25 \times 0.2 \times 0.25 \times 0.25 \times 0.5 \times 0.9 = 0.0014$$

4. Conclusion

In this research GERT Networks were used and operations scheduling of sugarcane production (land preparation, planting and preserve operations) in Khuzestan province of Iran as a case study was analysed, by using WinQsb software. Critical activities, events and path were determined. The earliest project completion time is 214.03 days. The results show a high potential for operations scheduling of sugarcane production.

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Table 1. Computation results and analysis of sugarcane production classical GERT network

Activity code	Activity description	Immediate predecessor	t_o	t_m	t_p	t_e	v_{t_e}	p_{ij}	Start time		Finish time		Start time variance		Finish time variance		Slack (LS-ES)	Variance slack
									ES	LS	EF	LF	VES	VLS	VEF	VLF		
S	START	-	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
001	Sampling of soil	S	1	1	1	1	0	1	0	4.36	1	5.36	0	0.25	0	0.25	4.36	0.25
002	Test results of soil	001	2	3	4	3	0.111	1	1	5.36	4	8.36	0	0.25	0.11	0.36	4.36	0.25
003	Bordering map supply	S	2	3	3	2.83	0.027	1	0	0.53	2.83	3.36	0	0.22	0.03	0.25	0.53	0.22
004	Tractors, border and grader supply	S	1	2	2	1.83	0.027	1	0	1.53	1.83	3.36	0	0.22	0.03	0.25	1.53	0.22
005	Operators employ	S	1	2	3	2	0.111	1	0	1.36	2	3.36	0	0.14	0.11	0.25	1.36	0.14
006	Oil and fuel supply	S	2	3	5	3.16	0.250	1	0	0	3.16	3.16	0	0	0.25	0.25	0	0
007	Oil and fuel for land preparation	006	0.1	0.1	0.1	0.1	0	1	3.16	3.16	3.26	3.26	0.25	0.25	0.25	0.25	0	0
008	Oil and fuel for bordering	007	0.1	0.1	0.1	0.1	0	1	3.26	3.26	3.36	3.36	0.25	0.25	0.25	0.25	0	0
009	Bordering	003,004,005,008	4	5	6	5	0.111	1	3.36	3.36	8.36	8.36	0.25	0.25	0.36	0.36	0	0
010	Decide to leaching	002,009	0	0	0	0	0	0.25	8.36	8.36	8.36	8.36	0.36	0.36	0.36	0.36	0	0
011	Decide to non- leaching	002,009	0	0	0	0	0	0.75	8.36	11.53	8.36	11.53	0.36	0.5	0.36	0.5	3.16	0.14
012	Leaching	010	7	8	10	8.16	0.250	1	8.36	8.36	16.53	16.53	0.36	0.36	0.61	0.61	0	0
013	Pre-irrigation	011	4	5	6	5	0.111	1	8.36	11.53	13.36	16.53	0.36	0.5	0.47	0.61	3.16	0.14
014	Decide to disc harrowing	012	0	0	0	0	0	1	16.53	16.53	16.53	16.53	0.61	0.61	0.61	0.61	0	0
015	Decide to non- disc harrowing	013	0	0	0	0	0	1	13.36	16.53	13.36	16.53	0.47	0.61	0.47	0.61	3.16	0.14
016	Disc harrow supply	014,015	1	1	1	1	0	1	16.53	16.53	17.53	17.53	0.61	0.61	0.61	0.61	0	0
017	Oil and fuel for disc harrowing	007	0.1	0.1	0.1	0.1	0	1	3.26	17.43	3.36	17.53	0.25	0.61	0.25	0.61	14.16	0.36
018	Primary disc harrowing	016,017	3	4	5	4	0.111	1	17.53	17.53	21.53	21.53	0.61	0.61	0.72	0.72	0	0
019	Leveler provide	018	1	1	1	1	0	1	21.53	21.53	22.53	22.53	0.72	0.72	0.72	0.72	0	0

Activity code	Activity description	Immediate predecessor	t_o	t_m	t_p	t_e	v_{t_e}	p_{ij}	Start time		Finish time		Start time variance		Finish time variance		Slack (LS-ES)	Variance slack
									ES	LS	EF	LF	VES	VLS	VEF	VLF		
020	Oil and fuel for leveling	007	0.1	0.1	0.1	0.1	0	1	3.26	22.43	3.36	22.53	0.25	0.72	0.25	0.72	19.16	0.47
021	Primary leveling	019,020	3	4	5	4	0.111	1	22.53	22.53	26.53	26.53	0.72	0.72	0.83	0.83	0	0
022	Scraper provide	021	1	2	2	1.83	0.027	1	26.53	26.53	28.36	28.36	0.83	0.83	0.86	0.86	0	0
023	Oil and fuel for scrapering	007	0.1	0.1	0.1	0.1	0	1	3.26	28.26	3.36	28.36	0.25	0.86	0.25	0.86	25	0.61
024	Scrapering	022,023	7	8	9	8	0.111	1	28.36	28.36	36.36	36.36	0.86	0.86	0.97	0.97	0	0
025	Mold board plow provide	024	1	1	1	1	0	1	36.36	36.36	37.36	37.36	0.97	0.97	0.97	0.97	0	0
026	Oil and fuel for plowing	007	0.1	0.1	0.1	0.1	0	1	3.26	37.26	3.36	37.36	0.25	0.97	0.25	0.97	34	0.72
027	Plowing	025,026	7	8	9	8	0.111	1	37.36	37.36	45.36	45.36	0.97	0.97	1.08	1.08	0	0
028	Bulldozer and subsoiler supply	027	1	2	2	1.83	0.027	1	45.36	45.36	47.2	47.2	1.08	1.08	1.11	1.11	0	0
029	Oil and fuel for subsoiling	007	0.1	0.1	0.1	0.1	0	1	3.26	47.1	3.36	47.2	0.25	1.11	0.25	1.11	43.83	0.86
030	Subsoiling	028,029	7	8	9	8	0.111	1	47.2	47.2	55.2	55.2	1.11	1.11	1.22	1.22	0	0
031	Tractors and disc harrow supply	030	1	1	1	1	0	1	55.2	55.2	56.2	56.2	1.22	1.22	1.22	1.22	0	0
032	Oil and fuel for second disc harrowing	007	0.1	0.1	0.1	0.1	0	1	3.26	56.1	3.36	56.2	0.25	1.22	0.25	1.22	52.83	0.97
033	Second disc harrowing	031,032	6	7	8	7	0.111	1	56.2	56.2	63.2	63.2	1.22	1.22	1.33	1.33	0	0
034	Second leveling	033	3	4	5	4	0.111	1	63.2	63.2	67.2	67.2	1.33	1.33	1.44	1.44	0	0
035	Furrower supply	034	1	1	1	1	0	1	67.2	67.2	68.2	68.2	1.44	1.44	1.44	1.44	0	0
036	Oil and fuel for furrowing	007	0.1	0.1	0.1	0.1	0	1	3.26	68.1	3.36	68.2	0.25	1.44	0.25	1.44	64.83	1.19
037	Furrowing	035,036	3	4	5	4	0.111	1	68.2	68.2	72.2	72.2	1.44	1.44	1.55	1.55	0	0
038	Chemical fertilizer and fertilizer attachments supply	037	1	2	2	1.83	0.027	1	72.2	72.2	74.03	74.03	1.55	1.55	1.58	1.58	0	0
039	Oil and fuel for fertilizering	007	0.1	0.1	0.1	0.1	0	1	3.26	73.93	3.36	74.03	0.25	1.58	0.25	1.58	70.66	1.33

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Activity code	Activity description	Immediate predecessor	t_o	t_m	t_p	t_e	v_{t_e}	p_{ij}	Start time		Finish time		Start time variance		Finish time variance		Slack (LS-ES)	Variance slack
									ES	LS	EF	LF	VES	VLS	VEF	VLF		
040	Fertilizering	038,039	3	4	5	4	0.111	1	74.03	74.03	78.03	78.03	1.58	1.58	1.69	1.69	0	0
041	Oil and fuel for planting stage	006	1	2	2	1.83	0.027	1	3.16	77.93	5	79.76	0.25	1.69	0.28	1.72	74.76	1.44
042	harvester for Cane cuttings supply	040	1	2	2	1.83	0.027	1	78.03	78.03	79.86	79.86	1.69	1.69	1.72	1.72	0	0
043	Oil and fuel for cane cuttings supply	041	0.1	0.1	0.1	0.1	0	1	5	79.76	5.1	79.86	0.28	1.72	0.28	1.72	74.76	1.44
044	Preparation of cane cuttings	042,043	1	2	3	2	0.111	1	79.86	79.86	81.86	81.86	1.72	1.72	1.83	1.83	0	0
045	Tractor and trailer for carry cuttings supply	044	1	2	2	1.83	0.027	1	81.86	81.86	83.7	83.7	1.83	1.83	1.86	1.86	0	0
046	Oil and fuel for carry cuttings	041	0.1	0.1	0.1	0.1	0	1	5	83.6	5.1	83.7	0.28	1.86	0.28	1.86	78.6	1.58
047	Carry cuttings	045,046	1	1	1	1	0	1	83.7	83.7	84.7	84.7	1.86	1.86	1.86	1.86	0	0
048	Oil and fuel for planting	041	0.1	0.1	0.1	0.1	0	1	5	84.6	5.1	84.7	0.28	1.86	0.28	1.86	79.6	1.58
049	Plant	047,048	8	9	10	9	0.111	1	84.7	84.7	93.7	93.7	1.86	1.86	1.97	1.97	0	0
050	Disc cover and shovel supply	049	1	1	1	1	0	1	93.7	93.7	94.7	94.7	1.97	1.97	1.97	1.97	0	0
051	Oil and fuel for covering	041	0.1	0.1	0.1	0.1	0	1	5	94.6	5.1	94.7	0.28	1.97	0.28	1.97	89.6	1.69
052	Covering (Disc covering and Hand covering)	050,051	8	9	10	9	0.111	1	94.7	94.7	103.7	103.7	1.97	1.97	2.08	2.08	0	0
053	Pesticide supply	052	1	1	1	1	0	1	103.7	104.53	104.7	105.53	2.08	2.11	2.08	2.11	0.83	0.03
054	Sprayer supply	052	1	2	2	1.83	0.027	1	103.7	103.7	105.53	105.53	2.08	2.08	2.11	2.11	0	0
055	Oil and fuel for Pre-emergence spraying	041	0.1	0.1	0.1	0.1	0	1	5	105.43	5.1	105.53	0.28	2.11	0.28	2.11	100.43	1.83
056	Pre-emergence spraying	053,054,055	1.5	2	3	2.08	0.062	1	105.53	105.53	107.61	107.61	2.11	2.11	2.17	2.17	0	0
057	Piping for irrigation	056	1	1	1	1	0	1	107.61	107.61	108.61	108.61	2.17	2.17	2.17	2.17	0	0
058	Primary irrigation	057	3.5	4	6	4.25	0.174	1	108.61	108.61	112.86	112.86	2.17	2.17	2.34	2.34	0	0
059	Recovering	058	2	3	4	3	0.111	1	112.86	112.86	115.86	115.86	2.34	2.34	2.45	2.45	0	0
060	Oil and fuel for preserve operations	006	0.1	0.1	0.1	0.1	0	1	3.16	122.75	3.26	122.85	0.25	2.65	0.25	2.65	119.58	2.4

Activity code	Activity description	Immediate predecessor	t_o	t_m	t_p	t_e	v_{t_e}	p_{ij}	Start time		Finish time		Start time variance		Finish time variance		Slack (LS-ES)	Variance slack
									ES	LS	EF	LF	VES	VLS	VEF	VLF		
061	Irrigation	059	3.5	4	6	4.25	0.174	1	115.86	115.86	120.11	120.11	2.45	2.45	2.62	2.62	0	0
062	Visit the farm (Evaluation of green field)	061	1	1	1	1	0	1	120.11	120.11	121.11	121.11	2.62	2.62	2.62	2.62	0	0
063	Decide to non- replant	062	0	0	0	0	0	0.8	121.11	127.11	121.11	127.11	2.62	3.34	2.62	3.34	6	0.72
064	Decide to replant	062	0	0	0	0	0	0.2	121.11	121.11	121.11	121.11	2.62	2.62	2.62	2.62	0	0
065	Oil and fuel for replant	060	0.1	0.1	0.1	0.1	0	1	3.26	122.85	3.36	122.95	0.25	2.65	0.25	2.65	119.58	2.4
066	Tractors, trailer, cane cutter and shovel supply	064	1	2	2	1.83	0.027	1	121.11	121.11	122.95	122.95	2.62	2.62	2.65	2.65	0	0
067	Preparation of cane cuttings	064	1	1	1	1	0	1	121.11	121.95	122.11	122.95	2.62	2.65	2.62	2.65	0.83	0.03
068	Replant	065,066,067	2	4	7	4.16	0.694	1	122.95	122.95	127.11	127.11	2.65	2.65	3.34	3.34	0	0
069	Decide to irrigation	068	0	0	0	0	0	1	127.11	127.11	127.11	127.11	3.34	3.34	3.34	3.34	0	0
070	Decide to irrigation	063	0	0	0	0	0	1	121.11	127.11	121.11	127.11	2.62	3.34	2.62	3.34	6	0.72
071	Irrigation	069,070	3.5	4	6	4.25	0.174	1	127.11	127.11	131.36	131.36	3.34	3.34	3.51	3.51	0	0
072	Visit the farm (weed infestation)	071	1	1	1	1	0	1	131.36	131.36	132.36	132.36	3.51	3.51	3.51	3.51	0	0
073	Decide to non- mechanical weed control	072	0	0	0	0	0	0.75	132.36	141.53	132.36	141.53	3.51	4.31	3.51	4.31	9.16	0.8
074	Decide to mechanical weed control	072	0	0	0	0	0	0.25	132.36	132.36	132.36	132.36	3.51	3.51	3.51	3.51	0	0
075	Labor, shovel and sickle supply	074	1	2	3	2	0.111	1	132.36	132.36	134.36	134.36	3.51	3.51	3.62	3.62	0	0
076	mechanical weed control	075	5	7	10	7.16	0.694	1	134.36	134.36	141.53	141.53	3.62	3.62	4.31	4.31	0	0
077	Decide to irrigation	076	0	0	0	0	0	1	141.53	141.53	141.53	141.53	4.31	4.31	4.31	4.31	0	0
078	Decide to irrigation	073	0	0	0	0	0	1	132.36	141.53	132.36	141.53	3.51	4.31	3.51	4.31	9.16	0.8
079	Irrigation	077,078	3.5	4	6	4.25	0.174	1	141.53	141.53	145.78	145.78	4.31	4.31	4.48	4.48	0	0
080	Oil and fuel for hilling up	060	0.1	0.1	0.1	0.1	0	1	3.26	147.51	3.36	147.61	0.25	4.51	0.25	4.51	144.25	4.26

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Activity code	Activity description	Immediate predecessor	t_o	t_m	t_p	t_e	v_{t_e}	p_{ij}	Start time		Finish time		Start time variance		Finish time variance		Slack (LS-ES)	Variance slack
									ES	LS	EF	LF	VES	VLS	VEF	VLF		
081	Hilling up implement supply	079	1	2	2	1.83	0.027	1	145.78	145.78	147.61	147.61	4.48	4.48	4.51	4.51	0	0
082	Hilling up	080,081	3	4	5	4	0.111	1	147.61	147.61	151.61	151.61	4.51	4.51	4.62	4.62	0	0
083	Irrigation	082	3.5	4	6	4.25	0.174	1	151.61	151.61	155.86	155.86	4.62	4.62	4.79	4.79	0	0
084	Optical trap provide	083	3	5	7	5	0.444	1	155.86	155.86	160.86	160.86	4.79	4.79	5.23	5.23	0	0
085	Mechanical pest control (optical trap)	084	1	1	1	1	0	1	160.86	160.86	161.86	161.86	5.23	5.23	5.23	5.23	0	0
086	Parasitoid wasps supply	085	5	7	10	7.17	0.694	1	161.86	161.86	169.03	169.03	5.23	5.23	5.92	5.92	0	0
087	Biological pest control- parasitoid wasps (first stage)	086	1	1	1	1	0	1	169.03	169.03	170.03	170.03	5.92	5.92	5.92	5.92	0	0
088	Visit the farm (weed infestation)	087	1	1	1	1	0	1	170.03	170.03	171.03	171.03	5.92	5.92	5.92	5.92	0	0
089	Decide to non- mechanical weed control (cultivator)	088	0	0	0	0	0	0.75	171.03	175.86	171.03	175.86	5.92	6.06	5.92	6.06	4.83	0.14
090	Decide to mechanical weed control (cultivator)	088	0	0	0	0	0	0.25	171.03	171.03	171.03	171.03	5.92	5.92	5.92	5.92	0	0
091	Oil and fuel for cultivator	060	0.1	0.1	0.1	0.1	0	1	3.26	172.86	3.36	172.86	0.25	5.95	0.25	5.95	169.5	5.7
092	Tractors and cultivator supply	090	1	2	2	1.83	0.027	1	171.03	171.03	172.86	172.86	5.92	5.92	5.95	5.95	0	0
093	mechanical weed control (cultivator)	091,092	2	3	4	3	0.111	1	172.86	172.86	175.86	175.86	5.95	5.95	6.06	6.06	0	0
094	Decide to irrigation	093	0	0	0	0	0	1	175.86	175.86	175.86	175.86	6.06	6.06	6.06	6.06	0	0
095	Decide to irrigation	089	0	0	0	0	0	1	171.03	175.86	171.03	175.86	5.92	6.06	5.92	6.06	4.83	0.14
096	Irrigation	094,095	3.5	4	6	4.25	0.174	1	175.86	175.86	180.11	180.11	6.06	6.06	6.23	6.23	0	0
097	Visit the farm (weed infestation)	096	1	1	1	1	0	1	180.11	180.11	181.11	181.11	6.23	6.23	6.23	6.23	0	0
098	Decide to non- herbicide spraying	097	0	0	0	0	0	0.5	181.11	185.03	181.11	185.03	6.23	6.32	6.23	6.32	3.91	0.09

Activity code	Activity description	Immediate predecessor	t_o	t_m	t_p	t_e	v_{t_e}	p_{ij}	Start time		Finish time		Start time variance		Finish time variance		Slack (LS-ES)	Variance slack
									ES	LS	EF	LF	VES	VLS	VEF	VLF		
099	Decide to herbicide spraying	097	0	0	0	0	0	0.5	181.11	181.11	181.11	181.11	6.23	6.23	6.23	6.23	0	0
100	Oil and fuel for herbicide spraying	060	0.1	0.1	0.1	0.1	0	1	3.26	182.85	3.36	182.95	0.25	6.26	0.25	6.26	179.58	6.01
101	Herbicide supply	099	1	1	1	1	0	1	181.11	181.95	182.11	182.95	6.23	6.26	6.23	6.26	0.83	0.03
102	Sprayer supply	099	1	2	2	1.83	0.027	1	181.11	181.11	182.95	182.95	6.23	6.23	6.26	6.26	0	0
103	Chemical control of post-emergence weed	100,101,102	1.5	2	3	2.08	0.062	1	182.95	182.95	185.03	185.03	6.26	6.26	6.32	6.32	0	0
104	Decide to irrigation	103	0	0	0	0	0	1	185.03	185.03	185.03	185.03	6.32	6.32	6.32	6.32	0	0
105	Decide to irrigation	098	0	0	0	0	0	1	181.11	185.03	181.11	185.03	6.23	6.32	6.32	6.32	3.91	0.09
106	Irrigation	104,105	3.5	4	6	4.25	0.174	1	185.03	185.03	189.28	189.28	6.32	6.32	6.49	6.49	0	0
107	Oil and fuel for cropping of green trap	060	0.1	0.1	0.1	0.1	0	1	3.26	191.01	3.36	191.11	0.25	6.52	0.25	6.52	187.75	6.27
108	Seed of corn and sorghum supply	106	1	1	1	1	0	1	189.28	189.28	190.28	191.11	6.49	6.52	6.49	6.52	0.83	0.03
109	Tractors and row planter supply	106	1	2	2	1.83	0.027	1	189.28	189.28	191.11	191.11	6.49	6.49	6.52	6.52	0	0
110	mechanical pest control-green trap	107,108,109	1	1	1	1	0	1	191.11	191.11	191.11	191.11	6.52	6.52	6.52	6.52	0	0
111	Crop logging equipment supply	110	7	14	20	13.83	4.694	1	192.11	192.11	205.95	205.95	6.52	6.52	11.21	11.21	0	0
112	Install crop logging equipment	110	1	2	2	1.83	0.027	1	192.11	204.11	193.95	205.95	6.52	11.18	6.55	11.21	12	4.66
113	Sampling and determining the need for fertilizer plant	111,112	2	2	2	2	0	1	205.95	205.95	207.95	207.95	11.21	11.21	11.21	11.21	0	0
114	Decide to non- top dressing	113	0	0	0	0	0	0.1	207.95	214.03	207.95	214.03	11.21	11.41	11.21	11.41	6.08	0.2
115	Decide to top-dressing	113	0	0	0	0	0	0.9	207.95	207.95	207.95	207.95	11.21	11.21	11.21	11.21	0	0
116	Fertilizer drum and fertilizer solution device supply	115	1	1	1	1	0	1	207.95	208.78	208.95	209.78	11.21	11.24	11.21	11.24	0.83	0.03
117	Chemical fertilizer supply	115	1	2	2	1.83	0.027	1	207.95	207.95	209.78	209.78	11.21	11.21	11.24	11.24	0	0

Activity code	Activity description	Immediate predecessor	t_o	t_m	t_p	t_e	v_{t_e}	p_{ij}	Start time		Finish time		Start time variance		Finish time variance		Slack (LS-ES)	Variance slack
									ES	LS	EF	LF	VES	VLS	VEF	VLF		
118	Irrigation and top-dressing	116,117	3.5	4	6	4.25	0.174	1	209.78	209.78	214.03	214.03	11.24	11.24	11.41	11.41	0	0
E	END (first part of operation)	114,118	0	0	0	0	0	1	214.03	214.03	214.03	214.03	11.41	11.41	11.41	11.41	0	0

References

Abdi, R., Ghasemzadeh, H. R., Abdollahpur, S., Sabzehparvar, M., & Mohammadi Nasab, A. D. (2009). Modeling and resource allocation of agricultural mechanization projects with GERT networks. *Journal of Food, Agriculture & Environment*, *7*(3&4), 438-441.

Abdi, R., Ghasemzadeh, H. R., Abdollahpour, S., Sabzeparvar, M., & Dabbag Mohamadi Nasab, A. (2010). Modeling and analysis of mechanization projects of wheat production by GERT networks. *Elsevier, Agricultural Sciences in China*, *9*(7), 1078-1083. http://dx.doi.org/10.1016/S1671-2927(09)60193-0

Manju, A., & Pooja, M. (2007). Reliability analysis of consecutive-k, r-out-of-rr. DFM system using GERT. *International Journal of Operations Research*, *4*(2), 110-117.

Monjezi, N., Sheikhdavoodi, M. J. and Basirzadeh, H. (2012). Application of Project Scheduling in Agriculture (Case Study: Mechanized Greenhouses Construction Project). *Research Journal of Applied Sciences, Engineering and Technology*, *4*(3), 241-244.

Monjezi, N., Sheikhdavoodi, M. J., Basirzadeh, H., & Zakidizaji, H. (2012). Analysis and Evaluation of Mechanized Greenhouse Construction Project using CPM Methods. *Research Journal of Applied Sciences, Engineering and Technology*, *4*(18), 3267-3273.

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Operations Scheduling of Sugarcane Production Using Classical Gert Method (Part Ii: Preserve Operations, Harvesting and Ratooning)

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Abstract

Graphical Evaluation and Review Technique (GERT) is a systems analysis technique for project management. GERT provides a visual picture of the system and helps to analyse the system in a less inductive manner. Therefore, the purpose of this paper is studying the application of project scheduling in agriculture, for operations scheduling of sugarcane production (preserve operations, harvesting and rationing) using classical GERT method in Khuzestan province of Iran. Results showed that the network model was able to answer any statistic all the questions concerning the project. GERT networks are increasingly becoming a powerful tool for modelling, scheduling, planning, controlling and analysing of agricultural mechanization projects.

Keywords: Scheduling, GERT network, Agricultural Mechanization, Sugarcane

1. Introduction

Many different techniques and tools have been developed to support better project planning and these tools are used seriously by a large majority of project managers (Fahimifard & Kehkha, 2009; Fox & Spence, 1998; Pollack, 1998). Graphical Evaluation and Review Technique (GERT) is popularly a graphical tool for the analysis of complex systems because GERT can easily analyse stochastic networks with logical node and directed branches (Lin et al, 2011). A GERT network is an activity-on-the-arc network. The network may contain cycles, allowing for the multiple execution of activities during the execution of the project. Each arc (ij) is assigned a weight vector (Pij, Fij). Pij > 0 is the conditional execution probability of the corresponding activity (ij) given that project event i has occurred. Fij is the conditional distribution function of the nonnegative duration dij of activity (ij) given that (ij) is carried out. Pij and Fij are assumed to be independent of the number of times that project event i have occurred or activity (ij) has been executed before, respectively (Neumann, 1999; Neumann, 1990; Neumann, 1984; Neumann & Steinhardt, 1979). Since the efficiency and capabilities of GERT networks for modelling, simulation, planning, scheduling and analysis of the projects in complicated systems had been proved and confirmed in different fields of industry (Matsumoto et al, 2007; Ahcom 2004; Takanobu et al, 2004; Gauri, 2003; Kenzo & Nobuyuki, 2002). Also, the planning and project controlling techniques, especially network models, have been used in agricultural projects (Monjezi et al, 2012a; Monjezi et al, 2012b; Abdi et al, 2009). Therefore, the purpose of this paper is studying the application of project scheduling in agriculture, for operations scheduling of sugarcane production (preserve operations, harvesting and rationing) using classical GERT method.

2. Materials and Methods

The study was carried out in Khuzestan province of Iran in 2015. Data were collected from variety sources such as reports and statistics of meteorological synoptic stations, opinions and comments of Khuzestan Sugarcane and by-Product Research and Training Institute experts and reports and statistics of Sugarcane Agro-Industry. All activity times are given in day. For the sake of completion, a brief introduction of GERT (Manju, & Pooja, 2007; Cheng, 1994; Whitehouse, 1973) is given. GERT is a procedure, which combines the disciplines of the flow graph theory, Moment Generating Function (MGF) and Project Evaluation and Review Technique (PERT) for analysing stochastic networks having logical nodes and directed branches. Each branch has a probability that the activity associated with it will be performed. Therefore, GERT provides a visual picture of the system by means of the corresponding graph and makes it possible to analyse the given system in a less inductive manner. The results are obtained based on the MGF using Mason's formula, which takes care of all possible products of transmittances of non-intersecting loops described later.

The following steps are employed, when applying GERT:

1. Convert a qualitative description of a system or problem to a model in a stochastic network form.

2. Collect the necessary data to describe the transmittances of the network.

3. Apply Mason's rule to determine the equivalent function or functions of the network.

4. Convert the equivalent function into the following two performance measures of the network:

(a) The probability that a specific node is realized.

(b) The moment generating function of the time associated with a node, if it is realized.

5. Make inferences concerning the system under study from the information obtained in the Step 4.

GERT is based on the following definitions and rules:

• GERT network:

A GERT network generally contains one of the following two types of logical nodes:

(a) Nodes with Exclusive-Or input function and Deterministic output function.

(b) Nodes with Exclusive-Or input function and Probabilistic output function.

Exclusive-Or input: The node is realized; when any arc leading into it is realized. However, one and only one of the arcs can be realized at a given time.

Deterministic output: All arcs emanating from the node are taken, if the node is realized.

Probabilistic output: Exactly one arc emanating from the node is taken, if the node is realized.

In this paper type (b) nodes are used.

• Path:

A path is a series of branches, which joins two nodes and do not pass through any node more than once. The value of a path is the product of the so-called transmittances along the path.

• Loop:

A loop is a series of branches, which emerges from a node, and eventually returns to that node without passing through any node more than once. The value of a loop is equal to the product of the transmittances around the loop. A first order loop can be viewed as a loop having a consecutive path of arrows emerging from a node and returning to the same node. A self-loop can be viewed as a degenerated first order loop.

A Loop of order n is represented by a set of n disjoint first order loops.

• Mason's Rule:

In an open flow graph, write down the product of the transmittances along each path from the independent to the dependent variable. Multiply its transmittance by the sum of the non-touching loops to that path. Sum these modified path transmittances and divide by the sum of all the loops in the open flow graph yielding the transmittance T:

$$T = \frac{\sum (path \sum nontouching\ loops)}{\sum loops} \tag{1}$$

Where:

$$\sum nontouching\ loops = 1 - \sum first\ order\ nontouching\ loops + \sum second\ order\ nontouching\ loops - \sum third\ order\ nontouching\ loops + \cdots$$

$$\sum loops = 1 - \sum first\ oeder\ loops + \sum second\ order\ loops - \cdots$$

W-function for GERT:

In a network G with only GERT nodes, let the random variable Y_{ij} be the duration of the activity (i, j) and f (y_{ij}) be the conditional probability of the duration y_{ij} of the activity (i, j).

The conditional MGF of the random variable Y_{ij} is given as:

$$M_{ij}(s) = E[e^{sY_{ij}}] = \sum e^{sY_{ij}} f(Y_{ij}) \tag{2}$$

The conditional probability p_{ij} that the activity (i, j) will be undertaken, given that node i is realized, is multiplied by the MGF to yield a W-function:

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$$W_{ij}(s) = p_{ij}M_{ij}(s) \tag{3}$$

The W-function is used to obtain the information about a relationship between the nodes.

3. Results and Discussion

GERT network model resulted from sugarcane production (preserve operations, harvesting and rationing) as follows (Fig. 1). Parameters of sugarcane production classical GERT network are presented in Table 1. Due to the nature of the data, the distribution density function of time for each activity, the constant function with zero variance. According to the Materials and Methods, the probability, mean and variance of the completion time of sugarcane production obtained. The worth of different parts of the network is calculated. The relationship 4 shows the worth of equivalent branch that connect the starting node to node 86.

$$W_{(t)_{start-86}} = \left[\left(W_{(t)_{121}} * W_{(t)_{122}}\right) + W_{(t)_{120}}\right] * W_{(t)_{119}} = e^{2t}(0.9e^{4t} + 0.1) \tag{4}$$

By placing t = 0 in function $W_{(t)_{start-86}}$, probability of Equivalent branch was calculated (according to relationship 5.

$$P_{start-86} = W_{(0)_{83-86}} = e^{0}(0.9e^{0} + 0.1) = 1 \tag{5}$$

To calculate the mean time from starting node to node 86, the first derivative of the function $W_{(t)_{start-86}}$ was taken and the answer was 5.6 days. And by using the relationships 3 and taking second derivative of function $W_{(t)_{start-86}}$, the variance was obtained 1.44. Also worth of network loops was calculated as follow:

1. The worth of the loop N. 1 with track start-86:

$$W_{(t)_{L_{11}}} = 0.7 * e^{68t} = 0.7e^{68t}$$

2. The worth of the loop N. 2 with track 86-87-88-89-90-start:

$$W_{(t)_{L_{12}}} = 0.1e^{7t}(0.9e^{4t} + 0.1)$$

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3. The worth of the loop N. 3 with track 86-91-start:

$$W_{(t)_{L_{13}}} = 0.1e^{5t}$$

4. The worth of the loop N. 4 with track 86-92-93-94-95-96-97-98-99-100-101-102-103-104-105-106-107-108-109-start:

$$W_{(t)_{L_{14}}} = 0.05e^{41t} * \frac{e^t}{1-0.5e^t}$$

A prerequisite for completing operation is that each loops in the network be done one time and with significant order (in the case of first loop, Activity No. 123, was repeated 17 times). So the worth of equivalent branch between starting node and node No. 109 was obtained as follows:

$$\begin{aligned} W_{(t)_{start-109}} &= W_{(t)_{start-86}} * W_{(t)_{L_{11}}} * W_{(t)_{L_{12}}} * W_{(t)_{L_{13}}} * W_{(t)_{L_{14}}} \\ &= e^{2t}(0.9e^{4t}+0.1) * e^{68t} * e^{7t}(0.9e^{4t}+0.1) * e^{5t} * 0.5 * e^{41t} \\ &* \frac{e^t}{1-0.5e^t} = e^{123t} * (0.9e^{4t}+0.1)^2 * \frac{e^t}{1-0.5e^t} * 0.5 \end{aligned} \quad (6)$$

By placing t = 0 in the function $W_{(t)_{start-86}}$, the probability of starting node to node 109 was obtained a hundred percent.

By using Equation 3, the moment generating function $W_{(t)_{start-86}}$ is:

$$M_{(t)_{start-109}} = e^{123t} * (0.9e^{4t}+0.1)^2 * \frac{e^t}{1-0.5e^t} * 0.5 \quad (7)$$

Average time between starting node and node N.109, by deriving from the moment generating function $W_{(t)_{start-86}}$ and placing t = 0 was obtained as follows:

$$\begin{aligned} \mu(t) &= 123e^{123t}[(0.9e^{4t}+0.1)^2 * \frac{e^t}{1-0.5e^t} * 0.5] + [7.2e^{4t}(0.9e^{4t}+0.1)] * [e^{123t} \\ &* \frac{e^t}{1-0.5e^t} * 0.5] + [\frac{e^t}{(1-0.5e^t)^2} * 0.5] * [e^{123t} * (0.9e^{4t}+0.1)^2] \end{aligned}$$

$$\mu(0) = 132.2 = \mu$$

The second derivative of the moment generating function $W_{(t)start-86}$ and placing t = 0, the variance between the two nodes was obtained as follows:

$$\frac{\partial^2 M_{(t)start-109}}{\partial t^2} = [123 * 123e^{123t} * (0.9e^{4t} + 0.1)^2 * (\frac{e^t}{1 - 0.5e^t} * 0.5)] + [7.2e^{4t} * (0.9e^{4t} + 0.1) * 123e^{123t} * (\frac{e^t}{1 - 0.5e^t} * 0.5)] + [\frac{e^t}{(1 - 0.5e^t)^2} * 0.5 * 123e^{123t} * (0.9e^{4t} + 0.1)^2] + [25.92e^{131t} * (\frac{e^t}{1 - 0.5e^t} * 0.5)] + [127e^{127t} * 7.2(0.9e^{4t} + 0.1) * (\frac{e^t}{1 - 0.5e^t} * 0.5)] + [(\frac{e^t}{(1 - 0.5e^t)^2} * 0.5) * 7.2e^{127t}(0.9e^{4t} + 0.1)] + [\frac{e^t(1 + 0.5e^t)}{(1 - 0.5e^t)^3} * 0.5 * e^{123t} * (0.9e^{4t} + 0.1)^2] + [123e^{123t} * \frac{e^t}{(1 - 0.5e^t)^2} * 0.5 * (0.9e^{4t} + 0.1)^2] + [7.2e^{4t} * (0.9e^{4t} + 0.1) * e^{123t} * \frac{e^t}{(1 - 0.5e^t)^2} * 0.5]$$

$$\frac{\partial^2 M_{(0)start-109}}{\partial t^2} = 17496.12$$

$$Var_{start-109} = 17496.12 - (132.2)^2 = 19.28$$

For each node, to conclude about the probability, mean and variance can use the above procedure and predict various events during operations.so with due attention to certain events that are occurring in the tracks of operation, good decisions can be adopted.

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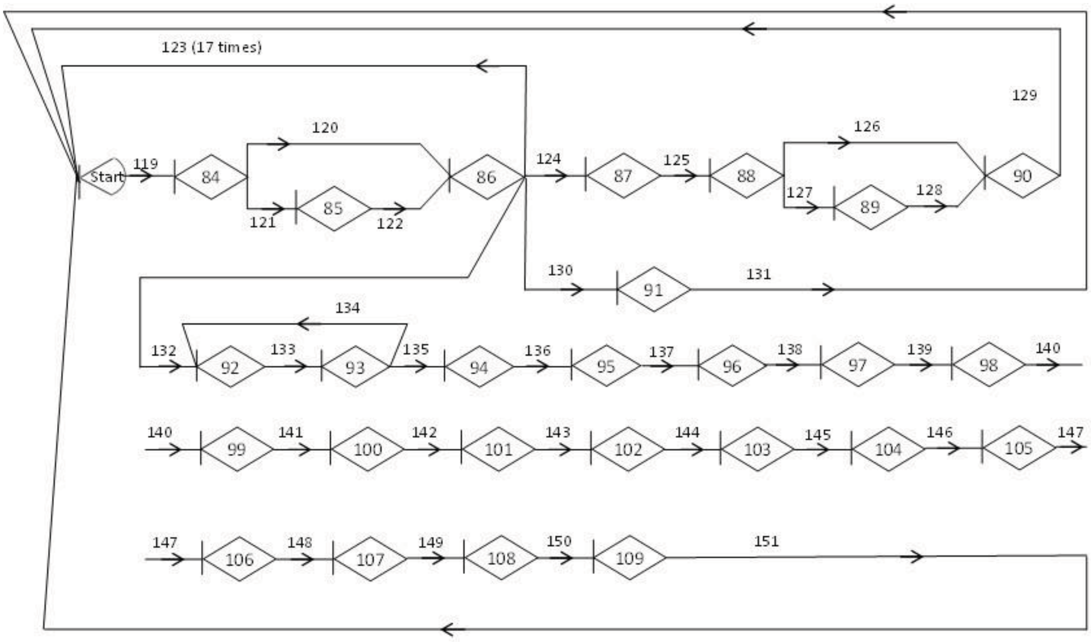

Figure 1. Operations of sugarcane production GERT network

4. Conclusion

The purpose of this paper is studying the application of project scheduling in agriculture, for operations scheduling of sugarcane production (preserve operations, harvesting and rationing) using classical GERT method in Khuzestan province of Iran. Results showed that the network model was able to answer any statistic all the questions concerning the project. GERT networks are increasingly becoming a powerful tool for modelling, scheduling, planning, controlling and analysing of agricultural mechanization projects.

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Table 1. Parameters of sugarcane production classical GERT network

Activity code	Activity description	Activity time	Repetition (times)	Moment Generating Function $M_{ij}(t)$	Probability P_{ij}	Worth of activity $W_{ij}(t)$
119	Sampling and determination of crop water requirement	2	1	Exp(2t)	1	Exp(2t)
120	Decide to non- irrigation	0	1	1	0.1	0.1
121	Decide to irrigation	0	1	1	0.9	0.9
122	Irrigation	4	1	Exp(4t)	1	Exp(4t)
123	Irrigation (The number of repeat 17 times)	4	17	Exp(68t)	0.7	0.7× Exp(68t)
124	Biological pest control- parasitoid wasps (second stage)	1	1	Exp(1t)	0.1	0.1× Exp(1t)
125	Sampling and determination of crop fertilizer requirement	2	1	Exp(2t)	1	Exp(2t)
126	Decide to non- top dressing	0	1	1	0.1	0.1
127	Decide to top-dressing	0	1	1	0.9	0.9
128	Irrigation and top-dressing	4	1	Exp(4t)	1	Exp(4t)
129	Irrigation	4	1	Exp(4t)	1	Exp(4t)
130	Biological pest control- parasitoid wasps (third stage)	1	1	Exp(1t)	0.1	0.1× Exp(1t)
131	Irrigation	4	1	Exp(4t)	1	Exp(4t)
132	Biological pest control- parasitoid wasps (fourth stage)	1	1	Exp(1t)	0.1	0.1× Exp(1t)
133	Sugarcane sap test determine the time of harvesting	1	1	Exp(1t)	1	Exp(1t)
134	Diagnosis of product prematurity	0	1	1	0.5	0.5
135	Diagnosis of product ripe	0	1	1	0.5	0.5
136	Cut off irrigation and collecting pipes	1	1	Exp(1t)	1	Exp(1t)

Activity code	Activity description	Activity time	Repetition (times)	Moment Generating Function $M_{1j}(t)$	Probability P_{1j}	Worth of activity $W_{1j}(t)$
137	Leveling of marginal lands and filling the beginning of furrows	1	1	Exp(1t)	1	Exp(1t)
138	The spunk supply and fire field	1	1	Exp(1t)	1	Exp(1t)
139	Harvester, tractor and transporter supply	2	1	Exp(2t)	1	Exp(2t)
140	Oil and fuel for harvesting	1	1	Exp(1t)	1	Exp(1t)
141	Harvesting and carrying cane to the factory	8	1	Exp(8t)	1	Exp(8t)
142	Tractor, trailer and grap loader supply	2	1	Exp(2t)	1	Exp(2t)
143	Liliko	2	1	Exp(2t)	1	Exp(2t)
144	Oil and fuel for ratooning	1	1	Exp(1t)	1	Exp(1t)
145	Subsoiling	5	1	Exp(5t)	1	Exp(5t)
146	Reshaper supply	1	1	Exp(1t)	1	Exp(1t)
147	Ratoon and reshape	4	1	Exp(4t)	1	Exp(4t)
148	Ratoon fertilizering	4	1	Exp(4t)	1	Exp(4t)
149	Ratoon spray	2	1	Exp(2t)	1	Exp(2t)
150	Piping for irrigation	1	1	Exp(1t)	1	Exp(1t)
151	Primary irrigation	4	1	Exp(4t)	1	Exp(4t)

References

Abdi, R., Ghasemzadeh, H. R., Abdollahpur, S., Sabzehparvar, M. & MohammadiNasab, A. D. (2009). Modeling and resource allocation of agricultural mechanization projects with GERT networks. *Journal Food, Agricultural & Environment*, *7*, 438-441.

Ahcom J. (2004). A model for benchmarking contractors project management elements in Saudi Arabia. Ph.D. Thesis. King Fahd University of Petroleum and Minerals.

Cheng, C. H. (1994). Fuzzy consecutive-k-out-of-n:F system reliability. *Microelectron. Reliability*. *34*, 1909-1922. http://dx.doi.org/10.1016/0026-2714(94)90286-0

Fahimifard, S. M., & Kehkha, A. A. (2009). Application of project scheduling in agriculture (case study: grape garden stabilization). *American-Eurasian Journal of Agricultural and Environmental Science*, *5*(3), 313-321

Fox, T. L., &. Spence, J. W. (1998). Tools of the trade: A survey of project management tools. *Project Management Journal*, *29*, 20-28

Gauri, S. (2003). GERT analysis of sampling plan for system reliability. Department of Mathematics and Statistics, Ravishankar University, Raipur (M.P.), India. *Microelectronics and Reliability*, 23-25

Kenzo, K., & Nobuyuki, N. (2002). Efficient Monte Carlo simulation method of GERT-type network for project management. *Computer and Industrial Engineering*, *42*, 521-531. http://dx.doi.org/10.1016/S0360-8352(02)00050-5

Lin, K. P., Wena, W. U., Chou, C. C., Jen, C. H., & Hung, K. C. (2011). Applying fuzzy GERT with approximate fuzzy arithmetic based on the weakest t-norm operations to evaluate repairable reliability, *Applied Mathematical Modelling*, *35*, 5314-5325. http://dx.doi.org/10.1016/j.apm.2011.04.022

Manju, A., & Pooja, M. (2007). GERT Analysis of m-consecutive-k-out-of-n:F Systems with Dependence, *Economic Quality Control*, *22*(1), 141-157

Matsumoto, T., Tokimatsu, K., Kosugi, T., & Yoshida, H. (2007). Evaluation for development of superconducting technologies in power sectors using GERT. Acta Press, USA. Power and energy systems.

Monjezi, N.; Sheikhdavoodi, M. J., & Basirzadeh, H. (2012a). Application of Project Scheduling in Agriculture (Case Study: Mechanized Greenhouses Construction Project). *Research Journal of Applied Sciences, Engineering and Technology*, *4*(3), 241-244

Monjezi, N.; Sheikhdavoodi, M. J.; Basirzadeh, H. & Zakidizaji, H. (2012b). Analysis and Evaluation of Mechanized Greenhouse Construction Project using CPM Methods. Research Journal of Applied Sciences, *Engineering and Technology*, *4*(18), 3267-3273

Neumann, K. (1999). Scheduling of Projects with Stochastic Evolution Structure, Chapter 14 in Weglarz, J. (ed.), Project Scheduling - Recent Models, Algorithms and Applications, Kluwer Academic publishers, Boston, 309-332.

http://dx.doi.org/10.1007/978-1-4615-5533-9_14

Neumann, K., (1990). Stochastic Project Networks, Lecture Notes in Economics and Mathematical Systems, Springer, Berlin, 344. http://dx.doi.org/10.1007/978-3-642-61515-3

Neumann, K. (1984). Recent Developments in Stochastic Activity Networks, *Information*, *22*(3), 219-248

Neumann, K., & Steinhardt, U. (1979). GERT Networks and the Time-Oriented Evaluation Projects, Lecture Notes in Economics and Mathematical Systems, *Springer, Berlin, 172*. http://dx.doi.org/10.1007/978-3-642-95363-7_5

Pollack, J. B. (1998). Project management software usage patterns and suggested research directions for future development. *Project Management Journal, 29*, 19-29.

Takanobu, K., Ayami, H., & Tsuyoshi, M. (2004). Time to realization: Evaluation of CO2 capture technology R & D by GERT analyses. *Energy, 29*, 1297-1308. http://dx.doi.org/10.1016/j.energy.2004.03.088

Whitehouse, G. E. (1973). Systems Analysis and Design Using Network Techniques. Prentice-Hall, Englewood Cliffs, New Jersey

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Evaluating Characteristics of Indigenous Chicken System with Flock Size Trends in a Participatory Research on Improved Management Practices in Kenya

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Abstract

This study investigates characteristics of indigenous chicken farms categorised on flock size patterns identified in a research involving 200 farmers in five regions in three counties (Nyandarua, Laikipia, Nakuru) in Kenya. Four villages were selected per region and10 farms in each village. Training and sensitisation meetings, introduction of intervention options (Housing, Feed Supplementation, Vaccination and Deworming), implementation by farmers, and monitoring and evaluation were carried out. The farmers used own inputs in implementing the project interventions and recorded various project activities and outputs. The project was monitored over a span of five, 3-months long periods. Variation analysis was used to identify similarities and differences between 7 farm categories (groups) based on their differences on the levels of the following factors: (1) Average farm flock sizes at five different periods (2) Treatment characteristics (interventions) application - (housing, vaccination, de-worming, and supplementation) (3) Demography characteristics (total flock additions, total flock reductions, total unplanned reductions and total controlled reduction) and (4) Production characteristics (mean hatchability and egg production per hen per cycle based on predicted egg production). Results indicate there were significant differences between the groups. Almost all the flock size differences between farm groups were significant at 1 percent level. There was a rise in differences of the between and within groups mean squares from period 1 to 5 as a result of the flock sizes levels also increasing with period. The treatment characteristics application levels had little differences between groups but housing and feed supplementation had larger values than the other two characteristics. The treatments application differences not being significant could be a consequence of influence from the research team being more or less the same in all the farms. The demography characteristics, total addition and total reduction values were close to one another among the farm categories. These together with flock size levels had little influence from the research team but were mostly a reflection of individual farm's decision and activities. However, the production characteristics reflected more both the farmer's action and the hen potential. The group with the lowest flock size trends had production values close to those of other groups. This would suggest that low flock size level in a farm is not a reflection of poor production dynamics. The demographic characteristics differences between farms compare well with significant levels on flock size differences between farms shown earlier, especially the total additions, total reductions and total controlled reductions. There was no single significant difference among the groups on vaccination and production characteristics – mean hatchability and egg production. Production characteristics may have been more influenced by hen factors, which may not have been different among the different farm groups. The analysis of variance made it possible to validate the flock size classification using values of dissimilarity group index between farms.

Keywords: Indigenous chicken, Flock size, Demography, Treatments, Production, Variation analysis, Kenya.

1. Introduction

About 80% of the population in most of African region live in rural areas eking out a living from subsistence farming, often under very difficult climatic and economic conditions (Ndegwa, 2006), to meet household food requirements.

Indigenous chickens are among the many local resources available in rural areas which, if well managed, could ease the burden of the people. Over 90% of rural households keep and rear indigenous chicken in small flocks of about 20 birds (Ndegwa et. al., 1999; Mbugua, 1990; MOLD, 1990; Stotz, 1983). Many authors (Ndegwa, 2013; Gonsalves et al., 2005 Ndegwa et al., 2001b; Okong'o et al 1998; Tuitoyet et al; 1999; Kitalyi, 1998; FAO, 2008, 2010 and SA PPLPP, 2011assert that indigenous chickens play a very significant role in rural livelihoods. In Kenya, and indeed in sub-Saharan Africa, indigenous chickens comprise over 70% of total poultry populations (MOLD, 1991; Ibe, 1990). They produce about 50% of the total eggs and over 80% of the poultry meat produced in many countries in sub-Saharan Africa (Ndegwa et al., 1998). Hence, there exists a potential for a local resource like indigenous chickens to turn around the misery that is the lives in rural areas as stated by Ndegwa, (2006) who also calls for an infrastructural and institutional support in research and development activities aimed at improving productivity at farm level.

Indigenous chicken system has generally been characterised by low productivity due to among other factors, poor management, inadequate and poor feeding regime, poor (or lack) of disease control measures, poor hygiene, inappropriate housing, negative attitudes, lack of technical knowledge and lack of institutional support in terms of policy and infrastructure (Ndegwa and Kimani, 1997). Importance of creating awareness and education is emphasised by Thieme et al (2014).

Proper harnessing of local resources of the poor people and their involvement in (the) research process can help bring about development of sustainable livelihoods and contribute to the fight on poverty alleviation in rural areas where the majority of the poor live (Ndegwa, 2006 and 2013; Gonsalves et al., 2005). Their number is mainly composed of women (Blair, 2000; Al-Sultan, 2001) who engage in subsistence agricultural activities as they struggle to survive and feed their families under often very hostile environments (Ndegwa et al., 2000, 1998a, 1999, 1997; Gueye, 2000a). Fanworth, et al., (2013) emphasise the fact that empowering women is key to poverty reduction as well as a key driver to agricultural productivity. According to FAO (2011), the agriculture sector is underperforming in many developing countries, and one of the key reasons is that women do not have equal access to the resources and opportunities they need to be more productive. FAO (2011) also recommends promoting gender equality and empowering women (Millennium Development Goal Schedule 3) in agriculture to win, sustainably, the fight against hunger and extreme poverty (MDG1).

Gonsalves, et al., (2005) write about new challenges to agricultural research and development that include shifting focus to less favourable environments, strengthening capacity of local farming communities to continuously learn and experiment ways of improving their agricultural livelihoods, research and development are no longer exclusive domain of scientist and that local stakeholders provide inputs to processes that find sustainable solutions. According to Okali et al., (1994) both farmers and researchers are involved at any or all points along a continuum of levels of participation.

There is however, little published peer-reviewed material regarding how benefits of participatory research are achieved in practice (Blackstock et al., 2007). This and other related studies by the same authors (Ndegwa et al., 2013, 2014) explore(s) and explain(s) importance of participatory research in practical terms. In a previous study by Ndegwa (2013) a demographic analysis used dissimilarity index analysis and identified seven distinct indigenous chicken farm groups categorised on flock size trends. The objective of the present study is to evaluate these farm groups' patterns and comparisons identifying similarities and differences between the groups. This will help to characterise indigenous chicken farms in Kenya and understand their character and potential for rural livelihoods. The aim was to generate and disseminate relevant information on improved production management practices for use by farmers and support services.

2. Methodology

This farmer participatory research was carried out between 1996 and 1999 to evaluate effects of improved management practices on performance of indigenous chickens at farm level. A total of twenty villages and 200 farmers were selected from 5 regions and 4 villages per region (Table 1) based on indication of willingness to participate. Ten farms were selected in each village. Training and sensitisation meetings were held with the selected farmers, their neighbours and extension personnel. This was followed by the introduction of treatments or intervention options (Feed supplementation, Housing, Vaccination, and Deworming) implementation by farmers, monitoring and evaluation by the main partners (farmers, extension and research). The project was monitored over a span of five, 3-months long periods. Monitoring was by a visit every three months to each farm to evaluate progress and confirm the farmer's records. This was also the time for more consultation and sharing of experiences.

The choice of this research design was influenced by the need to have a diverse representation of farmers participating in the project in order to collect information that might yield generalizable outcomes. The design involved:

•Selection of locations-5 regions in different Agro-Ecological Zones (aezs) and 4 villages per region. Each cluster has ten farmers and were based on land size as well as aezs criteria as shown in Table 1.

•Farmer selection-along a transect line in the cluster area and systematically sampled during baseline studies (Ndegwa *et al*. 1999). Main criteria, was willingness of the farmers to participate and carry out activities and have at least five indigenous chicken hens.

•Emphasis on use of farmer's own locally available resources and mobilisation of farmers in acquiring some external inputs jointly. Use of own local inputs is also emphasised by Sonaiya (1990).

•Training and sensitisation seminars-done per cluster in farmers' localities.

•Mode and plan of experimentation - individual farmer's decision.

•Implementation of the research activities was entirely by the farmers to decide which intervention/s to take up among the options available.

•Monitoring and evaluation-daily by farmers taking records, and periodically by extension and researchers' visits to individual farms.

Table 1. Research locations with farm size, regional features and number of selected farmers

Regions	Villages	Average Farm size (acres)	Regional features	No. farmers
Laikipia Ngarua	Kinamba Sipili Cheleta Ol Moran	2 2.5 10 1	low potential semi-arid, poor infrastructure and frequent livestock theft incidences	10 10 10 10
OlKalou	Olkalou South Passenga Milangine Kaibaga	2.5 5 2 - 4 1	low to high potential and cold with frequent frost and water logging incidences. Has impassable road network for transportation during wet seasons.	10 10 10 10
Bahati	Munanda Kabazi Scheme Wanyororo	2 1.5 3 0.5	high potential with adequate rainfall and good soils for agricultural activities, with land size ranging from 5 to 0.25 acres per household and relatively good road network and market opportunities	10 10 10 10
Njoro	Njokerio Gichobo Piave Likia	0.25 5 2.5 1	high to medium potential with good to poor road network and market opportunities.	10 10 10 10
Naivasha	Karate Maraigushu Karai Mirera	1.5 2.5 5 1	low potential, porous volcanic soils of high infiltration. Good to poor road network especially during wet periods villages	10 10 10 10
5 (Total)	20 (Total(	2.65 (Mean)		200 (Total)

The demography analysis (Ndegwa, 2013) had used dissimilarity index as a tool for differentiating and confirming groups classified from among individual farms through to village clusters and on to regional groups and lastly down to the final farms grouping. One hundred and seventy three farms with varying flock size trends over 5 periods were reduced first into 48 village groups and 12 outliers. The village groups were further classified into a smaller number of 25 regional groups and 9 outliers. Finally, a further elaboration of classification reduced regional groups into seven final groups and 3 outliers (Table 2) each with a distinct characteristic pattern defining it.

The objective of the present study is to evaluate these 7 farm groups' patterns and comparisons identifying similarities and differences between the groups as influenced by application of the improved management practices. This will help to characterise indigenous chicken system in Kenya and understand its potential for rural livelihoods. This will aid in generating and disseminating relevant information on improved production management practices for use by farmers and support services.

These final groups were used in the present study investigating for their differences on the levels of the following factors:

- Average farm flock sizes at five different periods

- Treatment characteristics (housing, vaccination, de-worming, and supplementation)

- Demography characteristics (total flock additions, total flock reductions, total unplanned reductions and total controlled reduction)

- Production characteristics (mean hatchability and egg production per hen per cycle based on predicted egg production).

Table 2. Distribution of farms among the identified groups in five regions

Final Farm Group	Region				
	1	2	3	4	5
1	13	15	11	13	23
2	10	10	16	3	11
3	2	0	2	7	3
4	1	3	0	3	0
5	6	2	0	0	0
6	4	3	4	1	1
7	1	0	2	0	2
8 (outlier)	0	0	1	0	0
9 (outlier)	0	0	0	1	0
10 (outlier)	0	0	0	1	0
Total farms	37	33	36	27	40

The investigations involved analysis of variance done only for the seven final farm groups excluding the three outliers and used standard general linear models (GLM) statistical procedures of SAS (1995). To check for significant differences between groups, a two-way Duncan-Dunnett sample test was done to separate different means. The analysis of the average flock sizes of the final groups was done at each of the five periods for the treatment and demography characteristics. Totals for the five periods were used while in the case of the production characteristics, the average mean hatchability and egg production per hen-cycle were used. The outlier farms were left out due to the obvious distortion of information they were likely to introduce.

3. Results and Discussion

Fig 1 provides indigenous chicken farm categories with levels and trends of their flock size in over five periods. Farm group 1 consists of farms characterised by a flock size trend starting from about 15 rising steadily to 25 birds per farm. Farm group 2 consists of farms characterised by a flock size trend starting from 20 and rising steadily over the periods to 35 birds per farm. Farm group 3 consists of farms characterised by a flock size trend starting from about 20 birds rising more sharply mid period to a high of about 50 birds per farm. Farm group 4 consists of farms characterised by a flock size trend that starts on a high of 30 birds rising sharply to a peak of 60 birds per farm. Farm group 5 consists of farms characterised by an unusual trend that starts from a high of about 30 birds dropping steadily to about 15 birds per farm. Farm group 6 consists of farms characterised by a steady flock size trend averaging about 40 birds per farm in the five periods of observation. Farm group 7 consists of farms characterised by low flock size trend with an average of about 10 birds per farm in all the five periods of observation.

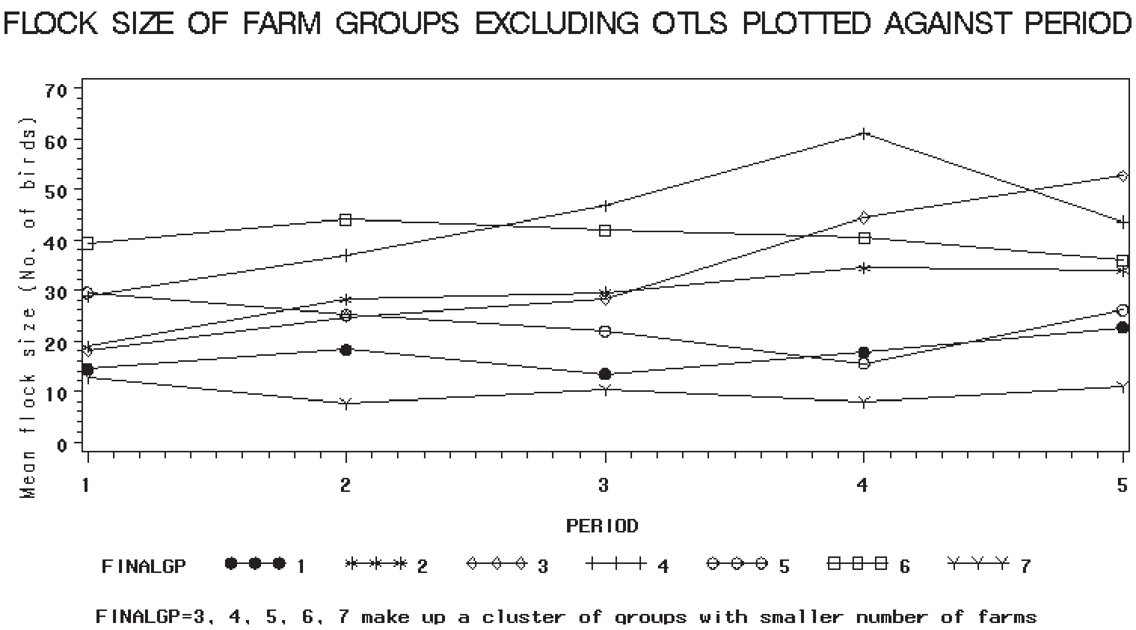

Figure 1. Flock size trends of seven groups of Kenyan indigenous chicken farms

The seven groups provides a snapshot of characteristics and behaviour of Kenyan small scale farms in regard to production and use of indigenous chicken as a livelihood strategy.

Table 3 shows a summary of the analysis of variance model or between groups mean square on 6 degrees of freedom for flock size because there were only seven final farm groups. The three outliers were excluded to avoid distortion of statistical analysis result by exaggerating mean values of the groups. The analysis was done for each period.

Table 3. Analysis of variance for average flock size among 7 final farm groups in five periods

Period	Between/Model MS (df)	Within/Error MS (df)[1]	F-ratio
1	1513 (6)	28 (166)	54.5
2	1915 (6)	32 (166)	60.1
3	3208 (6)	47 (166)	68.7
4	4462 (6)	61 (166)	73.0
5	2428 (6)	94 (164)	26.9

[1]df: the degrees of freedom of error MS in period 5 reduced by removal of 2 farms with flock sizes values of zero and 3.

Overall, the results from the analysis indicate significant differences between the farm groups hence confirming the distinctness of the groups as categorised, as well as affirming the validity of our classification procedures using the dissimilarity index values (Ndegwa, 2006). Only the comparisons 1v5, 1v7 and 2v3 were non-significant twice in five periods. No comparison was non-significant more than twice. In case of groups 1 and 5, both had close flock size values at periods 4 and 5. Groups 1 and 7 were close to each other flock size-wise at periods 1 and 3, as was the case with groups 2 and 3.

Table 4 shows significance comparisons of flock sizes between the farm groups in periods 1 to 5. Almost all the differences were significant at 1 percent level. There was a rise in differences of the between and within groups mean squares from period 1 to 5 as a result of the flock sizes levels also increasing with period. This is better shown using pair-wise comparison standard errors for farm group pairs with large differences in their number of farms provided by Table 5 which also includes the flock size differences between the pairs.

The standard errors (SE) provide the precision with which the difference is determined, and as such are standard errors of the difference. The larger they are, the less the precision and hence the lower the significant level of the difference. This implies that pairs with similar differences might have different significant levels depending on their SE values, as was the case between the pairs, 1v2 and 1v3. The differences, SE, and confidence interval width all increased with period.

Table 4. Significance comparisons between groups on average flock sizes in period 1-5

Group Comparison	Period significant level[1]				
	1	2	3	4	5
1v2	***	***	***	***	***
1v3	*	***	***	***	***
1v4	***	***	***	***	***
1v5	***	**	***		
1v6	***	***	***	***	***
1v7		***		*	*
2v3		*		***	***
2v4	***	***	***	***	*
2v5	***		**	***	*
2v6	***	***	***	*	
2v7	*	***	***	***	***
3v4	***	***	***	***	*
3v5	***		*	***	***
3v6	***	***	***		***
3V7	*	***	***	***	***
4v5		***	***	***	**
4v6	***	*		***	
4V7	***	***	***	***	***
5v6	***	***	***	***	*
5v7	***	***	**		*
6v7	***	***	***	***	***

[1]Period significant level: 3 stars refers to significant level at 0.1%, 2 stars, 1% and 1 star at 5%

Table 5. Pairwise standard errors comparisons on flock size of large farm groups at 5 periods

Group Pairs	No of farms (n1, n2)	Period[1]														
		1 (s^2=28)			2 (s^2=32)			3 (s^2=47)			4 (s^2=61)			5 (s^2=94)		
		Diff	SE	CIW	Diff	SE	CIW	Diff	SE	CIW	Diff	SE	CIW	Diff	SE	CIW
1v2	76, 50	4.3	0.96	3.8	9.9	1.03	4.1	16.1	1.24	4.9	16.7	1.42	5.6	11.2	1.76	7.0
1v3	76, 13	3.6	1.59	6.2	6.5	1.70	6.7	14.8	2.06	8.1	26.8	2.34	9.3	30.0	2.91	11.5
1v4	76, 7	14.3	2.09	8.2	18.7	2.23	8.8	33.2	2.71	10.7	43.3	3.08	12.2	20.9	3.83	15.1
2v3	50, 13	0.78	1.65	9.63	3.4	1.76	6.8	1.3	2.13	12.4	10.0	2.43	9.6	18.8	3.02	11.9
2v4	50, 7	10.0	2.13	8.4	8.8	2.28	9.0	17.2	2.77	10.6	26.6	3.15	12.5	9.7	3.91	15.4
3v4	13, 7	10.8	2.48	9.8	12.2	2.65	10.4	18.5	3.21	12.6	16.5	3.66	14.5	9.1	4.54	17.9

[1]Period: Diff = difference in flock size between pairs of final groups; SE = standard error; CIW = confidence interval width

Summaries of the treatment (Total Housing, Total Vaccination, Total Deworming and Total Supplementation), demography (Total Addition, Total Reduction, Total Unplanned Reduction and Total Controlled Reduction), and production (Mean Hatchability and Predicted Eggs/hen/cycle) parameters mean values for the farm groups are given in Tables 6, 7, and 8 respectively.

Table 6. Average levels of treatment characteristics and number of farms in each final farm group category.

Final Farm Group	No of farms	Total Housing	Total Vaccination	Total Deworming	Total Supplementation
1	73	2.82	1.21	1.94	3.67
2	48	2.56	1.10	1.80	4.06
3	13	3.08	1.54	1.77	3.85
4	8	4.25	1.25	2.0	3.87
5	8	2.25	1.75	2.37	3.75
6	14	3.0	1.36	2.14	3.86
7	5	1.6	1.0	3.2	4
8	1	5	2	5	5
9	1	5	2	3	5
10	1	4	2	2	4

NB: Values are average totals in each farm in 5 periods for each character.

The number of farms used in the investigation with egg production parameters, was less than for the other categories of characteristics mainly because not all farms whose flock size information was available had also records on egg production.

The treatment characteristics application levels (Table 6) had little differences between groups but housing (3 out of 5 periods) and feed supplementation (4 out of 5 periods) had larger application values than the other two characteristics. Treatment characteristics were much influenced by our intervention as a research team and were more or less uniformly applied due probably to the near equal coverage access of all participating farmers to our information and expertise.

The demography characteristics, total addition and total reduction values (Table 7) were close to one another among the groups. Inevitably, the flock sizes in period 1 would also be expected to be close to flock sizes at the end of period 5 (start of period 6), which has not been included in our presentation but was used to determine demography values in period 5. For instance, in the case of the farm group 1, the difference between the two, which is 4.2, added to flock size value of 15 in period 1, is 19.2. Total controlled reduction representing real benefit to farmers ranged from 29-52 birds per form over the five periods. This table shows production characteristics and behaviour of various farm categories on utilisation of indigenous chicken as a livelihood strategy. Despite clear differences in flock size levels, the farm groups appears similar in the way they produce and benefit from indigenous chicken looking at the total additions and total controlled reductions.

Table 7: Average levels of demography characteristics and number of farms in each final farm group category.

Final Farm Group	No of farms	Total Addition	Total Reduction	Total Unplanned Reduction	Total Controlled Reduction
1	73	55.1	50.9	17.7	33.4
2	48	62.4	53.8	18.8	35.0
3	13	72.5	53.4	15.6	37.9
4	8	68.3	68.1	16.1	52.0
5	8	66.2	72.9	27.3	45.6
6	14	47.7	68.8	17.1	51.7
7	5	52.0	51.8	23.0	28.8
8 (outlier)	1	195	199	26	173
9 (outlier)	1	157	198	26	172
10 (outlier)	1	213	178	14	164

NB: Values are totals in 5 periods for each character.

The demography characteristics had little influence from the research team but were mostly a reflection of individual farm decision and activities. On the other hand, the production characteristics (Table 8) reflected more both the farmer's action and the hen potential. Mean hatchability ranged from 65% (farm group 2) to 76% (farm group 7) while egg production ranged from 21-24 predicted eggs/hen/cycle. These hatchability values compare well with results from other authors investigating this characteristic among indigenous chicken (Albrecht, 2011; Abiola et al., 2008; Asuquo, et al., 1992).

Table 8. Average values of production characteristics among 7 final groups and outlier farm 8

Final Farm Group	Number of farms	Mean Hatchability	Predicted Eggs/hen/cycle
1	48	70.3	21.8
2	36	68.3	22.7
3	9	71.4	21.1
4	6	73.5	23.5
5	5	73.6	21.3
6	8	71.9	20.9
7	3	74.6	20.5
8	1	85.7	15.5

The farm group 7 with the lowest flock size trends had production values close to those of other groups. This would suggest that low flock size level in a farm is not a reflection of poor production dynamics.

Table 9 provides the between and within mean squares with F values from the analysis of variance on treatment, demography and production characteristics differences of the final groups. The pair-wise significant comparisons for these characteristics are shown in Table 10.

Hence, less variation between farms would be expected, and in practice, there were only four significant differences for housing, 3 for deworming, 1 for supplementation. On the other hand, the demography characteristics, total addition, total reduction and total controlled reduction had significant differences between groups.

Table 9. Analysis of variance summary with treatment, demography and production characteristics

Characteristic	Between Groups / Model Mean squares (df)	Within Groups / Error Mean Squares (df)	F-ratio
1. Treatments:			
Housing	5.1 (6)	4.8 (162)	1.1
Vaccination	0.78 (6)	1.3 (162)	0.6
Deworming	1.84 (6)	1.4 (162)	1.31
Supplementation	0.78 (6)	1.3 (162)	0.6
2. Demography:			
Total Addition	1194 (6)	281 (162)	4.2
Total Reduction	1326 (6)	277 (6)	4.8
Total Unplanned Reduction	156 (6)	93 (162)	1.7
Total Controlled Reduction	1155 (6)	185 (162)	6.25
3. Production:			
Mean Hatchability	58 (6)	124 (108)	0.47
Predicted Eggs	8.7 (6)	7.9 (99)	0.47

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Table 10. Pairwise standard errors comparisons[1] of farm groups on treatment and production parameters

Group Pairs	Treatments			Demography			
	Housing	Deworming	Supplementation	Total Additions	Total Reductions	Total Unplanned Reductions	Total Controlled Reductions
1v2			*(p=0.07)	*			
1v3				**			
1v4	*(p=0.08)			*	*		***
1V5				p(0.10)	***	*	*
1v6					***		***
1v7		*					
2v3				*			
2v4	*				*		**
2v5					**	*	*
2v6				**	**		***
2v7		*					
3v4					*		*
3v5					*	*	
3v6				***	*		*
3v7		*		*			
4v5	* p(0.0697)					*	
4v6							
4v7	*						**
5v6				*		*	
5v7					*		*
6v7		*(p=0.09)			*		**

NB: p is the probability associated with the F-statistics level of significance and the smaller the value the higher the significance level. It is advisable to indicate value of p for single star levels (>5%). [1]significant level: 3 stars refers to significant level at 0.1%, 2 stars, 1% and 1 star at 5%

As was the case with flock sizes levels, the demography characteristics, total addition, total reduction and total controlled reduction were a manifestation of individual farmer's management decisions. Farmers would have had little influence on the total unplanned reduction. In the significant levels comparison of final farm groups (Table 10), there was no single significant difference among the groups on vaccination and production characteristics-mean hatchability and egg production. Production characteristics may have been more influenced by hen factors, which may not have been different among the different farm groups.

The flock demography dynamic characteristics were under direct influence of farmers' actions and these varied from farm to farm which might explain the reason behind the observed effects. The demographic characteristics differences between farms compare well with significant levels on flock size differences between farms shown earlier, especially the total additions, total reductions and total controlled reductions.

In classification of groups using flock size values, village average would be unsuitable when identified groups are distinctly different as was the case here.

The analysis of variance made it possible to validate the flock size classification using values of dissimilarity group index between farms.

The flock sizes levels and demography characteristics were a manifestation of the individual farmer's management decisions, which varied from one farm to another. On the other hand, the treatments application levels were more than anything else influenced by the research team and were almost similar among the participating farmers. These characteristics were much influenced by the research team and were more or less uniformly applied due probably to the near equal coverage access of all participating farmers to information and expertise provided. The production characteristics values had much influence from hen factors.

The seven farm groups provides a snapshot of characteristics and behaviour of Kenyan small scale farms in regard to production and use of indigenous chicken as a livelihood strategy. Hence this local resource should be harnessed as a strategy to bring about development of sustainable livelihoods and contribute to the fight on poverty alleviation in rural areas.

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References

Abiola, S. S., Meshioye, O. O., Oyerinde, B. O., & Bamgbose, A.M. (2008). Effect of egg size on hatchability of broiler chicks. *Arch. Zootech., 57*(217): 83-86.

Albrecht, H. N. (2011). Reproductive soundness and egg quality in chickens selected for low and high antibody response, M.Sc. Thesis, Faculty of the Virginia Polytechnic Institute and State University, Blacksburg, V.A: 5-32.

Asuquo, B. O., Okon, B., & Eking, A. A., (1992). Quality parameters of Isa Brown and Nigerian local chicken eggs. Nigerian Journal of Animal Production, 19" 1-5.

Fanworth, C., Sudell, M., Nzioki, A., Shivutse, V., & Dan, M., 2013 (eds).Transforming gender relations in agriculture in Sub-Saharan Africa.Swedish International Agricultural Network Initiative (SIAN), Stockhom Environmental Institute, Sweden.

FAO, (2008). Poultry in the 21st century: Avian influenza and beyond. O. Thieme and D Pillings eds. Proceedings of International Poultry Conference held 5-7 November, Bangkok, FAO Animal Production and Health Proceedings, No. 9. Rome FAO. (Available at ftp://ftp.fao.org/docrep/fao/011/i0323e/i0323e.pdf).

FAO, (2010). Smallholderpoultyr production: Livelihoods, food security and socio-cultulral significance. K. N. Kryger, K. A. Thonsen, M. A. Whyte and M. Dissing. (available at www.fao.org/docrep/013/al.674e/al674e00.pdf)

FAO, (2011). Women in Agriculture: Closing the gender gap for development. The state of food and agriculture 2010-2011. FAO of UN, Rome, Italy. [Online] Available: http://www.fao.org/publication/sofa/2010-11/en.

Gonsalves, J., Becker, T., Braun, A., Camplan, D., Chavev, H., Fajber, E., Kapiriri, M., Rivacamirade, J., Vernooy, M. (edts) 2005. Participatory research and development for sustainable agriculture and natural resource management: A sourcebook Vol 1: Understanding research and development. International Potato Centre-Users' Perspectives with Agricultural Research and Development, Laguna, Philippines and International Development Research Centre, Ottawa, Canada.

Gueye, E. F. (2000). The role of family poultry in poverty alleviation, food security and the promotion of gender equality in rural Africa. *Outlook on Agriculture. 29*(2), 129-136.

Kitalyi, A. J. (1998). Village chicken production system in rural Africa: Household food security and gender issues. FAO Animal Production and Health Paper, 142. Rome, FAO. [Online] Available: ww.fao.org/docrep/003/w8989e/w8989e00.htm

Ndegwa, J. M. (1992a). Digestibility and Metabolic Energy determination of ground and unground sesame (Sesamum indicum) seeds in broiler diets. Msc Thesis, 1992, Wageningen Agricultural University, Wageningen, The Netherlands.

Ndegwa, J. M. (1992b). Use of sesame seeds (Sesamum indicum) in broiler feeds. Proceedings, IX World Poultry Congress - Young professionals program. October 1992. Amsterdam, The Netherlands.

Ndegwa, J. M., Mbugua, H. C. W., Owango, M. O., & Mburu, B. M. (eds) (1994). Proceedings of second Poultry Research Priority setting Workshop. Naivasha, 15-16 November. Kenya Agricultural Research Institute.

Ndegwa, J. M., & Kimani, C. W. (1997). Rural poultry production in Kenya: Research and development strategies. In: Proceedings of 5th Kenya Agricultural Research Institute (KARI) scientific conference, October, 1996. KARI, Nairobi.

Ndegwa, J. M., Tchombe, T., Kabuage, L. W., Mukkibi-Muka, G., & Kosgey, I. S., (1998). Improvement of indigenous poultry production in Sub-Saharan Africa. A paper presented at the International Course on Intensive Poultry Production held at the Centre for International Agricultural Development Co-operation (CINADCO). Kibbutz Shefayim, 4 March - 1 April 1998. P.O. Box 7011, Tel-Aviv, Israel.

Ndegwa, J. M., Kimani, C. W., Siamba, D. N., Mburu, B. M., Mukisira, E. A., & de Jong, R., (1999). Characteristics of rural poultry production in different agro-ecological zones in Kenya. In Proceedings of the 6th biennial Kenya Agricultural Research Institute (KARI) scientific conference 9 - 13 November 1998, pp 540 - 547. Nairobi, Kenya. KARI.

Ndegwa, J. M., Norrish, P. Mead, R., Kimani, C. W., Wachira, A. M., (2000). A research process and methodology focusing on indigenous Kenyan chickens. A paper presented at the Symposium of the International Network for Family Poultry Development (INFPD) at the XXI World's Poultry Congress. 20-24 August, 2000. Montreal, Canada. [Onl;ine] Available:http//www.fao.org//ag/againfo/subjects/en/infd/documents/newsletters/Infd111.pdf and http://www.fao.org/docrep/019/aq634e/aq634e.pdf - The Bangladesh model and other experiences in family poultry development. International Network for Family Poultry Development (INFPD) May-July 2002.

Ndegwa, J. M., Norrish, P. Mead, R., Kimani, C. W., Wachira, A. M. (2001a). The growth performance of Kenyan indigenous chicken fed diets containing different levels of protein during rearing. Tropical Animal Health and Production 33 (5), 441-448.

Ndegwa, J. M ., D. D. Shephered1, Norrish, P.1 Mead, R., Kimani, C. W., Wachira, A. M. , Siamba D. N., & Githinji, M. M., (2001b). Participatory strategic approach to development of improved indigenous poultry systems in East Africa. A paper presented at the International Development Conference, Rotorua, New Zealand 2-6 April 2001. [Online] Available: http://www.fao.org/docrep/019/aq634e/aq634e.pdf - 'The Bangladesh model and other experiences in family poultry development'. International Network for Family Poultry Development (INFPD) May-July 2002 and published in Global Journal of Agricultural Research Vol 1 No 2 pp 14-28 also [Online] Available: (http://www.eajournals.org/journals/global-journal-of-agricultural-research-gjar/vol-1-issue-2-september-2013/)

Ndegwa, J. M, Norrish, P. Mead, R., Kimani, C. W., Wachira, A. M., (2002). Hatching characteristics of eggs artificially incubated from six reciprocal crosses of indigenous Kenyan chickens. Tropical Agriculture (Trinidad), Vol. 9 No 1.

Ndegwa, J. M, Norrish, P. Mead, R., Kimani, C. W., Wachira, A. M. (2005). Growth characteristics of indigenous chicken lines and a cross with Rhode Island Red in Kenya. Tropical Agriculture (Trinidad)) Vol 82 No 1

Ndegwa, J. M., (2006). Participatory research approaches in development of improved management practices in indigenous chicken production system with smallholder farmers in Kenya. PhD. Thesis, University of Reading, UK.

Ndegwa, J. M, Norrish, P. Mead, R., D. D. Shephered, Kimani, C. W., Wachira, A. M., (2012). Growth characteristics of six reciprocal crosses of Kenyan indigenous chickens Journal of

Agricultural Science Vol 4 No.6.Pp 160-170.

Ndegwa, J. M. (2013 ed). Improving indigenous chicken production in Kenya-A livelihood strategy. LAP Lambert Academic Publishing https://www.lap-publishing.com/

Ndegwa, J. M, Norrish, P. Mead, R., D. D. Shephered, Kimani, C. W., Wachira, A. M., (2014). Investigating eggs hatchability in indigenous chicken system with smallholder farms in Kenya in a participatory research using analysis of variation. Journal of Applied Biosciences 80: 7000-7013.

Okali, C., Sumberg, J., & Farrington, J., (1994). Farmer participatory research. Rhetoric and reality. Intermediate Technology publications London, UK: Overseas Development Institute.

Okong'o, Kabuage, L., Mbugua, P. N., & Ndegwa, J. M., 1998. The effect of cooking grain amaranth (Amaranthus hypochodriacus) on its utilisation by broiler and indigenous chickens. In Proceedings of Rural Poultry Workshop. Kakamega, July 1998. Kenya

Pica-Ciamarra, V., & Dhawan, M. (2010). Small-scale poultry farming and poverty reduction in South Asia: From good practices to good policies in Bangladesh, Bhutamn and India. New Delhi, South Asia pro-poor Livestock policy Programmes. [Online] Available: http//:sapplpp.org/lessonslearnt/smallscale-poultry-farming-and-poverty-reduction-in-south-asia)

SA PPLPP, (2011). Proceedings of the Workshop in Bangladesh on "Implementation of the National Livestock Development Policy (2007) and National Livestock Development Policy (2008): Impact on Small-scale Livestock Rearers". [Online] Available: http//:sapplpp.org/files/repository/informationhub/workshop%20proceedings20%28Babgladesh%205thApril%202011.pdf.

Thieme, O., Sonaiya, E. B., Alders, R., Saleque M. A., & De Besi, C. (2014). Family poultry development-Issues, Opportunities and Constraints. Animal Production and Health Working Paper No. 2. Rome (http//:www.fao.org/docrep/i019/i595e/i3595e.pdf).

Siamba, D. N., Ndegwa, J. M. Kimani, C. W., & Mburu, B. M., (1998). Ethno-Veterinary practices among the Kikuyu in the Rift Valley Province in Kenya. In Proceedings of Rural Poultry Workshop. Kakamega, July 1998. Kenya Agricultural Research Institute (KARI) Kenya.

Sonaiya, E. B. (1990). Rural Poultry in Africa. Proceedings of the International Workshop, Obafemi Awolowo University, Ile-Ife, Nigeria, 13-16 November 1998. Ile-Ife, Nigeria, Thelia House Ltd.

Tuitoek, J. K., Chemjor, W., Ndegwa, J. M., & Ottaro, J. M., (1999). Morphological characteristics and protein requirements of indigenous Kenyan chicken. In Proceedings of the 6th biennial Kenya Agricultural Research Institute (KARI) scientific conference

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Yield and Iron Toxicity Response of Rice Cultivars to Nitrogen and Phosphorus Application Rates in Lowland Ecology of Moist Savanna of Northern Nigeria

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Abstract

Evaluation of ameliorative effect of nitrogen and phosphorus rates on iron toxicity of lowland rice was examined. Trials were conducted in the Research Farm of National Cereal Research Institute, 2006 and 2007 wet season. The experiment was laid out in a randomized complete block design (RCBD) in split-split-plot arrangement replicated three times. The main blocked consisted of three levels of phosphorus (0, 30 and 60 P_20_5 kg ha^{-1}); the sub-block four levels of nitrogen (0, 30, 60 and 120 N kg ha^{-1}) and the sub-sub-block ten rice varieties (five lowland NERICAs (NERICA L-19, 20, 41, 42 and 60), four improved *sativa* (FKR 19, TOX 4004, BW 348-1and WITA 4) and one local variety (Ebagichi). Significant interactions (P <0.05) of phosphorus × nitrogen × variety at 42 and 63 DAT were observed on iron toxicity score with significant depression at 30 kg P_20_5 ha^{-1} of lower nitrogen rates in all varieties except NERICA L-60. Increasing application rates of nitrogen resulted in increase in grain yield, while maximum grain yield was observed at 30 kg P_20_5 ha^{-1}. WITA 4 at lower N application rates and 30 kg P_20_5 ha^{-1} remained the most promising in terms of grain yield and iron toxicity tolerance in the moist Savanna of northern Nigeria.

Keywords: Iron toxicity, Lowland, NERICA

1. Introduction

Iron toxicity is a predominant nutritional disorder found in the lowland ecology of rice production (Dobermann and Fairhurst, 2000). The problem is even more severe in the valley bottom soil (Sahrawat and Diatta, 1995). The increasing human population density and attendant nutritional requirements is placing much pressure on available arable land, thus necessitating the need to explore and utilise other ecologies, especially the lowland ecologies for rice production. Rice is a staple crop for most of the developing countries of the world. Increase in crop productivity could be achieved through the utilisation of lowland ecologies. The cultivated area for lowland rice is estimated to be around 128 million hectare of irrigated and rainfed lowland (Maclean *et al.,* 2002). Further exploration of lowland ecology is constrained by iron toxicity (Dobermann and Fairhurst, 2000). Available literature indicated that in West Africa, rice yield reduced by as much as 12-100 % as a result of iron toxicity (Abifarin, 1988; Sahrawat *et al*., 1996; Sahrawat, 2004). Various factors are responsible for iron toxicity in the lowland; namely anoxic condition coupled with edaphic factors. Humid tropical region is mostly affected due to the intensity of precipitation in the presence of low soil pH and cation exchange capacity, sandy textural class; increased soil bulk density with reduced porosity, contributing to reduced oxidation front. Becker and Asch, (2005) opined that microbial reduction of iron, could accentuate reduction of insoluble iron to soluble form in the soil.

The physiological implication of iron toxicity in crops is reflected on reduced growth and yield (Abifarin, 1988; Sahrawat *et al*., 1996; Sahrawat, 2004; Mehraban *et al*., 2008). Fageria *et al*., (2008), reported that iron toxicity resulted in reduced plant height and tillering, while loss of chlorophyll, leaf discolouration and reduced root growth was reported by Vechenevetskaia and Roy (1999). One possible explanation for this is the antagonistic effect of iron uptake on the availability of other essential nutrients like potassium, zinc and manganese, which could cause nutritional disorder. The other effect is the elicitation of reactive oxygen radical and the accumulation of oxidised polyphenol, with their cytotoxic effect on macro molecules, such as peroxidation of lipids, denaturation of proteins and DNA (da silveira *et al*., 2007), leading to a disruption in the cellular structural organisation.

Further use of lowland valley for rice production would demand integrated cultural practices addressing soil, water and crop management in order to ameliorate the adverse effect of iron on crop yield. Severity of iron toxicity is influenced by the genotype and the phenology of the crop (Tanaka *et al*., 1968; Yoshida, 1981; Genon *et al*; 1994; Sahrawat, 2004; Fageria *et al*., 2008). Van Breeman and Moormann, (1978) reported that maximum iron toxicity was observed in rice at maximum tillering period and heading stage. However, it was observed that there was compatibility between iron tolerance and yield in some selected varieties (Audebert and Sahrawat, 2000; da Silveira *et al*., 2007). The use of tolerant varieties with nutrition management techniques could ameliorate the negative productive effect of iron toxicity in rice. Sahrawat and Sika, (2002) reported that *Oryza glabberima* are more tolerant of iron toxicity than *Oryza sativa*. The use of interspecific varieties could give a promising perspective and insight towards reducing the effect of iron toxicity in rice.

The objective of the this study was to investigate the effect of the application rates of inorganic phosphorus and nitrogen fertilisers at different growth stages on iron toxicity in lowland rice of moist Savanna of northern Nigeria.

2. Materials and Methods

2.1 Location and Site Characterisation

Field experiments were conducted at the West Africa Rice Development Association (WARDA) fields situated at the Research farm of National Cereals Research Institute (NCRI), Edozhigi, Bida, Niger State, Nigeria. NCRI is located at 09°45'N, 06°7'E, 70.5 m above sea level, in the moist Savanna agroecology of northern Nigeria, 2006 and 2007 wet seasons.

It was observed during the growing seasons that the minimum amount of rainfall was recorded in March (< 50 mm), while maximum amount was observed in August for both years (345 mm and 310 for years 2006 and 2007 respectively). However, rainfall was higher in 2007 compared to 2006 only at April, June and September.

The textural class of the site was determined using the USDA textural triangle. Soil particle size distribution was determined using the hydrometer method (Bouyoucus, 1962). The organic content of the samples was determined using wet – oxidation method. Walkey-Black Method, modify by Allison (1965). The pH was determined (1: 1 soil: water) using a pH meter (glass electrode) (Mclean, 1982).Total nitrogen was determined using modified micro Kjeldahl digestion technique (Jackson, 1962). Available phosphorus was determined using Bray-1 (Bray and Kurtz, 1945) and evaluated colometrically using the method of Murphy and Riley (1962). K^+ in the extract was determined by flame photometry while Ca^{2+} and Mg^{2+} was determined using Atomic Absorption Spectrophotometer (AAS). The physico-chemical properties of the site in both years indicated that pH in 2006 was very strongly acidic (4.4) compared to slightly acidic status of 2007 (6.5). Percentage of organic carbon was low in both years; 0.81 and 0.83 % in 2006 and 2007 respectively. Similar pattern was observed for total Nitrogen in both years (0.08%). The amount of available phosphorus on the experimental site in both years was moderate; 12.48 ppm and 12.62 ppm in 2006 and 2007 years respectively. The amount of exchangeable Potassium, Magnesium and Calcium in both years was very low with a high concentration of soluble iron on the site for both years; 27.39 ppm and 27.59 ppm in 2006 and 2007 years respectively. The textural class for the site in both years was sandy loam.

2.2 Experimental Design and Treatments

The experiment was laid out in a randomised complete block design (RCBD) in split-split-plot arrangement and replicated three times. The main plot size was 21. 5 m × 33 m consisted of three application rates of phosphorus (0, 30 and 60 kg P_20_5 ha^{-1}) using triple super phosphate (46 % P_2O_5) at land preparation just before transplanting and a blanket application of 30 kg K_2O ha^{-1} as muriate of potash (60 % K_2O). The sub-plot size was 5 m × 33 m consisted of four application rates of nitrogen (0,30, 60 and 120 kg N ha^{-1}) using Urea (46 % N) in two split doses of $^1/_3$ at tillering and $^2/_3$ at panicle initiation stages and applied by broadcasting on the rice plots. The sub-sub-plot size was 5 m × 3 m, with ten rice varieties (five lowland NERICAs (NERICA L-19, 20, 41, 42 and 60), four improved *sativa* (FKR 19, TOX 4004, BW 348-1and WITA 4) and one local variety (Ebagichi). The net plot size was 3 m × 2 m (6 m^2). Planting materials were sourced from Africa Rice Centre, Ibadan substation. Total treatment combination was 120 (3 × 4 × 10) in three replicates.

2.3 Land Preparation and Transplanting

The experimental site was ploughed manually, thereafter the soil was loosened and field marked out to size and number of plots required with a pathway of 1.0 m between replicates and 0.3 m between plots of 5 m × 3 m each. Rice seedlings were transplanted at the rate of two seedlings per hill four weeks after seeding on 13th August, 2006 and 24th July, 2007 during the cropping seasons with spacing of 20 cm × 20 cm. Missing hills were replenished to ensure optimum plant population. There were 15 rows of 25 hills of rice in each plot of 5 m × 3 m (15 m^2) and 10 rows of 15 hills of rice were in each net plot of 3 m × 2 m (6 m^2). Weeding was done manually; thrice during the growing season to keep the field weed free.

2.4 Data Collection

Ten hills were randomly sampled per plot from which measurements was taken at 50 % flowering and at harvest maturity. Iron toxicity score was taken per plot by visual judgment using a scale of 1-9 according to IRRI standard evaluation system for iron toxicity score (IRRI, 1980).

Straw yield was obtained through straw dry weight sampled per plot and then converted to Mg ha^{-1}. Grain yield obtained per plot was weighed and then extrapolated to give grain yield in Mg ha^{-1}.

2.5 Data Analysis

Data collected were subjected to analysis of variance using the mixed model procedure with the restricted maximum likelihood method (REML) for variance estimates over years (SAS Institute, 2001). Significant mean were separated using the SAS LSMEANS test (probability of difference [PDIFF]) at $P < 0.05$. LSMEANS and standard error of means (SE) are presented.

3. Results

3.1 Iron toxicity score at 42 and 63 DAT

Nitrogen and variety had significant effect (P <0.05) on iron toxicity score at 42 and 63 DAT. (Table 1). Increasing inorganic nitrogen application rates lead to a significant reduction in iron toxicity score at both periods of observation. In both cases the least significant iron toxicity score was observed when 120 kg N ha^{-1} was applied, however, a lower iron toxicity score was observed at 42 DAT (1.88) than 63 DAT (4.21). At 42 DAT NERICAs L - 19, NERICA L-20, NERICA L-42 and FKR 19 had significantly the least iron toxicity score compared to others. At 63 DAT, NERICA L-42 had significantly the least iron toxicity score (4.36). However, higher iron toxicity score was observed at a later growth stages than earlier. Year and phosphorus application rates had no significant effect (P > 0.05) on iron toxicity score at both growth stages.

Table 1: Effect of year, phosphorus and nitrogen application rates on iron toxicity score of rice varieties at flowering and maturity growth stages in 2006 and 2007 seasons.

	Iron toxicity score	
Sources of variation	(42 DAT)	(63 DAT)
Year		
2006	2.10	4.91
2007	2.33	4.88
SE± (df4)	Ns	Ns
Phosphorus (main plot) kg P_2O_5 ha^{-1}		
0	2.33	4.73
30	2.15	4.70
60	2.04	5.25
SE ± (df 8)	Ns	Ns
Nitrogen (sub plot) Kg N ha^{-1}		
0	2.75a	5.56a
30	2.18b	5.00b
60	2.04c	4.81c
120	1.88d	4.21d
SE ± (df 36)	0.12**	0.16**
Varieties (sub-sub plot)		
NERICA L -19	2.03c	4.61d
NERICA L -20	2.08c	4.61d

NERICA L -41	2.21b	4.94c
NE RICA L -42	2.02c	4.36e
NERICA L -60	2.88a	6.36a
FKR 19	2.09c	5.00c
TOX 4004	2.20b	4.69d
BW 348-1	2.24b	5.31b
WITA 4	2.19b	4.52d
EBAGICHI (FV)	2.19b	4.53d
SE $\pm$ (df 432)	0.10**	0.17**

Means with the same letter (s) in a treatment column are not significantly different using standard error of means (SE) at 1 % probability level **.df – degree of freedom, DAT-days after transplanting.

3.2 Phosphorus application rates × variety on Iron Toxicity Score at 42 DAT

Increasing application rates of phosphorus, especially at 30 kg P_20_5 ha^{-1} resulted in a significant decrease in iron toxicity score for most varieties, except NERICA L-60 that remained stable. The least significant iron toxicity score was observed in NERICAs L- 42 (1.63), NERICA L- 19 (1.79) and BW 348-1 (1.75) at 30 kg P_20_5 ha^{-1}, while application of 60 kg P_20_5 ha^{-1} recorded no visible effect on iron toxicity score in most varieties (Table 2).

Table 2: Phosphorus application rates × rice varieties on iron toxicity score at flowering (42 DAT).

Phosphorus rates (kg P_2O_5 ha^{-1})			
Rice varieties	0	30	60
NERICA L-19	2.04cd	1.79de	2.25d
NERICA L-20	1.96cd	1.83d	2.46bc
NERICA L-41	2.13c	2.33b	2.17d
NERICA L-42	1.96cd	1.63e	2.50bc
NERICA L-60	2.63a	3.08a	2.92a
FKR 19	1.88d	2.00c	2.74cd
TOX 4004	2.33b	2.04c	2.25d
BW 348-1	2.54a	1.75de	2.42cd
WITA 4	2.00cd	1.96cd	2.63b
EBAGICHI (FV)	2.08c	2.04c	2.46bc
SE$\pm$ (df 432)	0.18**		

Means with the same letter (s) within a set of a treatment column and between rows are not significantly different using standard error of means (SE) at 1 % probability level **.df – degree of freedom, DAT-days after transplanting.

3.3 Nitrogen application rates × rice variety on Iron Toxicity Score at 42 And 63 DAT

At 42 and 63 DAT (Table3) most varieties recorded significantly lower iron toxicity score with increasing application rates of nitrogen except NERICA L- 60. At 42 DAT, at application rate of 120 kg N ha^{-1} NERICA L-20 had the least significant iron toxicity score (1.67). At 63 DAT NERICA L-19 (4.11), NERICA L-20 (4.33), NERICA L-42 (4.55) , WITA 4 (4.33) and Egbagichi (4.44) had significantly lower iron toxicity score at 60 kg N ha^{-1} than other varieties. Increasing application rates of inorganic nitrogen however, did not result in any significant reduction in iron toxicity score of those earlier mentioned varieties. Other varieties did not indicate any particular trend in iron toxicity score at increasing application rates of inorganic nitrogen.

Table 3. Nitrogen application rates × rice varieties on iron toxicity score at flowering (42 DAT) and physiological maturity (63 DAT).

Iron toxicity								
(42 DAT)	**Nitrogen rates kg N ha^{-1}**				(63 DAT)			
Rice varieties	0	30	60	120	0	30	60	120
NERICA L-19	2.67cd	1.94d	1.61d	1.89bc	5.22c	5.00c	4.11f	4.11c
NERICA L-20	2.83c	1.94d	1.89cd	1.67d	5.67b	4.56de	4.33ef	3.89d
NERICA L-41	2.39ef	2.28b	2.28b	1.89bc	5.67b	5.11c	4.67cd	4.33b
NERICA L-42	2.56de	2.00cd	1.78d	1.78bcd	4.89d	4.33ef	4.55cde	3.67de
NERICA L-60	3.56a	3.17a	2.56a	2.22a	6.67a	7.11a	6.11a	5.56a
FKR 19	2.33f	2.17bc	1.94cd	1.94b	5.11cd	5.22bc	5.33b	4.33b
TOX 4004	2.61d	2.22b	2.06c	1.94b	5.00cd	4.78d	4.78c	4.22c
BW 348-1	2.61d	2.17bc	2.22b	1.94b	5.78ab	5.44b	5.44b	4.56b
WITA 4	3.06b	2.00cd	200c	1.72cd	5.78ab	4.11f	4.33ef	3.89d
EBAGICHI (FV)	2.89b	1.94d	2.11bc	1.83bcd	5.78ab	4.33ef	4.44de	3.56e
SE± (df 432)	0.18**				0.27**			

Means with the same letter (s) within a set of a treatment column and between rows are not significantly different using standard error of means (SE) at 1 % probability level **.df – degree of freedom, DAT-days after transplanting.

3.4 Year × rice variety on Iron Toxicity Score at 42 DAT

Most varieties had similar iron toxicity score in both years, except NERICA L-60 with stable iron toxicity score in both years (Table 4.).

Table 4: Year × rice varieties on iron toxicity score at flowering (42 DAT).

Rice varieties	2006	2007
NERICA L-19	2.03bc	2.03d
NERICA L-20	2.06bc	2.11cd
NERICA L-41	2.17b	2.25bc
NERICA L-42	1.92c	2.14cd
NERICA L-60	2.47a	3.28a
FKR 19	1.97c	2.22bc
TOX 4004	2.08bc	2.33b
BW 348-1	2.14b	2.33b
WITA 4	2.03bc	2.36b
EBAGICHI (FV)	2.14b	2.25bc
	0.15**	

Means with the same letter (s) within a set of a treatment column and between rows are not significantly different using standard error of means (SE) at 1 % probability level **.df – degree of freedom, DAT-days after transplanting.

3.5 Phosphorus × nitrogen × rice variety on iron toxicity at 42 DAT

At 0 kg P_20_5 ha^{-1}, it was observed that most varieties had significantly lower iron toxicity score at lower inorganic nitrogen application rates (0 kg N ha^{-1} and 30 kg N ha^{-1}) than other rates , with NERICA L-41 having significantly the least iron toxicity score (1.67) at 0 kg N ha^{-1}. At 30 kg P_20_5 ha^{-1} similar trend was observed with NERICA L-42 (2.00) and BW 348-1 (2.17) having significantly the least iron toxicity score at 0 kg N ha^{-1}. Sixty (60 kg P_20_5 ha^{-1}) did not lead to a drastic reduction in the iron toxicity score, with similar trend as observed in the earlier application rates of inorganic nitrogen. However, FKR 19(2.33) and TOX 4004 (2.50) had significantly the least iron toxicity score at 0 kg N ha^{-1}, with a higher iron toxicity score than 0 application rates of inorganic phosphorus and nitrogen. Application of all rates of phosphorus and nitrogen to NERICA L-60 had significantly the highest iron toxicity scores with a significant depression (1.83) at application rates of 0 kg P_20_5 ha^{-1} and 120 kg N ha^{-1} (Table 5).

Table 5. Phosphorus × nitrogen × rice varieties on iron toxicity score atflowering (42 DAT).

Iron toxicity												
Nitrogen kg N ha^{-1}												
	0 kg P_2O_5 ha^{-1}				30 kg P_2O_5 ha^{-1}				60 kg P_2O_5 ha^{-1}			
Rice varieties	0	30	60	120	0	30	60	120	0	30	60	120
NERICA L-19	2.67bc	2.17c	1.50cd	1.83b	2.33cd	1.83c	1.33d	1.67b	3.00c	1.83d	2.00c	2.17a
NERICA L-20	2.00e	1.67e	2.33a	1.83b	2.83b	1.83c	1.33d	1.33c	3.67b	2.33b	2.00c	1.23b
NERICA L-41	1.67f	2.67b	2.33a	1.83b	2.83b	2.17b	2.67a	1.67b	2.67de	2.00cd	1.83c	2.17a
NERICA L-42	2.17de	2.17c	1.67c	1.83b	2.00e	1.50d	1.67c	1.33c	3.50b	2.33b	2.00c	2.17a
NERICA L-60	3.17a	3.17a	2.33a	1.83b	3.50a	3.50a	2.83a	2.50a	4.00a	2.83a	2.50a	2.33a
FKR 19	2.33d	2.00cd	1.50cd	1.67b	2.33cd	1.83c	2.00b	1.83b	2.33f	2.67a	2.33b	2.33a
TOX 4004	2.50cd	2.83b	2.17b	1.83b	2.83b	1.83c	1.67c	1.83b	2.50ef	2.00cd	2.33b	2.17a
BW 348-1	2.83b	2.67b	2.50a	2.17a	2.17de	1.67cd	1.67c	1.50c	2.83d	2.17c	2.50a	2.17a
WITA 4	3.17a	1.83d	1.33d	1.67b	2.83b	1.67cd	2.00b	1.33c	3.17c	2.50b	2.67a	2.17a
EBAGICHI (FV)	2.17de	2.17c	2.33a	1.67b	2.83b	1.67cd	2.00b	1.67b	3.67b	2.00cd	2.00c	2.17a
SE± (df 432)	0.31**											

Means with the same letter (s) within a set of a treatment column and between rows are not significantly different using standard error of means (SE) at 1 % probability level **.df – degree of freedom, DAT-days after transplanting.

3.6 Phosphorus × nitrogen× rice variety on iron toxicity score at 63 DAT

At 63 DAT NERICA L-60 recorded significantly the highest iron toxicity scores across different application rates of inorganic phosphorus and nitrogen (Table 6). The trend reported at 42 DAT was also observed at 63 DAT, where significantly lower toxicity was recorded at the lowest application rates of inorganic nitrogen and phosphorus than other applied rates. NERICA L-42 had significantly lower iron toxicity scores within a range of (3.67-5.00) and (4.67 – 3.67) at 0 and 30 kg P_20_5 ha^{-1} respectively than other varieties. At 60 kg P_20_5 ha^{-1} most varieties had significantly higher iron toxicity score within the range of (7.00 -3.67) at different rates of nitrogen application than earlier observed at lower application rates of inorganic nitrogen and phosphorus.

Table 6. Phosphorus × nitrogen × rice varieties on iron toxicity at physiological maturity (63 DAT).

Iron toxicity												
	Nitrogen kg N ha^{-1}											
	0 kg P_2O_5 ha^{-1}				30 kg P_2O_5 ha^{-1}				60 kg P_2O_5 ha^{-1}			
Rice varieties	0	30	60	120	0	30	60	120	0	30	60	120
NERICA L-19	5.00c	5.67b	4.33c	3.67c	5.00c	5.00c	3.67e	4.33b	5.67c	4.33d	4.33d	4.33c
NERICA L-20	5.00c	3.67e	5.00b	4.33b	5.67b	4.33d	3.67e	3.67c	6.33b	5.67b	4.33d	3.67d
NERICA L-41	4.33d	5.67b	4.33c	4.33b	6.33a	4.67cd	4.67cd	4.33b	6.33b	5.00c	5.00c	4.33c
NERICA L-42	3.67e	5.00c	5.00b	3.67c	4.67d	3.67e	4.33d	3.67cd	6.33b	4.33d	4.33d	3.67d
NERICA L-60	6.33a	7.67a	5.67a	5.00a	6.67a	6.67a	6.33a	5.00a	7.00a	7.00a	6.33a	6.67a
FKR 19	4.67cd	4.33d	5.00b	3.67c	5.00c	5.67b	5.67b	4.33b	5.67c	5.67b	5.33bc	5.00bc
TOX 4004	4.33d	5.00c	5.00b	3.67c	5.00c	4.33d	4.33d	3.67c	5.67c	5.00c	5.00c	5.33b
BW 348-1	5.67b	5.00c	5.67a	5.00a	5.33bc	5.67b	5.00c	4.00bc	6.33b	5.67b	5.67b	4.67c
WITA 4	6.33a	3.07e	4.33c	3.67c	5.33bc	3.67e	3.67e	3.67cd	5.67c	5.00c	5.00c	4.33c
EBAGICHI (FV)	5.00c	4.33d	4.00c	3.67c	5.33bc	3.67e	5.00c	3.33d	7.00a	5.00c	4.33d	3.67d
SE± (df 432)	0.47**											

Means with the same letter (s) within a set of a treatment column and between rows are not significantly different using standard error of means (SE) at 1 % probability level **.df – degree of freedom, DAT-days after transplanting.

3.7 Grain and Straw Yield

Year and inorganic nitrogen application rates had (Table 7) a significant effect ($P < 0.05$) on straw yield. Phosphorus and variety had no significant effect ($P > 0.05$) on straw yield. Straw yield was significantly higher in 2007 (9.11 Mg ha^{-1}) than 2006 (6.98 Mg ha^{-1}). Increasing application rates of inorganic nitrogen resulted in significant increase in straw yield. All treatments had significant effect ($P < 0.05$) on the grain yield. Grain yield was significantly higher in 2007 (2.68 Mg ha^{-1}) than 2006 (1.76 Mg ha^{-1}). A significant curvilinear response was observed with increasing application rates of inorganic phosphorus. A significant increase in grain yield was observed with increasing application rates of inorganic nitrogen. WITA 4 had a significantly higher grain yield (2.56 Mg ha^{-1}) than other varieties, which was not significantly different from Ebagichi (2.45 Mg ha^{-1}) and BW 348-1 (2.47 Mg ha^{-1}). NERICA L-60, however, had the least significant grain yield (1.58 Mg ha^{-1}).

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Table 7: Effect of year, phosphorus and nitrogen application rates on straw and grain yield of rice varieties in 2006 and 2007 seasons.

Source	Straw yield (Mg ha^{-1})	Grain yield (Mg ha^{-1})
Year		
2006	6.98b	1.76b
2007	9.11a	2.68a
SE± (df 4)	0.49**	160.53*
Phosphorus (main plot) kg P_2O_5 ha^{-1}		
0	8.03	2.0b
30	8.80	2.5a
60	7.31	2.06b
SE ± (df 8)	ns	137.68*
Nitrogen (sub plot) Kg N ha^{-1}		
0	6.81c	1.89c
30	8.00b	2.14b
60	8.13b	2.23b
120	9.24a	2.42a
SE ± (df 36)	0.50**	133.51**
Varieties (sub-sub plot)		
NERICA L -19	8.68	1.98d
NERICA L -20	7.42	1.93d
NERICA L -41	7.39	2.23c
NERICA L -42	7.91	2.31bc
NERICA L -60	7.33	1.58f
FKR 19	7.55	1.78e
TOX 4004	8.26	2.39b
BW 348-1	8.29	2.47ab
WITA 4	9.03	2.56a
EBAGICHI (FV)	8.35	2.45ab
SE ± (df 432)	ns	134.85**

Means with the same letter (s) in a treatment column are not significantly different using standard error of means (SE) at 1 % probability level **.df – degree of freedom, DAT-days after transplanting.

4. Discussion

The severity of iron toxicity in lowland ecology is dependent on the variety, stage of crop growth and the soil nutrient status (Tanaka *et al*., 1966; Jayawardana *et al*., 1977). Integrated approach had always been favoured in the reducing the negative impact of iron toxicity in lowland rice production (Mathias and Folkard, 2005). A combination of resistant lowland rice with nutrient management had been reported as one of such ameliorative measures (WARDA, 1995; WARDA 2002; Mathias and Folkard, 2005). Reduced iron toxicity score with the increasing application rates of nitrogen, phosphorus and potassium fertiliser had earlier been reported (Sahrawat *et al*., 2001). It could be suggested that predominance of ammonium in a waterlogged condition due to reduced soil redox potential and the increasing denitrification of nitrogen due to the activities of denitrifying bacteria in the soil could have adversely accentuated the negative influence of iron with increased concentration of ammonium, which had been reported to be toxic to plant (Gerendas *et al*., 1997). The combined source of nitrogen in both forms was observed to have positively affected crop growth (Kirk and Kronzucker, 2005).

Resistant lowland rice varieties had been implicated in the reduction of negative impact of iron toxicity (Audebert and Sahrawat, 2000; Nozoe *et al*., 2008; da Silveira *et al*., 2007). Various mechanism had been reported for this resistance mechanism; avoidance/inclusion (compartmentalisation and exclusion of iron from the symplast) (Audebert and Sahrawat, 2000), avoidance/ exclusion (rhizospheric oxidation and root ion selectivity) (Kawase, 1981; Green and Etherington, 1977), tolerance/ inclusion (detoxification by enzymes and the activity of phytoferritin) (Hu *et al*., 199; Smith, 1984) in the maintenance of Fe^{2+} homeostasis. At both growth stages (flowering and maturity) of investigation NERICA L-60 was observed to be the susceptible variety, while other varieties investigated had significant resistant to iron toxicity, however, the mechanism responsible for the resistant varieties could not be ascertained in this study. The non-significant effect of year on the iron toxicity score would have suggested similarity in the physico-chemical properties of the soil in both years.

Phosphorus is one of the macronutrient reported to be unavailable to the plant (soil and growth medium, root surface and within the plant) under the condition of iron toxicity (Ward *et al.,* 2008). In the soil and growth medium precipitation of phosphorus and its reduced availability had been observed (Von Vexhall and Mutert, 1998). The root plagues from iron in lowland rice was reported to act as a barrier to phosphorus uptake in Arabidiopsis (Zhang *et al*., 1999), while its translocation was impaired within the plant (Cumbus *et al*., 1977; Mathan and Auberger, 1977). This would have informed the increasing application rates of phosphorus. However, alone there was no significant effect of it on iron toxicity score in both growth stages. We propose that one of the reasons would be the concentration of zinc in the soil, though was not determined in this study, since zinc is antagonistic to the uptake of phosphorus. However, in combination with variety, for most varieties investigated its ameliorative measure was observed at increasing application rates, especially at 30 kg P_20_5 ha^{-1} except NERICA L-60.

Significant reduction in iron toxicity score with increasing application rates of nitrogen in varieties investigated, except NERICA L-60 would have suggested ameliorative measure of nitrogen. Iron toxicity impairs protein synthesis. Nitrogen on the other hand is a major macronutrient in protein synthesis. The enzymes that are responsible for scavenging reactive oxygen radicals and chlorophyll involved in the interception of radiant energy are made of protein. Ameliorative effect of phosphorus on varieties with increasing nitrogen application rates was more pronounced at 30 kg P_20_5 ha^{-1}. This could have suggested antagonistic interaction of phosphorus with other nutrients, probably zinc in the soil. Zinc is a major cofactor of Superoxide dismutase (Mousavi, 2011), suppression of its activities could have negative influence on oxidative stress. Variation in grain and straw yield over the years could not be explained based on edaphic factors alone, other factors could have been responsible for that that could not be ascertained in this study. Grain and straw yield per hectare was also more at 30 kg P_20_5 ha^{-1}, indicating it to the optimum for such agroecology zone as reflected above. Increase in grain yield per hectare with increasing application rates of nitrogen could have indicated not only its nutritional effect but also a decline in the phytotoxic effect of iron. Susceptible variety (NERICA L-60) had least significant grain yield indicating the negative impact of iron toxicity on it, while resistant varieties had better performance.

5. Conclusion

Increasing application rates of inorganic nitrogen fertiliser resulted in significant depression in iron toxicity score at both growth stages, especially at 120 kg N ha^{-1}. No significant effect was observed with the increasing application rates of phosphorus. Significant varietal differences were observed on iron toxicity score at both growth stages. At 63 DAT, NERICA L-42 had significantly the least iron toxicity score than other varieties. NERICA L-60 was the most susceptible variety at both growth stages. Most varieties recorded no significant differences in iron toxicity score on both years. Significant interactions (P <0.05) of phosphorus × nitrogen × variety at 42 and 63 DAT were observed on iron toxicity score with significant depression at 30 kg P_20_5 ha^{-1} of lower nitrogen rates in all varieties except NERICA L-60. Increasing application rates of nitrogen resulted in increase in grain yield, while maximum grain yield was observed at 30 kg P_20_5 ha^{-1}. WITA 4 at lower N application rates and at 30 kg P_20_5 ha^{-1} remained the most promising in terms of grain yield and iron toxicity tolerance in the moist Savanna of northern Nigeria.

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References

Abifarin, A. O. (1988). Grain yield loss due to iron toxicity. West African Rice Development Association (WARDA) Technical Newsletter 8, 1-2.

Audebert, A., & Sahrawat, K. L. (.2000). Mechanism for iron toxicity tolerance in lowland rice. *Journal of Plant Nutrition.* *23*(11 &12), 1877-1885. http://dx.doi.org/10.1080/01904160009382150

Becker, M., & Asch, F. (2005). Iron toxicity in rice- condition and management concepts. *Journal of Plant Nutrition, Soil Science.* *168*(4), 558-573. http://dx.doi.org/10.1002/jpln.200520504

Bouyoucus, G. J. (1962). Hydrometer method improved for making particle size analysis of soil. *Agronomy Journal. 54*, 464-465. http://dx.doi.org/10.2134/agronj1962.00021962005400050028x

Bray, R. H., & L. T. Kurtz. (1945). Determination of total, organic, and available forms of phosphorus in soils. *Soil Science. 59*, 39-45. http://dx.doi.org/10.1097/00010694-194501000-00006

Cumbus, I. P., Horasey, D. J., & Robinson, L.W. (1977). The Influence of phosphorus, Zinc and Manganese on absorption and translocation of iron in watercress. *Plant Soil. 48*, 655-660. http://dx.doi.org/10.1007/BF00145775

da Silveira, V. C., Oliveira, A. P., Sperotto, R. A., Espindola, L. S., Amaral, L., Dias, J. F., Cunha, J. B., & Fett, J. P. (2007). Influence of iron on mineral status of two rice (Oryza sativa L.) cultivars. *Brazilian Journal of Plant Physiology. 19*(2), 127-139. http://dx.doi.org/10.1590/S1677-04202007000200005

Dalton, C. C., Iqbal, K., & Turner, D. A. (1983). Iron phosphate precipitation in Murashige and Skoog media. *Physiologia Plantarium. 57*(4), 472-476. http://dx.doi.org/10.1111/j.1399-3054.1983.tb02771.x

Dobermann, A., & Fairhust, T. H. (2000). Rice: Nutrient disorders and nutrient management. The international Rice Research Institute, Manilla, The Philippines: 191.

Fageria, N. K., Santos, A. B., Barbosa Filho, M. P., & Guimaraes, C. M. (2008). Iron toxicity in lowland rice. *Journal of Nutrition 31*, 1676-1697. http://dx.doi.org/10.1080/01904160802244902

Genon, J. C., de Hepcee, N., Delvaux, B., Duffey, J. E., & Hennebert, P. A. (1994). Redox conditions and iron chemistry in highland swamps of Burundi. *Plant and soil 166*, 165-171. http://dx.doi.org/10.1007/bf00008329

Gerendas, J., Zhu, Z., Bendixen, R., Ratcliffe, R. G., Sattelmacher, B. (1997). Physiological and Biochemical processes related to ammonium toxicity in higher plants. *Z. Pflanzenernaehr Bodenkd. 160*, 239-251. http://dx.doi.org/10.1002/jpln.19971600218

Green, M. S., & Etherington, J. R. (1977). Oxidation of ferrous iron by rice roots. A mechanism for waterlogging tolerance. *Journal of Experimental Botany. 28*, 678-690. http://dx.doi.org/10.1093/jxb/28.3.678

Hu, B., Wu, P., Liao, C. Y., Jing, W. Z., & Zhu, J. M. (1999). Effect of ascorbate-specific H202-scavanging on tolerance to iron toxicity in rice. *Acta Phytophysiology Sinia. 25*, 43-48.

International Rice Research Institute. (1980). Standard evaluation system for rice. 2nd Edition. International Rice Testing Programme. Manilla, Phillippines.

Jackson, M. L. (1962). Soil chemical analysis. New Delhi, Prentice Hall of India Pvt.Ltd, 498p.

Jayawardana, S. D. G., Watanabe, T., & Tanaka, A. (1977). Relation between oxidizing power and resistance to iron toxicity in rice. *Japan Society of Crop Science and Breeding. 22*, 38-47.

Kawase, M. (1981). Anatomical and morphological adaptation of plants to waterlogging. *Horticultural Science. 16*, 30-34.

Kirk, G. J. D., & Kronzucker, H. J. (2005). The potential for nitrification and nitrate uptake in the rhizosphere of wetland plants: A modelling study. *Annals of Botany. 96*(4), 639-646. http://dx.doi.org/10.1093/aob/mci216

Maclean, J. L, Dave, D. C, Hardy, B, & Hettel, G. P. (2002). Rice Almanac. Wallingford, UK. CABI Publishing, p 253.

Mahapatra, I. C., & Patrick Jr, W. H. (1969). Inorganic phosphate transformation in waterlogged soils. *Soil Science. 107*, 281-288. http://dx.doi.org/10.1097/00010694-196904000-00008

Mathan, K. K., & Auberger, A. (1977). Influence of iron on the uptake of phosphorus by maize. *Plant Soil. 46*, 413-422. http://dx.doi.org/10.1007/BF00010097

Mathias, B., & Folkard, A. (2005). Iron toxicity in rice-conditions and management concepts. *Journal of Plant Nutrition and Soil Science. 168*, 558-573. http://dx.doi.org/10.1002/jpln.200520504

Mehraban, P., Zadeh, A. A., & Sadeghipour, H. R. (2008). Iron toxicity in rice (Oryza sativa) under different Potassium nutrition. *Asian Journal of Plant Sciences*, 1682-3974.

Mousavi, S. R. (2011). Zinc in crop production and interaction with phosphorus. Australian *Journal of Basic and Applied Sciences. 5*(9), 1503-1509.

Murphy, J., & Riley, J. P. (1962). A modified single solution method for determimnation of phosphate in natural waters. *Analytical chemistry Acta. 27*, 31-36. http://dx.doi.org/10.1016/S0003-2670(00)88444-5

Nozoe, T., Agbisit, R., Fukuta, Y., Rodriguez, R., & Yanagihara, S. (2008). Characteristics of iron tolerant rice lines developed at IRRI under field conditions. *Japan Agricultural Research Quarterly .42*, 187-192. http://dx.doi.org/10.6090/jarq.42.187

Sahrawat, K. L. (2004). Iron toxicity in wetland rice and the role of other nutrients. *Journal of Plant Nutrition. 27*, 1471-1504. http://dx.doi.org/10.1081/PLN-200025869

Sahrawat, K. L, Mulbah, C. K., Diatta, S., De Laune, R. D., Patrick, W. H .Jr., Singh, B. N., & Jones, M. P. (1996). The role of tolerant genotypes and nutrients in the management of iron toxicity in lowland rice. *Journal of Agricultural Sciences Cambridge, 128*, 146-149. http://dx.doi.org/10.1017/S002185960007307X

Sahrawat, K. L., & Diatta, S. (1995). Nutrient management and season affect soil iron toxicity. Annual Report 1994. West Africa Rice Development Association, Bouake, Cote d'Ivoire: 34-35.

Sahrawat, K. L., Diatta, S., & Singh, B. N. (2001). Nutrient application reduces iron toxicity in lowland rice in West Africa. *International Rice Research Notes. 26*, 51-52.

Sahrawat, K. L., & Sika, M. (2002). Comparative tolerance of Oryza sativa and O. glaberrima rice cultivars for iron toxicity in West Africa. *International Rice Research Notes. 27*, 30-31.

SAS, Institute. (2001). Technical Report. SAS/STAT software: Changes and Enhancements. Release 8.02. SAS Institute, Cary. NC.

Smith, B. N. (1984). Iron in higher plant, storage and metabolic role. *Journal of Plant Nutrition. 7*, 759-766. http://dx.doi.org/10.1080/01904168409363239

Tanaka, A., Loe, R., & Navasero, S. A. (1966). Some mechanism involved in the development of iron toxicity symptoms in rice plant. *Soil Science and Plant Nutrition. 14*, 1-6. http://dx.doi.org/10.1080/00380768.1966.10431951

Tanaka, A., Mulleriyawa, R. P., & Yosu, T. (1968). Possibility of hydrogen sulphide induced iron toxicity of rice plant. *Soil Science and Plant Nutrition. 14*, 1-6. http://dx.doi.org/10.1080/00380768.1968.10432000

Vechnevetskaia, K. D, & Roy, D. N. (1999). Oxidative stress and antioxidative defence with emphasis on plant oxidants. *Environmental Review. 7*(1), 31-51. http://dx.doi.org/10.1139/a99-004

Von Vexhall, H. R., Mutert, E. (1998). Global extent, development and economic impact of acid soils. In: R.A. Date, N.J. Greendon, G.E. Rayment, Probert M.E. (eds). Plant-Soil Interactions at low pH. Principles and Management. Kluwer Academic Publishers. Dordrecgt, The Netherland. pp 5-19.

Walkley, A., & Black, I. A. (1934). An examination of the Degtjareff method for determining carbon in soils: Effect of variation in digestion conditions and of organic soil constituents. *Soil Science. 63*, 251-263. http://dx.doi.org/10.1097/00010694-194704000-00001

WARDA (West Africa Rice Development Association). (1995). Annual Report 1994. WARDA, Bouake, Cote d'Ivoie. pp.57-59.

WARDA (West Africa Rice Development Association). (2002). Annual Report 2001-2002. WARDA, Cote d'Ivoire.pp.25-37.

Yoshida S. 1981. Fundamentals of rice crop science. International Rice Research Institute, Manila, Philippines.p269.

Zhang, X., Zhang, F., 7 Mao, D. (1999). Effect of iron plague outside roots on nutrient uptake by rice (Oryza sativa L.): phosphorus uptake. *Plant Soil. 209*, 187-192. http://dx.doi.org/10.1023/A:1004505431879

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Evaluation of the Efficacy of Plant Powders, Cow Dung Ash and Malathion Dust against *Callosobruchus Chinensis* L. (Coleoptera: Bruchidae) On Chickpea in Jole Andegna: Southern Ethiopia

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Abstract

Callosobruchus chinensis is one of the major insect pest of chickpea and other stored legume which is known to cause significant yield loss both quantitatively and qualitatively. This investigation was done to study the efficacy of leaf powders of basil (*Ocimu basilica L.*) and neem (*Azadirachta indica*), cow dung ash and Malathion dust against bruchid on two chickpea varieties namely Desi (local) and Habru (improved Kabuli). Levels of infestation, weight loss, germination capacity (delete) and germination of the seeds were evaluated monthly up to six months. In the bruchid infested treatment (control), hundred seeds weight, seed germination decreased through time while levels of infestation and weight loss increased. All the tested locally available treatments (cow dung ash, leaf powder of neem and leaf powder of basil) were found to be effective in reducing the damage inflicted by bruchid compared to the control. Malathion dust was observed to be the most effective of all treatment in this study. However, looking in to the side effects of synthetic pesticides, we suggest that the locally available plant powders and cow dung ash which is cheap, ecologically friendly and non-hazardous to human health can play an important role in protection of chickpea during storage against invasion by bruchid.

Keywords: *Azadirachta indica , Ocimu basilica, bruchid,* chickpea*,* Malathion dust.(delete)

1. Introduction

Chickpea (*Cicer arietinum* L.) is a highly nutritious pulse cultivated throughout the world and is placed third in the importance list of the food legumes. Ethiopia is the largest producer of chickpea in Africa accounting for about 46% of the continent's production. It is also the seventh largest producer worldwide and contributes about 2% to the total world chickpea production (FAOSTAT, 2008). Chickpea, locally known as *shimbra*, is one of the major pulse crops in Ethiopia and it is the second most important legume crop after faba bean. It contributed about 16% of the total pulse production during 1999-2008.The total annual average (1999-2008) chickpea production was estimated to be about 173 thousand tones. During the same period, chickpea was third after faba beans and field peas in terms of area coverage (Menale et al., 2009).

Pulses are invariably infested with beetle and weevil in fields as well as during storage time (Adugna, 2006). *Callosobruchus chinensis* L. is one of the most destructive pests of chickpea in storage (Aslam, 2004). The pest not only inflicts qualitative and quantitative losses, but also damage their germinating capacity, and nutritional value which make the grains unfit for human consumption as well (Atwal and Dhaliwal, 2005; Righi-Assia et al.,2010). Losses as high as 50% often encountered in some of the important legumes such as faba bean, field pea, chickpea and lentil from some belligerent storage insect pests like *C. chinensis* (Ali and Habtewold, 1993; Damte and Dawd, 2006). Even with only a small amount of actual biological losses, economic losses can reach up to 100% (Boeke et al.; 2004; Somta et al., 2006). Despite the importance of storing seeds as a strategy of stabilizing market prices associated with the balance between supply and demand (CIAT, 1986), the damages often wreaked by the pests, particularly under small-scale farmers' conditions obstruct optimal use of the market opportunities (Damte and Dawd, 2006). Traders, food processors, and finally consumers also suffer from the loss due to storage pest damage.

Synthetic insecticides play a significant role in reducing storage losses due to insect pests (Tapondjou et al., 2002). However, the persistent use of these insecticides in granaries of small- scale farmers has led to a number of problems such as killing non-target species, pose risk to human health, toxic residues in food, development of genetic resistance,,(delete) increased cost of application and destruction of the balance of the ecosystem (Shaheen and

Khaliq, 2005; Boateng and Kusi, 2008). Plant products have been used for many years by the small scale farmers in parts of Africa to protect stored products from insect infestation (Bekele, 2002; Tapondjou et al., 2002). In this regard many efforts have been made to screen plants with better botanical insecticides which can be used as an alternative to synthetic insecticide (Emana et al., 2003). Thus this investigation was carried out to evaluate the efficacy of locally available botanical plant powders and cow dung ash at Jole Andega province (Southern Ethiopia) for controlling *C. chinensis*.

2. Materials and Methods

2.1 Survey of the Chickpea Storage Practices and Problems

A survey was conducted at Meskan Woreda, Jole Andegna Kebele having 10°C to 17°C annual mean temperature, 1001 to 1200 mm annual rainfall, and red (22%), black (53%) and grayish (25%) soil type. The area has high potential for chickpea production but heavily suffers from the damage by bruchid during storage.

Purposive sampling technique was used to select target group of farmers who have been cultivating and storing one of the chickpea varieties under the study for at least a year. The survey was administered for 86 farmers with ample experience and knowledge about storing, managing and identification of the causes of postharvest losses of chickpea.

2.2 Storage Experiment

2.2.1 Sample Seed Preparation and Insect Rearing

Chick pea seeds varieties (Harbu and local) bought from local market in Meskan were cleaned and kept in refrigerator for four weeks to avoid any latent insect infestation before treatment application (Ileke et al., 2013). Insect rearing was carried out in farmer's home at Jole Andegna Kebele in ambient condition. Chickpea seeds infested with bruchids (*C. chinensis*) were mixed with the healthy one and were kept in plastic jars, which were covered by muslin cloth, for one month.

2.2.2 Plant Extracts, Dung Ash and Chemical Insecticides

Fresh green leaves of neem (*Azadirachta indica*) and basil leaf (*Ocimu basilica*) were collected and kept in the laboratory for 7 days for air drying followed by one day sun drying before making powder. Dried leaves were milled using electric grinder and sieved through 60-mesh sieve to get the finest powder. Similarly, dried cow dung was collected from farmers' home at Jole Andegna Keble and burned on clean sheet metal and then the ash was sieved via 710 µm mesh size to get the finest dust. Storage treatment was applied according to recommendations set by Organic Organization HDRA (1998), Shaheen and Khaliq (2005) and Ahmed and Din (2009) where: 100 g of neem leaf powder, 200 g of basil leaf powder and 100 g of cow dung ash were applied respectively to 5kg of chickpea samples. Malathion dust of 3.75 g was applied to the same amount of sample.

The 5kg chickpea seed samples were filled in polyethylene bags in triplicate. All treatments were maintained under ambient conditions for 6 months at Butajira Horticulture Research

Centre. All bags were loaded on pallets that were made from wood slabs. The polyethylene bags were kept in round orientation keeping the infested chickpea seed bag at the centre and while the remaining treatments were kept at equal distance from the infested treatment. The experiment was laid down in completely randomized design (CRD) with five treatments and three replications.

List of treatments in the experiment

T1. Chick pea treated with cow dung ash and infested with bruchid

T2. Chick pea treated with neem leaf powder and infested with bruchid

T3. Chick pea treated with basil leaf seed powder and infested with bruchid

T4. Chick pea treated with Malathion dust and infested with bruchid

T5. Chick pea with no treatment and infested with bruchid (control)

2.2.3 Percent of Infestation

For determination of percent infection, 100 seeds were drawn randomly from each treatment and investigated manually. Seeds with holes, egg spot or both were counted as infested seeds and the percentage of infestation were calculated as follow:

$$\%I = \left(\frac{Nh}{No}\right)x100$$

Where: %I= percent of infestation, Nh= number of seeds with emergent holes &

No= total number of seeds observed

2.2.4 Weight Loss

The weight loss of chickpea seed caused by *C. chinensis* was measured every month throughout the experiment according to the method of Farid and Abdul (2005) using the following formula:. (delete)

$$\text{Weigh loss}(\%) = \left(\frac{A - B}{A}\right)x100$$

Where A = initial weight at initial storage time

B = weight of grains at sample taking time

2.2.5 Seed Size and Hundreds (delete) Seeds (delete) Weight

The seed size was measured simply using a digital calliper before and after storage. Thirty randomly selected seeds were used to measure length, width and thickness using the digital calliper and mean values were calculated. Hundred seed weight was determined according to the AACC method 56-35.01. Broken and damaged seeds along with foreign materials were handpicked from the sample. One hundred seeds were counted using a custom-made seed sampling paddle and weighed.

2.2. 6 Seed Germination

For germination test, one hundred seeds of chickpea from each treatment and variety were placed on moistened soft paper on flat dish and kept at room temperature. Germinated seeds were recorded and the remaining samples were watered daily for ten days. Speed of germination was calculated by using formula:

$$SG = \frac{N1 + N2 + N3 + \cdots + Nn}{D1 + D2 + D3 + \cdots + Dn}$$

Where: SG = Speed at germination

N_1, N_2, N_3------Nn= Number of seedling emerged on D_1, D_2, D_3-------and Dn days after sowing, respectively

2.3 Data Analysis

The Statistical Analysis System program (SAS version 9.0) was used for analysis of variance (ANOVA). Mean values were separated using the Fischer's least significant differences (LSD) procedures. Significance levels were given for $P < 0.05$.

3. Results and Discussion

3.1 Survey on Chickpea Production and Storage Practices in Jole Andegna Kebele

The survey result indicated that only one farmer completely allocate the farm for chickpea production and about 52 farmers (60.5%) cultivate the crop using one fourth of their land (Table 1). This clearly indicated that the crop is not very popular in the area comparing to other crops. In most cases they produced chickpea for home consumption and partly for sale and some cultivated the crop for seeds to the next season which serve as a good source of income.

Table 1. Land size allocation for chickpea production in Jole Andegna Kebele

Land size allocated for chickpea production	No. of Farmers	Percent (%)
$1/4^{th}$ of the total land	52	60.5
$1/2^{th}$ of the total land	26	30.2
$3/4^{th}$ of the total land	2	2.3
The whole land	1	1.2
$1/3^{th}$ of the total land	5	5.8

It was found that only one farmer used (delete) leaf powder of China berry (*Melia Azdarach*) for chickpea storage while the rest of the farmers used the synthetic chemical insecticides Malathion dust (MD) to minimize the damage inflicted by bruchid during storage of the grains (Table 2).

Table 2. Common chickpea storage methods in Jole Andegna Kebele

Methods used for chickpea storage	Frequency	Percent (%)
Sundry	1	1.2
Chemical treatment	74	86
Locally available plant	1	1.2
Sundry and Chemical treatment	4	4.7
Chemicals and Locally available plant	2	2.3
Cold place	2	2.3
Other	1	1.2
Nothing	1	1.2

The local farmers dislike the odour of Malathion dust and fear that it may cause breathing system complications on the person who applies it. In this regard, the chemical insecticides residual toxicity, environmental hazards and pest resistance of made botanical extracts a prime alternative choice again. In this regard DARP (2003) reported that Malathion resistance developed by the bruchid pest was found all over the world and currently about 122 insect-pest species have been found to be resistant to this insecticide. Therefore, utilization of locally available storage methods is economical and healthy for the resource poor farmers.

3.2 Storage Experiment

3.2.1 Percent Seed Infestation and Weight Loss

Clear difference in percentage of infestation was observed between the two chickpea varieties during storage experiments (Figure 1). The result indicated that the control sample of desi (local variety) was highly susceptible to *C. chinesis* (55 %) than that of the control sample of Habru (20 %) at the end of six months of storage. The different storage treatments decreased the infestation of chickpea by *C. chinesis* compared to control (untreated chickpea seeds). In the local variety, cow dung ash minimized infestation of seeds with *C. chinesis* which had only average 0.83 % infested followed by leaf powder of neem 1.17 % and leaf powder of basil 4.50 % in six months of storage. In Harbu variety, leaf powder of basil was the best in reducing infestation 1.17 % followed by leaf powder of neem 2.33 % and cow dung ash 3.33 %. However, Malathion dust gave least infestation in both desi and harbu type samples.

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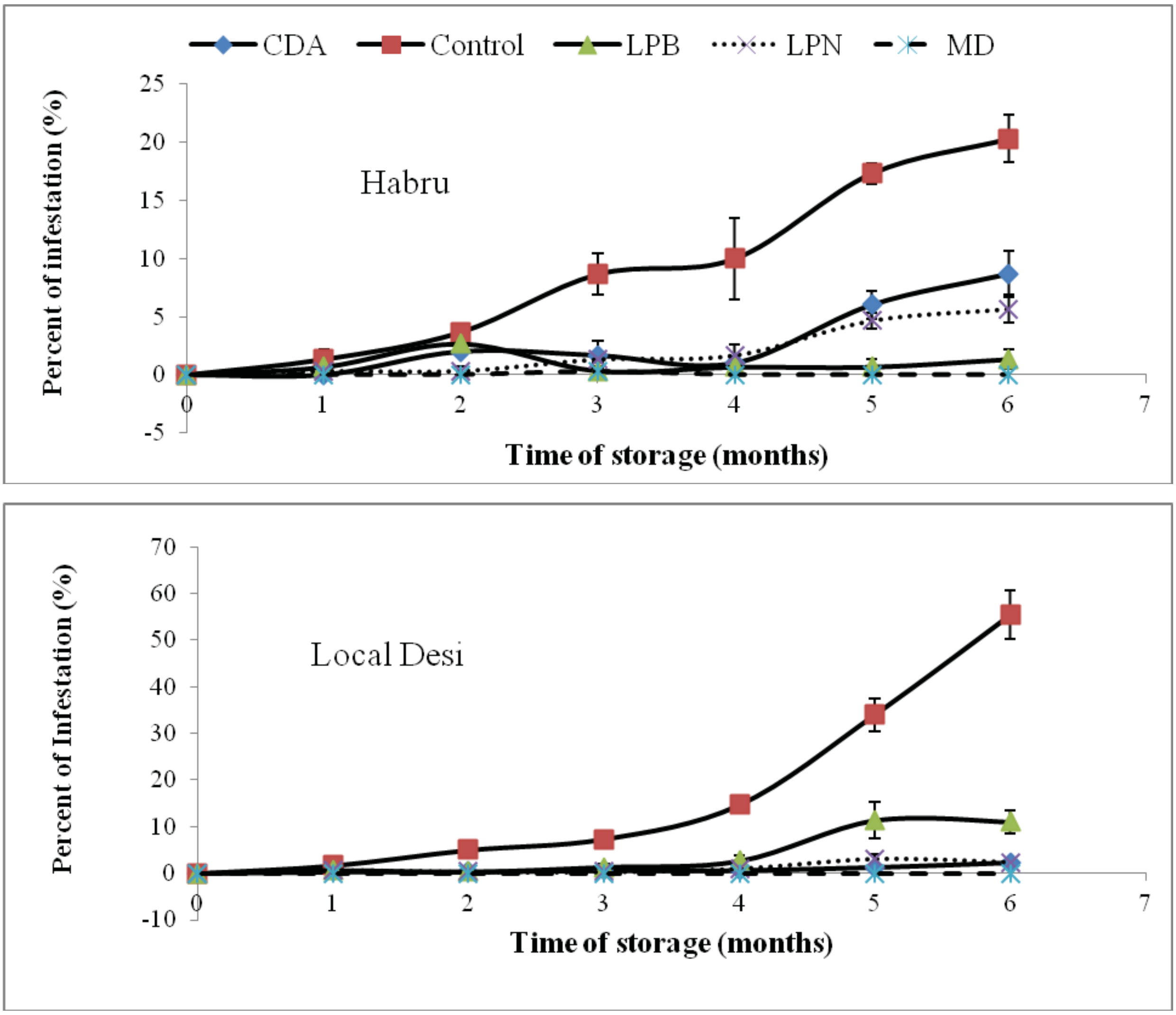

Figure 1. Effects of storage treatments on percent of infestation of chickpea

The result indicated that all storage treatments had considerable effect on reduction of weight compared to the control. The least loss was recorded for sample treated with Malathion dust (MD) which was 0.25 % and 0.5 % on Habru and Local varieties of chickpea, respectively. Among the locally available treatments cow dung ash (CDA) reduced the weight loss by 3.78 % in Habru and 3.98 % in Local varieties followed by of leaf powder of basil by 8.3 % and 8 % and leaf powder of neem by 7.43 % and 8.6 % in Habru and Local, respectively (Figure 2).

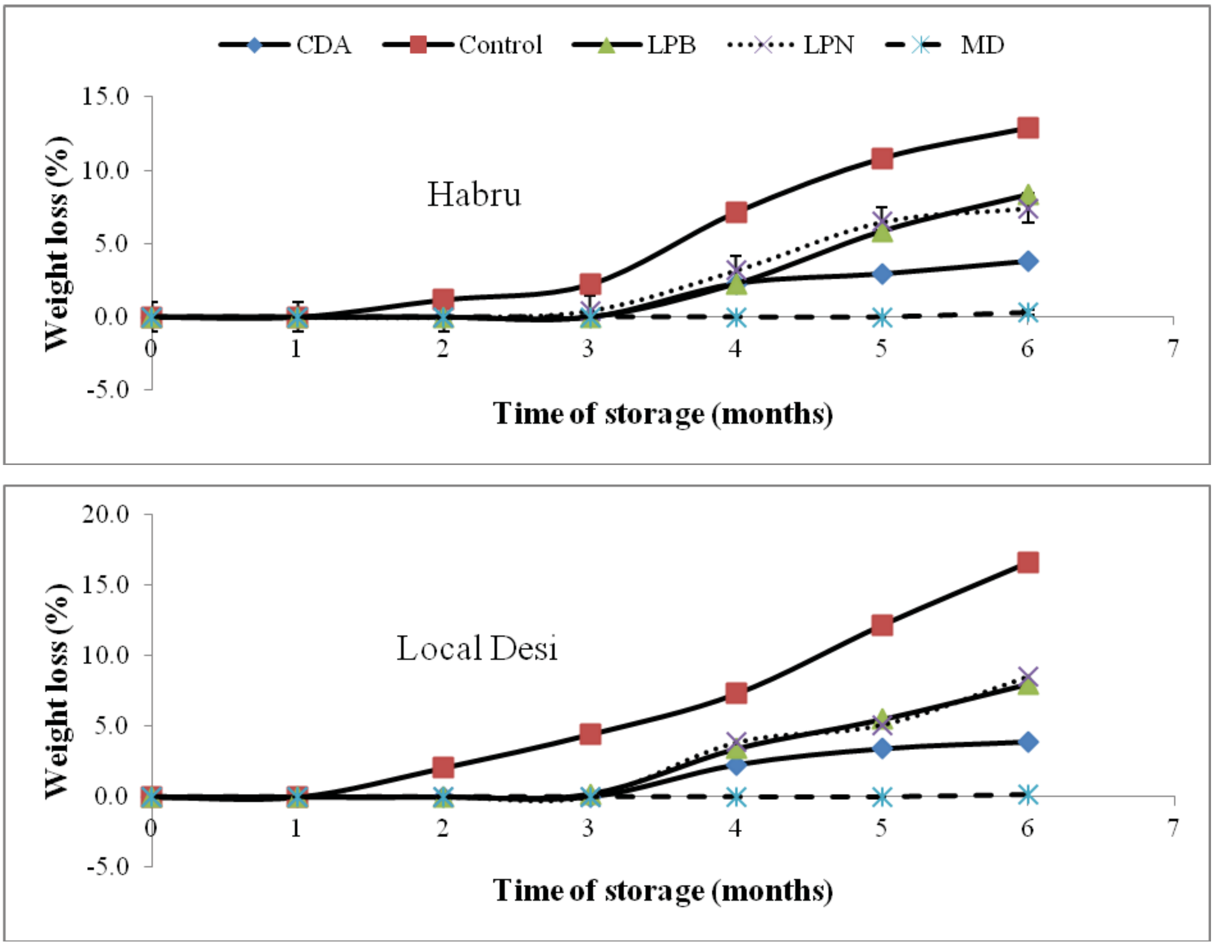

Figure 2. Effects of storage treatments on weight loss of chickpea

The findings of the present investigation showed that the repellent and deterrent effects of the leaf powders of neem and basil agianst *C.chinensis* was a promising alternative to Malathion dust. The repellent and deterrent effects of leaf powder of basil and neem was different on the survival and emergence of *C. chinensis* indicating the pest controlling factors are not uniformly present in every aromatic plant. The leaf powder of neem showed better activity against bruchid than leaf powder of basil. The reduction in percent infestation in this experiment could be explained either as egg mortality or larval mortality. It has been reported that the larvae which hatch from the eggs of *Callosobruchus* species must penetrate the seeds to survive (FAO, 1999). The larvae are unable to do so unless the eggs are firmly attached to the seed surface. In the present study, the eggs were found to be loosely attached to the chick pea seed surface in the treated sets of treatments. The leaf powders of basil and neem might thus have inhibited the larval penetration into the seed and thus showed reduced levels of seed infestation and weight loss.

The growth inhibitory or insecticidal effect of plant powders may attribute to one or more such properties as stomach poisoning effect where insects feed on admixed grains and pickup lethal doses of treatment particles and these particles might reduce insect movement and also cause death through occlusion of their spiracles, thereby preventing respiration via trachea (Shaheen and Khaliq, 2005). In this regard the characteristic garlicky odour of neem materials presumably repelled the bruchid and the bitter components present in neem deterred feeding. Furthermore, different researches have revealed that the neem materials whether raw, enriched, or purified affect insect pest behaviour, growth and development, and survival and reproduction.. (delete) (Pascual et al., 1990; Saxena et al., 1989; Singh, 1993). The findings of the present investigation is in accordance with that of other researchers who have previously reported the effectiveness of *Lantana camara* (Koona and Njoya, 2004), *Murraya koenigii* and *Eupatorium cannabinum* (Shukla et al., 2007) and Neem (Hasan *et al.*, 2012, Tabu et al., 2012) against *C. chinensis*. Dried powders of clove, red and black pepper have also been reported to prevent the infestation of legume by bruchids at a dose of 25g/kg (Aslam, et al., 2002). In the current experiment chickpea seed damage is not 100% reduced by neem or basil leaf powders. However, the use of the plant powders has a significant economic advantage and service to rural areas in tropical developing countries if reliable recommendations can be made and given to farmers for the protection of stored commodities.

Similarly, cow dung ash can offer an effective way to protect stored seeds against storage beetles, if it is applied in large quantities. The effect of the ash is caused by a mechanical rather than by a chemical action. The ash hinders adult movement and thus hampers oviposition (Boeke et al., 2003). The applied ash does not only hamper beetle movement, but it can also do physical damage to the adult beetles. If the adult insects move over or through the ash, their bodies (De Groot, 1991), especially the layer of chitin on the adults' abdomen are grazed. This result in clogging of insect spiracles and tracheae (Wolfson et al., 1991) or blocking of the lateral stigmates, all essential for respiration, cause suffocation of the adult and enhance mortality (De Groot, 1997). The result of the current investigation also comply with that of (Hampanna et al., 2006) who reported that cow dung ash (2.0%) and dry cow dung powder (20.0%) were effective in reducing weight loss, seed damage and population build up of rice weevil and pulse beetle. Sudheer Reddy et al. (1993) also reported that addition of cow dung ash at 200 g/kg seeds to be effective without grain damage by *Rhizopertha dominica* after storage period of six months.

3.2.2 Seed Size and Hundred Seeds Weight

Habru variety (Kabuli type) chickpea had larger seed size (7.13 to 7.50 mm) than that of the local desi variety (5.59 and 5.99 mm). The time of storage and storage treatments did not affect the seed size of both chickpea varities.

Hundred seed weight decreased for both varieties after the six months storage period (Figure 3). The hundred seeds (delete) weight of Habru variety decrease from 26.6 g to 24.6 g. The seed weight of the local variety decreased from 12.47 g to 11.17 g. All the seed treatments gave some degree of protection against seed weight loss. In this regard Malathion dust was the most effective followed by cow dung ash. Leaf powder of neem better maintained seed weight the local variety chick pea than the leaf powder of basil. Neem leaf powder was more effective in maintaining the seed weight for the Habru variety.

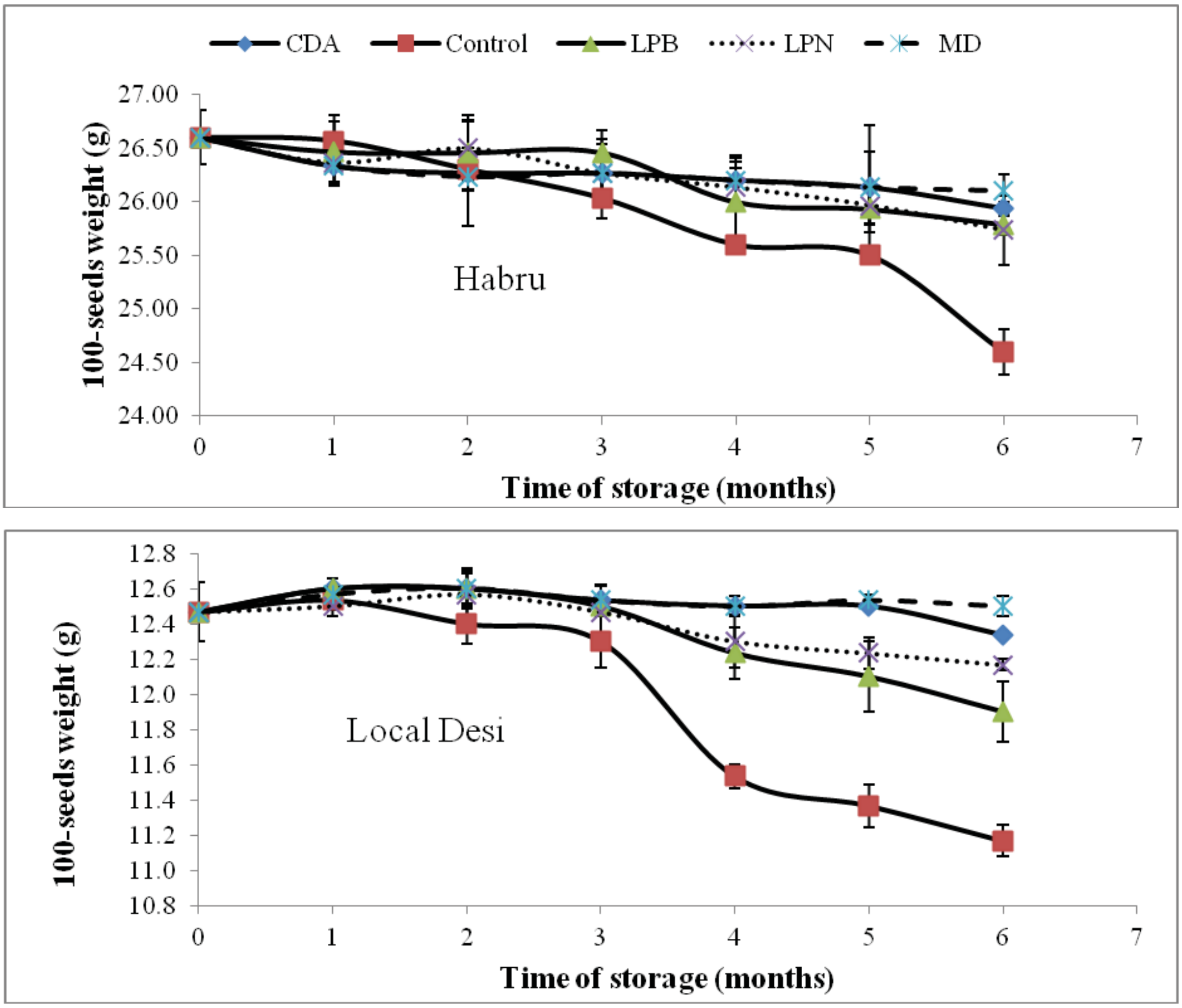

Figure 3. Effects of storage treatments on hundred seeds weight of chickpea.

The seed size and weight (100-seeds weight) depend one on each other. The local Desi type chickpea had a smaller seed size and 100-seeds size than the improved Kabuli type of Habru chickpea. This was supported by the results of study by Hossain et al. (2010). There was no change on seed size during the six months storage due to the different storage treatments. Seed size is an important attribute that determines the consumer preference and cooking quality of chickpea cultivars (Malik et al., 2011) and it is one of the factors which determine the storability of seeds. The morphology of the seed such as size, uniformity of size and seed shape are varietals character that are key factors affecting the de-hulling process of pulses (Reichert et al., 1984). These properties play a vital role in the selection of sieves and de-hulling machines. In the current investigation, the different treatments had no significant effect on chickpea seed size in both varieties over the six months of storage experiment which is in agreement with the results of Hossain et al. (2010). Hundred seeds(delete) weight of the chickpea seeds in both varieties decreased in the control treatment due to damage inflicted by *C. chinensis* during storage experiment. However, all treatments managed to reduce the damage compared to the control.

3.2.3 Seed Germination

The chickpea seed sample stored without any protection against bruchids (control) reduced the germination performance of the seeds (Figure 4). The germination of seeds of Habru declined from 1.81 to 1.68 seeds day^{-1} and the Local variety from 1.82 to 1.75 seeds day^{-1} after six months of storage. The storage treatments maintained germination capacity of the seeds compared to the control. The sixth month of result of speed of germination were 1.79, 1.78, 1.76 and 1.68 seeds day^{-1} for the Habru samples treated with leaf powder of basil, Malathion dust, both cow dung of ash and leaf powder of neem and the control, respectively. The speed of germination of local variety sample were 1.81, 1.80, 1.79 and 1.75 seeds day^{-1}due to treatments of Malathion dust, cow dung ash and leaf powder of neem, leaf powder of basil and control sample at the end of six months of storage.

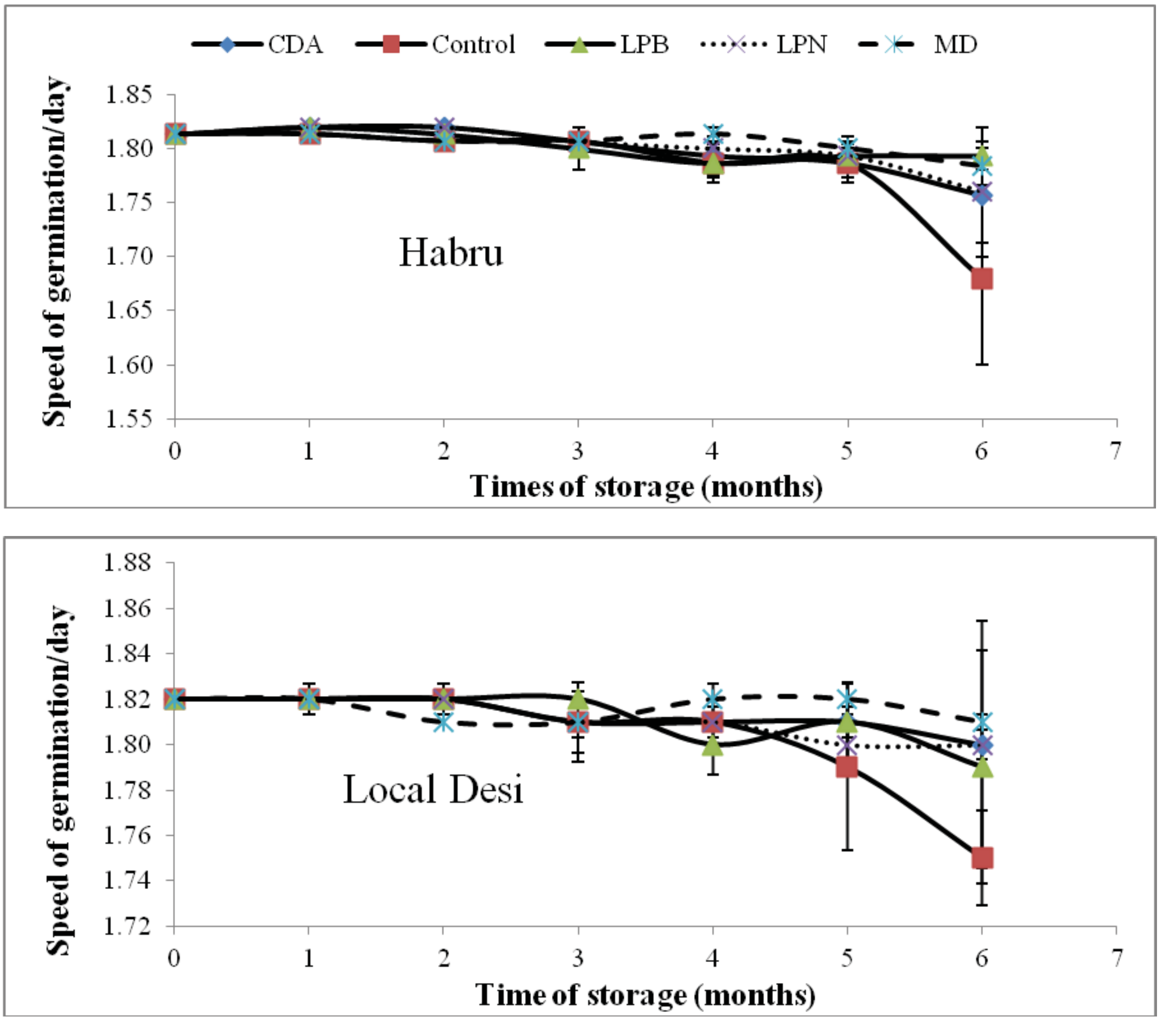

Figure 4. Effects of storage treatments the rate of seed germination of chickpea

The result of germination of chickpea seed (Fig 4) showed that the germination of chickpea grain declined with the increase of storage time. Germination rate in the treated seeds was significantly higher. The treated chickpea seeds in both varieties showed higher germination performance compared to the control. This result indicated the bruchid attack altered the germination of the control samples. It also showed that the powders of plant leaves, cow dung ash and the synthetic insecticides did not show any adverse effect on the germination capacity of chickpea seeds. Kasa and Tadesse (1995) investigated the use of crude powders from 17 plants for the control of *S. zeamais* on sorghum and reported that the plants had no effect on seed germination. Similarly, Keita et al. (2001) and Araya and Emana (2009) reported that powders of *O. basilica* ; *J. curcas* , *D. stramonium* , *C. ambrosioides*, *P dodecondra* , *A. indica* and *P. hysterophorus* provided complete protection against *C. maculatus* and Z. *subfasciatus* , respectively and also did not show significant effect on seed germination.

4. Conclusion

The current investigation demonstrated that the tested botanicals and cow dung ash possesses insecticidal properties that can be used for the control of *C. chinensis* in stored chickpea. The availability of these botanical plant powders and cow dung ash in the farm yard of most of the chickpea grower is another additional value which made these methods of storage preferred than other methods of control like chemical of insecticides. Thus, the result of this study showed that the locally available treatments gave good protection the damage inflicted by bruchid on chickpea grains during storage. Therefore, much effort should be done for the success and sustainability of this inexpensive, healthy, easily available and ecological friendly pest control method for the small-scale and resource poor farmers.

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References

Adugna, H. (2006). On farm storages studies in Eritrea. *African Journal of Biotechnology*, *5*(17), 1537-1544.

Ahmed, S., & Din, N. (2009). Leaf Powders of basil (*Ocimum Basilicum* L.), Lantana (*Lantana Camara* L.) and Garenia (*Gardenia Jasminoides* Ellis) Affect Biology of *Callosobruchus Chinensis* L. (Coleoptera: Bruchidae). *Journal of. Pakistan Entomology*, *31*(1), 5-8.

Araya, G. S., & Emana, G. (2009). Evaluation of botanical plants powders against *Zabrotes subfasciatus* (Boheman) (Coleoptera: Bruchidae) in stored haricot beans under laboratory condition. *African Journal of Agricultural Research*. 4, 1073-1079.

Aslam, M. (2004). Pest status of stored chickpea beetle *Callosobruchus chinensis* L. on chickpea. *Journal of Entomology, 1*(1), 28-33. http://dx.doi.org/10.3923/je.2004.28.33

Atwal, A. S., & Dhaliwal, G. S. (2005). Agricultural pests of South Asia and their management. 5th edition. Kalyani publishers, New Delhi, India p 390.

Bekele, J. (2002). Evaluation of the toxicity potential of *Milletia ferruginea* (Hochest) Baker against *Sitophilus zeamais* Mots. *International Journal of Pest Management*, *42*(1), 29-32. http://dx.doi.org/10.1080/09670870110065253

Boateng, B., & Kusi, F. (2008). Toxicity of *Jatropha* Seed Oil to *Callosobruchus maculatus* (Coleoptera: Bruchidae) and its Parasitoid, *Dinarmus basali* (Hymenoptera: Pteromalidae). *Journal of Applied Science Research*, *4*, 945-951.

Boeke. S. J., Baumgarta, I.R., Jvan Loona, J.A., van Huisa, A., Dickea, M., & Kossoub, D.K. (2004). Toxicity and repellence of African plants traditionally used for the protection of stored cowpea against *Callosobruchus maculatus*. *Journal of Stored Product Research*, *40*, 423-438. http://dx.doi.org/10.1016/S0022-474X(03)00046-8

Boeke, S. J., Antonia, A. C., Rauls, W. M., Gilsang, P. J., Dansai, K. K., & Jrop, J. A. (2003). Side effects of cowpea treatment with botanical insecticides on two parasitoiuds of *Callosobruchus maculatus*. *Entomologia Experimentalis at Applicata*, *108,* 43-51. http://dx.doi.org/10.1046/j.1570-7458.2003.00066.x

CIAT (Centro Internacional de Agricultura Tropical). (1986). Main Insect Pests of Stored Beans and Their Control: A Study Guide, Series 04EB-05.03, Apartado Aéreo 6713; CIAT (Centro Internacional de Agricultura Tropical): Cali, Colombia.

Damte, T., & Dawd, M. (2006). Cickpea, lentil and grass pea insect pest research in Ethiopia: A review. In: Ali K, Keneni G, Ahmed S, Malhotra R, Beniwal S, Makkouk K, Halila MH, editors. Food and Forage Legumes of Ethiopia: Progress and Prospects, Proceedings of a Workshop on Food and Forage Legumes, Addis Ababa, Ethiopia, 22–26 September 2003; ICARDA: Aleppo, Syria. pp. 260-273.

DARP. (2003). Data base of Arthropods Resistant to Pesticides. Resistant Management at Michigan State University. Available at http://www.pestcideresistance.org/DB/.

De Groot, U. M. (1991). Protection of stored grains and pulses. Agrodok 18, Agromisa, Wageningen, The Netherlands, 45 pp.

De Groot, U. M. (1997). Niébé techniques de controle intégré des problèmes phytosanitaires. (CIPP) Volet Recherche et Développement Activité 33272. 14 pp.

Emana, G., Ahmed, I., & Fridissa, I. (2003). Review of lowland pulse insect pest research in Ethiopia. Proceedings of grain legume workshop, 22-27 September, 2003, Addis Ababa, Ethiopia.

FAO. (1999). Botanical oils as grain protectants, In: The use of spices and medicinals as bioactive protectants for grains. FAO Agricultural Services Bulletin No. 137. FAO,Vialle delle Terme di Caracalla, 00100 Rome, Italy.

Farid, A. S., & Abdu, l. K. (2005). Management of Pulse Beetle, *Callosobruchus chinensis* L. (Coleoptera: Bruchidae) in Stored Chickpea using Ashes, Red Soil Powder and Turpentine Oil. Department of Entomology, University of Arid Agriculture, Rawalpindi. Ref.Pak. Entomol. Vol. 27, No.2, 2005.

Hampanna, A.Y.L., Naganagoud, & Patil, B.V. (2006). Evaluation of Animal Origin Inert Materials against Rice Weevil and Pulse Beetle in Stored Sorghum and Chickpea. Karnataka *Journal of Agricultural Science*, *19*(1), 54-57

Hasan, M., Sagheer, M., Saleem, S., Hanif, S., Akhter, S., & Hanif, C.S.M. (2012). Evaluation of insecticidal potential of powders of Azadirachta *indica*, *Momordica charentia* and *Allium sativum* against *Callosobruchus chinensis* (Coleoptera: Bruchidae). *Pakistan Entomology*, *34*(2), 71-73.

HDRA-the Organic Organization. 1998. The Neem Tree. www.hdra.org.uk, United Kingdom.

Hossain, S., Pittock, C., Panozzo, F., Ford, R., & McNeil, D. (2010). Inheritance of seed size in chickpea (*Cicer arietinum* L.) and identification of QTL based on 100-seed weight and seed size index. *African Journal of Crop Science*, *4*(2), 126-135.

Ileke, K. D., Bulus, D.S., & Alaegoroye, A.Y. (2013). Effects of Three Medicinal Plant Products on Survival, Oviposition and Progeny Development of Cowpea Bruchid, *Callosobruchus maculatus* (Fab.) [Coleoptera: Chrysomelidae] Infesting Cowpea Seeds in Storage. *Jordan Journal of Biological Science*, *6*(1), 61-66. http://dx.doi.org/10.12816/0000260

Kasa, A., & Tadesse, A. (1995). Evaluation of some botanicals against the maize weevil, *Sitophilus zeamais* Motsch., on stored sorghum at Bako. In: Bekele E, Abdulahi A & Yemane A, editors. Proc. 3rd annual conference of the crop protection society of Ethiopia. May 18-19, 1995, Addis Abeba, Ethiopia. Crop Protection Society of Ethiopia. pp. 120-126.

Keita, S. M., Vincent, C., Schmit, J. P., Arnason, J. T., & Belanger, A. (2001). Efficay of essential oil of *Occimum basilicum* and *O.gratissmum* L. applied as an insecticidal fumigant and powder to control *Callosobruchus maculates* (Fab.) (Coleoptera: Bruchidae). *Journal of Stored Products Research*, *37*(4), 339-349. http://dx.doi.org/10.1016/S0022-474X(00)00034-5

Koona, P., & Njoya, J. (2004). Effectiveness of soyabean oil and powder from leaves of *Lantana camera* Linn. (Verbenaceae) as protectants of stored maize against infestation by *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae). *Pakistan Journal of Bioscience*, *7,* 2125-2129.

Malik, S.R., Saleem, M., Iqbal, U., Zahid, M.A., Bakhsh, A., & Iqbal, S.M. (2011). Genetic analysis of physiochemical traits in chickpea (*Cicer arietinum*) seeds. International *Journal of Agricultural Biology*, *13*, 1033-1036.

Menale, K., Bekele, S., Solomon, A., Tsedeke, A., Geoffrey, M., Setotaw, F., Million, E., & Kebebew, A. (2009). Current Situation and Future Outlooks of the Chickpea Sub-sector in Ethiopia. International Crops Research Institute for the Semi-Arid Tropics (ICRSAT), Nairobi &Ethiopian Institute of Agricultural Research ,(EIAR) Deber Zeit Agricultral Research Centre, Debre Zeit, Ethiopia. 8 pp.

Pascual, N., Marco, M. P., & Belles, X. (1990). Azadirachtin induced imaginal moult deficiencies in *Tenebrio molitor* L. (Coleoptera: Tenebrionidae). *Journal of Stored Product Research*, *26*, 53-57. http://dx.doi.org/10.1016/0022-474X(90)90037-S

Reichert, R. D., Ooman, B. D., & Young, C. G. (1984). Factors affecting the efficiency of abrasive type dehulling of grain legumes investigated with a new batch dehuller. *Journal of Food Science and Technology*, *49*, 267-272.

Rigi-Assia, A.,Khelil,M.A.,Medjdoub,B.F,m & Righi,K. (2010).Efficacy of oils and powders of some medicinal plants in biological control of the pea weevil (*Callosobrchus chinensis* L.). *African Journal of Agricultural Research, 5*, 1474-1481.

Saxena, R. C., Jilani, G., & Abdul Kareem, A. (1989). Effects of neem on stored grain insects.. In: Jacobson M, editor. Focus on Phytochemical Pesticides. Vol. I, The Neem Tree. CRC Press, Boca Raton, FL.pp 97-111

Shaheen, F. A., Khaliq, A. (2005). Management of Pulse Beetle, *Callosobruchus chinensis* L. (Coleoptera: Bruchidae). Department of Entomology, University of Arid Agriculture. *Rawalpindi Pakistan Entomology*, *27*(2), 19- 23.

Shukla, R., Srivastava, B., Kumar, R., & Dubey, N. (2007). Potential of some Botanical Powders in reducing infestation of Chickpea by *Callosobruchus chinensis* L. (Coleoptera : Bruchidae). *Journal of Agricultural Technology*, *3*, 11-19.

Singh, R. P. (1993). Neem for the management of stored grain insects in developing countries. World Neem Conf. Bangalore, India, 1993. Souvenir, pp. 69-80.

Somta, P., Talekar, N. S., & Srinives, P. (2006). Characterization of *Callosobruchus chinensis* (L.) resistance in *Vigna umbellata* (Thunb.) Ohwi & Ohashi. *Journal of Stored Product Research*, *42*, 313-327. http://dx.doi.org/10.1016/j.jspr.2005.05.003

Sudheer Reddy, V., Ramesh Babu, T., & Hussaini, S.H. (1993). Effect of inert materials on germination and grain damage by stored grain pets of sorghum. *Seed Research*, *1*, 285-287.

Tabu, D., Selvaraj, T., Singh, S. K., & Mulugeta, N. (2012). Management of Adzuki bean beetle (*Callosobruchus chinensis* L.) using some botanicals, inert materials and edible oils in stored chickpea. *Journal of Agricultural Technology*, *8*(3), 881-902.

Tapondjou, L., Adlerb, C., Boudaa H., & Fontemc, D. (2002). Efficacy of powder and essential oil from *Chenopodium ambrosioides* leaves as post-harvest grain protectants against six-stored product beetles. *Journal of Stored Product Research*, *38*, 395-402. http://dx.doi.org/10.1016/S0022-474X(01)00044-3

Wolfson, J.L., Shade, R.E., Mentzer, P.E., & Murdock, L.L. (1991). Efficacy of ash for controlling infestations of *Callosobnichus maculatus* (F.) (Coleoptera: Bruchidae) in stored cowpeas. *Journal of Stored Products Research*, 27, 239-243. http://dx.doi.org/10.1016/0022-474X (91) 90006-X

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Evaluating Interventions Uptake in Indigenous Chicken Production in a Participatory Research with Smallholder Farmers in Kenya

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Abstract

Indigenous chicken production system has long been characterised by low productivity due to among other factors, poor management, inadequate and poor feeding regime, poor (or lack) of disease control measures, poor hygiene, inappropriate housing, negative attitudes, lack of technical knowledge and lack of institutional support in terms of policy and infrastructure. This research was carried out to evaluate uptake by farmers of improved management practices (interventions) and their effect on performance of indigenous chickens at farm level and consequences for farmer participation in the implementation of research activities. The research involved 200 farmers in five regions in three counties. Four villages were selected per region and10 farms in each village. Interventions housing, feed supplementation, vaccination and deworming were implemented by farmers and monitoring and evaluation carried out. Farmers used own local inputs in implementing the project interventions and recorded various project activities and outputs. The project was monitored over a span of five, 3-months long periods. 25% of farmers in the entire five regions did not have housing as a treatment in any of 5 periods. Feed supplementation had high level of use by all farmers in each period. More farmers applied deworming in later periods, 25% had vaccination in period 1, and 40% in period 5. Periods 3 – 5 generally seem to be the time most applications were done. Flock sizes rose from 10 – 20 birds per farm to 20 – 30. Farmer participatory research is a tool for technology testing and transfer and a quick and effective means of generating and disseminating information.

Keywords: Africa, Kenya; Indigenous chicken, Production, Interventions uptake, Participatory research

1. Introduction

In sub-Saharan Africa, about 80% of the population live in rural areas eking out a living from subsistence farming, often under very difficult climatic and economic conditions (Ndegwa et al., 2001a; Ndegwa, 2013), to meet household food requirements.

Indigenous chickens are among the many local resources available in rural areas which, if well managed, could ease the burden of the people. Over 90% of rural households keep and rear indigenous chicken in small flocks of about 20 birds (Ndegwa et. al., 1999; Mbugua, 1990; MOLD, 1990; Stotz, 1983). According to Ndegwa, (2013), indigenous chickens play a very significant role in rural livelihoods. In Kenya, and indeed in sub-Saharan Africa, indigenous chickens comprise over 70% of total poultry populations (MOLD, 1991). They produce about 50% of the total eggs and over 80% of the poultry meat produced in many countries in sub-Saharan Africa (Ndegwa et al., 1998a). Hence, there exists a potential for a local resource like indigenous chickens to turn around the misery that is the lives in rural areas as stated by Ndegwa, (2006) who also calls for an infrastructural and institutional support in research and development activities aimed at improving productivity at farm level.

Indigenous chicken system has generally been characterised by low productivity due to among other factors, poor management, inadequate and poor feeding regime, poor (or lack) of disease control measures, poor hygiene, inappropriate housing, negative attitudes, lack of technical knowledge and lack of institutional support in terms of policy and infrastructure (Ndegwa and Kimani, 1997). Hence the importance of creating awareness and education as emphasised by Thieme et al (2014).

Proper harnessing of local resources of the poor people and their involvement in the research process can help bring about development of sustainable livelihoods and contribute to the fight on poverty alleviation in rural areas where the majority of the poor live (Ndegwa, 2013; Gonsalves et al., 2005 Ndegwa et al., 2001b; Okong'o et al 1998; Tuitoyet et al; 1999; Kitalyi, 1998; Dolberg, 2008; FAO, 2008, 2010 and SA PPLPP, 2011). Their number is mainly composed of women (Blair, 2000; Al-Sultan, 2001) who engage in subsistence agricultural activities as they struggle to survive and feed their families under often very hostile environments (Ndegwa et al., 2000, 1998b, 1999, 1997; Gueye, 2000). A number of authors (Fanworth, et al., 2013; SA PPLPP, (2011) and Dolberg, (2008) emphasise the fact that empowering women is key to poverty reduction as well as a key driver to agricultural productivity. According to FAO (2011), the agriculture sector is underperforming in many developing countries, and one of the key reasons is that women do not have equal access to the resources and opportunities they need to be more productive. FAO (2011) also recommends promoting gender equality and empowering women (Millennium Development Goal Schedule 3) in agriculture to win, sustainably, the fight against hunger and extreme poverty (MDG1).

Gonsalves, et al., (2005) write about new challenges to agricultural research and development that include shifting focus to less favourable environments, strengthening capacity of local farming communities to continuously learn and experiment ways of improving their agricultural livelihoods, research and development are no longer exclusive domain of scientist and that local stakeholders provide inputs to processes that find sustainable solutions. According to Okali et al., (1994) both farmers and researchers are involved at any or all points along a continuum of levels of participation.

There is however, little published peer-reviewed material regarding how benefits of participatory research are achieved in practice (Blackstock et al., 2007). This study and other related studies by same authors (Ndegwa *et al*., 2013, 2014) explores and explains importance of participatory research in practical terms.

This farmer participatory research was carried out between 1996 and 1999 to evaluate effects of improved management practices on performance of indigenous chickens at farm level and most importantly, the consequences for farmer participation in the implementation of the research activities. We were highly enthusiastic to work directly with farmers in their own surroundings, situations and circumstances in order to not only impart our ideas and visions, but also to learn from their rich experiences.

2. Methodology

The study involved selection of location (5 regions and 4 villages per region – Box 1), selection of farms based on farmer's willingness to participate (10 farms selected per village), training and sensitisation meetings (selected farmers and their neighbours plus frontline extension personnel), introduction of intervention options (see Box 2), implementation by farmers, and monitoring and evaluation. The farmers used their own local inputs in implementing the project interventions and recorded various project activities and outputs including some aspects of management and production. Sonaiya, E. B., (1998) also refers to use of local inputs in family poultry production. The project was monitored over a span of five, 3-months long periods. Monitoring was by a visit every three months to each farm to evaluate progress and confirm the farmer's records. This was also the time for more consultation and sharing of experiences.

There was however, a six-month gap between visits 2 and 3 when there was no visit to the farms due to the security concerns at the time especially in regions 1 and 2. These factors might have therefore played a key role in the behavioural patterns of flock demography. For the purpose of this study, 'periods 1 - 5' refer to the records at the end of the period.

The study deals with initial analyses of the data recorded by the farmers. The aim was to investigate effects of the introduction of a number of interventions (**improved management practices)**, referred in this context as treatments to each of the 200 farms selected across 20 villages in five different regions on the characteristic behaviour of these farms and their indigenous chicken flocks. The interventions were introduced through training and sensitisations services and consultations. Ten farms were initially selected in each village but some dropped out due to factors outside the scope of the study such as security concern

Box 1 Regions and villages

1. Laikipia Ngarua – low potential semi-arid, poor infrastructure and frequent livestock theft incidences. Selected villages (with average farm sizes) were, 1 - Kinamba (2 acres); 2 - Sipili (2.5 acres); 3 - Cheleta (10 acres); 4 - Ol Moran (1 acre).

2. Ol Kalou – low to high potential and cold with frequent frost and water logging incidences. Has impassable road network for transportation during wet seasons. The selected villages were: 1) Ol Kalou South with average farm size of 2.5 acres; 2) Passenga with 5 acres as the average farm size; 3) Mirangine with average farm size of 2 acres and 4) Kaibaga with average farm size of 1 acre.

3. Bahati – high potential with adequate rainfall and good soils for agricultural activities, with land size ranging from 5 to 0.25 acres per household and relatively good road network and market opportunities. The selected villages (with average farm sizes) were, 1) Kabazi (1.5 acres); 2) Munanda (2 acres holdings); 3) Scheme (3 acres); 4) Wanyororo (0.5 acres).

4. Njoro –high to medium potential with good to poor road network and market opportunities. The selected villages (with average farm sizes) were, 1) Piave (2.5 acres); 2) Gichobo (5 acres); 3) - Njokerio (0.25 acres); 4) Likia (1.5 acres).

5. Naivasha – low potential, porous volcanic soils of high infiltration. Good to poor road network especially during wet periods villages (with average farm sizes) were: 1) Karate (1.5 acres); 2) Maraigushu (2.5 acres); 3) Karai (5 acres); 4) Mirera (1 acres).

3. Results and Discussion

The records on all the treatments (interventions) uptake were analysed for 173 farms disaggregated by region and village and is shown in Table 1. Half of the villages had their original total of 10 selected farms with records on flock demography and treatment characteristics. The average number of farms with records in each village was 8.7. The shortfall in the number of farms with records on treatments uptake is mostly indicative of drop out by some from the project. This scenario points to the complexity of participatory on-farm experimentation and the need for input of statistical expertise in designing stage.

Box 2. Indigenous chicken project improved intervention options and how they were adapted by farmers

1. Housing: (Reference: Ndegwa, *et al* 1998b)

- majority of farmers had adopted housing interventions designed to provide shelter from heat, wind cold, rain, thieves, and predators; provide adequate ventilation , lighting and space for birds, feeders, drinkers, nests, resting rafts and for people getting in and out with ease, easy to clean and disinfect to prevent diseases, internal and external parasite infestation. Features included:

- Roofing(farmers used materials such as iron sheet, plastic sheeting, reeds ('*makuti*') and grass)

- Walls (had to be smooth – mainly mud, some timber, others rafters)

- Floor (dry and smooth and had to be kept clean – mostly earthen, some raised timber, a few were cemented)

- Chicken run (provided scavenging area to glean feeds and exercise – farmers used chicken wire, chain link, offcut timber or droppers)

- Chick pen (high priority for chicks rearing up to 8 weeks, and which contributed to relatively very low mortality levels of 5 -20% compared to over 80% normally reported for ordinary systems(Ndegwa *et. al.,* 1999*)* – most were portable made from timber, tin, wire mesh, intertwined rafters, and reeds baskets)

2. Feeding: (Reference: Ndegwa J. M., 1992a, 1992b; Ndegwa, et al 1998b)

- recommendation on feeding was for a free-choice system comprising both scavenging and supplementation

- almost all farmers supplemented their chicken flocks using mostly local materials (cereal grains – maize, sorghum, millet, wheat, oats, barley; boiled potatoes tubers and peelings, sweet potatoes (*Ipomeo batata*), cassava (*Tapioca*), arrow roots, beetroots, carrots; pumpkins, boiled grain and leafy *amaranthus* ('*terere*'), sesame seeds (*Sesamum indicum*), green vegetables, leafy weeds, grasses; fullfat oiseeds – sunflower, rapeseed,'thawani' (rapeseed family), croton megalocapus ('*mukinduri'*), groundnuts; cooked legume seeds and leafy parts – peas, beans;*leuceana*, *cariandra,*and *sesbania;*in-season fruits - avocados, plums, mangoes, pineapple, bananas;mineral sources - ground egg shells, ash, common salt*)*

- a few farmers bought external materials to feed their birds (compounded feeds, fishmeal, maize bran, cotton seed meal, soya meal, sunflower meal, bone meal, limestone, common salt, mineral and vitamin premix)

- scavenging was practised by all farmers mainly within 'runs' or enclosures during cropping and around the homestead and farm when there was no crop

- clean and relatively cool water was also provided by all farmers in a variety of containers

3. Health management: (Reference: Siamba, *et al* 1998; Ndegwa, *et al* 1998b)

- to prevent and treat diseases some farmers used either or both conventional and traditional strategies:-

- almost all farmers used traditional medication and some did not use any conventional methods.

- conventional medication included:

a) vaccination against Newcastle disease;

b) drugs for respiratory, gut and other problems;

c) control and treatment of endo-parasites – *helminths* using *dewormers*

d) control and treatment of ecto-parasites - mites, fleas and lice using powders

- traditional medication was done using a variety of materials e.g. *Aloe spp.('mugwanugu', 'thukurui'*), hot pepper, garlic, *Mexican marigold* ('*mubangi*'), stinging nettle *('thabai'*), *neem*, pumpkin leaves, pyrethrum, black soot('carbon'), hot ashes;

- other strategies included maintaining clean chicken houses and use of disinfectants such as '*kerol*' or *magadi s*oda and spraying walls with *acaricides.*

4. Hatching and Brooding: (Reference: Ndegwa, *et al* 1998b)

- this was a strategy to produce replacement and incremental flocks rather than buying replacement day-old chicks from a commercial hatchery as is the case with commercial poultry systems.

- the strategy also focused on minimising flock mortality associated with unimproved systems.

Hatching (synchronised and consecutive) involved use of a cock:hen ration of 1:10 to maximise fertility, proper nests (dry, clean, good litter material, quiet, with less light, isolated).

- Synchronised hatching – several hens let to get broody and provided incubation eggs at the same time.

- Consecutive hatching - a broody hen provided with incubation eggs immediately chicks are hatched repeatedly for up to 5 times.

- These strategies ensured farmers got many chicks at once hence increasing flock size several fold within a short period of time.

- Only a few farmers, though were able to apply synchronised and consecutive hatching

Brooding aimed at preventing chick mortalities by providing good management:

- separating chicks from mature birds – special chick housing (portable baskets, pens, isolated chick area).

- feeding good quality feed – high energy and protein, well ground

- clean cool drinking water

- protection against cold, predators, diseases,

5. Breeding: (Reference: (Ndegwa, *et al* 1998b)

-aimed at improving genetic potential of indigenous chickens

- maintaining of cock:hen ratio of 1:10,

- selecting high performers(eggs and growth) and good features (large body size, sturdy)

- avoiding inbreeding (removal of cocks after six months and exchanging with others farmers)

To sustain enthusiasm and revive interest among the farmers, we used some persuasion and education with a good measure of success. Most kept up-to-date records even when we took a longer time to visit them and even long after the project had been phased out. This happened also in areas where serious insecurity problems had previously occurred forcing many people to temporarily flee their homes.

Generally, the response on records keeping was encouraging. The treatments uptake had the most records and it seems many farmers found these easier to handle. All the variables were based on farmer records. The intervention treatment included the four explanatory variables housing, vaccination, de-worming and feed supplementation, introduced through a process of training and sensitisation of farmers. Exploratory variables to investigate effects were the flock demography and the production characteristics discussed in Ndegwa, (2013).

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Table 1. Number of farms in 20 villages with records on treatment uptake

Region/Village	Number of selected farms	Treatment/Flock Demography
1 / 1	10	10
1 / 2	10	10
1 / 3	10	10
1 / 4	10	7
2 / 1	10	10
2 / 2	10	8
2 / 3	10	8
2 / 4	10	7
3 / 1	10	9
3 / 2	10	10
3 / 3	10	9
3 / 4	10	6
4 / 1	10	10
4 / 2	10	7
4 / 3	10	9
4 / 4	10	3
5 / 1	10	10
5 / 2	10	10
5 / 3	10	10
5 / 4	10	10

Application of the treatments depended on individual farms capacity, ability and time allocation. Farmers used their own local resources and new knowledge from the training to apply the treatments. Hence, the treatments were not uniform in all the farms.

Table 2 illustrates the treatment uptake raw data at period 1 for farms in each village and region, using an example farm from each village. Complete records from all the farms in the five regions and for the rest of the five periods are shown in appendix 5.2 in Ndegwa, (2006) but are generally in the form shown here.

The treatment uptake records illustrated here show whether and when a particular farmer implemented the specific treatment in the form of housing, vaccination, de-worming or feed supplementation. Once the housing treatment was applied, it inevitably remained applied in subsequent periods. In case of the other three treatments, application could have been done in one period and be skipped in the next period(s). When a treatment was applied in a certain period, this was indicated with a value of one, otherwise a zero was entered. For example, the first row shows that farm LK1 in village 1 and region 1, had applied housing and supplementation (each given a value of 1) in period 1, but did not apply vaccination and deworming (each given a value of 0) in the same period.

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Table 2. Treatment uptake from farms selected from 20 villages in five regions in period 1.

Region	Village	Farm	Treatment Uptake[1]			
			Housing	Vaccination	Deworming	Supplementation
1	1 (LK)	LK1	1	0	0	1
1	2 (LS)	LS1	0	0	0	1
1	3 (LC)	LC1	1	0	0	1
1	4 (LO)	LO3	1	0	0	1
2	1 (OS)	OS1	1	0	0	0
2	2 (OP)	OP1	0	0	1	1
2	3 (OM)	OM1	0	0	0	1
2	4 (OK)	OK2	1	0	0	1
3	1 (BK)	BK1	0	0	1	1
3	2 (BM)	BM1	1	0	1	1
3	3 (BS)	BS1	0	0	0	1
3	4 (BW)	BW1	1	1	1	1
4	1 (NP)	NP1	1	0	0	1
4	2 (NG)	NG1	1	1	1	1
4	3 (NN)	NN1	0	1	1	1
4	4 (NL)	NL1	0	0	0	1
5	1 (NSK)	NSK1	0	0	0	1
5	2 (NM)	NM1	1	0	0	1
5	3 (NKR)	NKR1	1	0	0	1
5	4 (NMR)	NMR1	1	0	1	1

[1]Treatment Uptake: 0 = treatment not applied; 1 = treatment applied

Looking at this illustration, the treatment uptake characteristics, housing and supplementation had most entries with one indicated. The records for the other four periods were similar to this illustration.

Levels of treatment uptake per farm are calculated as totals for each form of intervention. These are illustrated in Table 3 for the selected sample of farms in the 5 regions.

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Table 3. Levels of treatment uptake distribution for 20 farms selected from 20 villages in five regions as totals for 5 periods

Region	Village	Farm	Treatment[1]			
			totHse	totVac	totDwm	totSpl
1	1	LK1	5	0	1	4
1	2	LS1	2	0	2	4
1	3	LC1	5	0	1	5
1	4	LO3	5	1	1	5
2	1	OS1	5	1	1	4
2	2	OP1	4	3	5	5
2	3	OM1	4	1	3	5
2	4	OK2	5	1	3	5
3	1	BK1	4	2	3	5
3	2	BM1	5	2	5	5
3	3	BS1	3	0	4	5
3	4	BW1	5	4	4	5
4	1	NP1	5	3	3	4
4	2	NG1	5	2	3	5
4	3	NN1	4	2	3	5
4	4	NL1	3	1	3	4
5	1	NSK1	0	3	1	5
5	2	NM1	5	1	2	5
5	3	NKR1	5	1	2	5
5	4	NMR1	5	1	2	5

[1]Treatment:

totHse = total periods housing intervention was applied

totVac = total periods vaccination intervention was applied

totDwm = total periods deworming intervention was applied

totSpl = total periods supplementation intervention was applied

The levels ranged from 0 – 5, indicating the number of times a given treatment was applied out of the possible 5 periods (0 - not applied at all in 5 periods; 5 - applied in all the 5 periods). For example, Total Housing uptake for 5 weeks (totHse) was obtained from:

Housing1 + Housing2 + Housing3 + Housing4 + Housing5

i.e. sum of housing values in periods 1 – 5.

In our illustration, farm LK1 in village 1 of region 1 had a totHse with a value of 5 meaning that housing was done at each of the five periods. The same farm had a total Vaccination uptake (totVac) of value zero, a total Deworming uptake value of 1 and a total supplementation value of 4

Two forms of diagrams are used to describe the pattern of uptake of interventions. The first is the frequency distribution of levels of each treatment shown by Fig 1 corresponding to the treatments housing, vaccination, deworming and supplementation respectively, as a pattern for each region. These levels indicate the number of times or periods a treatment was applied and range from 0 (no application at any period) to 5 (application of an intervention in each period).

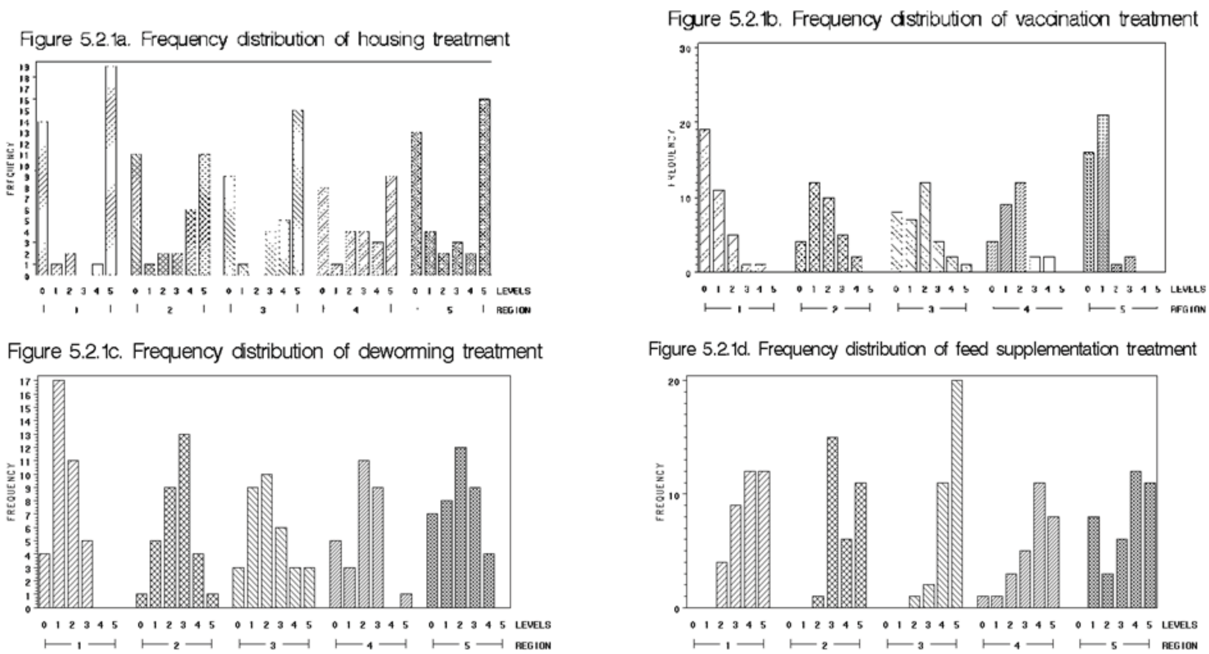

Figure 1. Frequency distribution of levels of treatments

The housing frequencies of farmers at levels of 0 and 5 in each region were larger compared to the frequencies at other levels. This is because of the fact that many of those who applied housing intervention as defined for the experiment, did so in period 1 and being a physical, more durable and non-consumable structure, it would be reflected in other periods. Only a few farmers had housing at levels 1 to 4 showing a few taking up housing after the initial period. One farmer in each of the regions 1 – 4 and 3 farmers in region 5 applied housing only once, which must mean the use of housing for the first time at period five. The proportion of farmers not using housing at all was large and as discernible as that of the farmers using housing all the time in each region. Regions 1 and 5 had the largest proportions in this category.

Having housing in all the five periods, implies that one had also housing treatment in period 1.

From Figure 1, 30% of all the farmers in the five regions had housing in period 1. Generally, only a quarter of farmers in the entire five regions did not have housing as a treatment in any period. This is a good reflection of the enthusiasm farmers had in taking up our interventions right from the beginning.

Housing intervention as a scientific technology was a familiar entity to the farmers although many of them had not felt the need to invest in it before. They easily understood from our training sessions its importance in reducing losses from vagaries of weather, theft, predation and infection by diseases. The application of housing was also easily affordable using locally available materials. Hence, the high frequencies at level 5 observed in all the five regions indicate early and sustained use by a large proportion of farmers. The reasons why some farmers did not use housing at all may be a reflection of their high level of poverty and hence they could not afford to invest in this activity. A majority of those who were able applied housing early in the project period.

The vaccination frequency distribution pattern is shown in Figure 1. The most frequent levels are 0, 1 and 2 in all regions except for region 5. There was hardly any vaccination at level 5. The zero level had a high frequency in regions 1 and 5. In general, most of the farms that had vaccinated had only done it once or twice. Regions 1 and 5 had the largest proportions of farmers (38 and 50% respectively) who did not vaccinate at any period. However, only about one quarter of farmers in all the five regions did not vaccinate at any period. This again is another good indication of the enthusiasm for participation in the project's activities by the farmers. Most vaccination was done on a group basis whereby farmers in a group jointly bought vaccine and shared doses. It is unlikely that individual farmers could have afforded to act independently due to the high cost and dosage packing of the vaccine.

The deworming pattern of levels of application shows a distribution with a peak in the middle with more farmers at levels 2 and 3 than at other levels in all the regions. There were only 3 farms (1 in region 2 and 2 in region 3) at level 5 overall. Hence, regular use of deworming was not frequently practised but the majority of the farms had dewormed at some period. Only a minority (10%) of the farmers in the entire five regions had not had deworming at any period at all. Deworming was done using anti-helminthic drugs easily available and cheap from local drug shops. Lack of application in every period was mainly because farmers were not able to discern or understand its importance in management of their flocks. However, this usage was a good indication of farmers' willingness to try out new formal ideas they learned from our training sessions.

The feed supplementation frequency distribution on levels of application was skewed to the right with most of the farmers at level 3 and above in every region as shown by Figure 1. There was generally an upward trend in the number of farmers from period 1 to 5. Almost all farmers had supplementation at least in one period. Close to a quarter of the farmers in each region applied supplementation in all five periods. Region 3 had the highest number of farmers at level 5 with more than half of them applying supplementation in every period. Application at levels 1 and 2 was by only a small number of farmers (only one farmer at level 2 while the other regions had between 4 and 5 farmers).

The second diagram describing the pattern of intervention uptake is shown by Fig 2 and provides a chronological summary of the numbers of farmers taking up the interventions on housing, vaccination, de-worming and feed supplementation in periods 1 to 5 and in each of the regions 1 to 5.

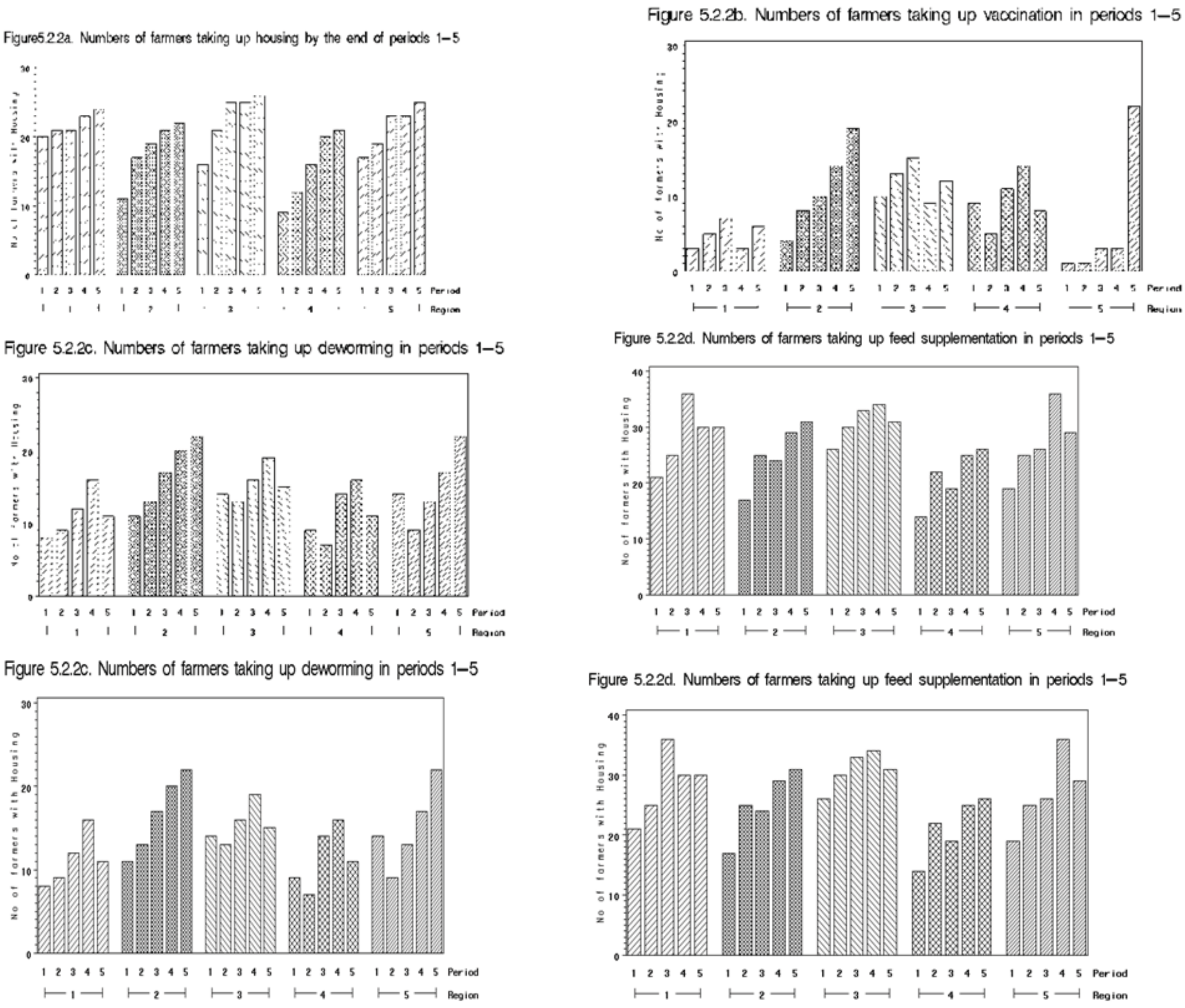

Figure 2. Pattern of interventions uptake in 5 periods in 5 regions

The housing pattern for the number of farmers, who applied in each period, shows an upward trend in all the 5 regions (Fig 2). Region 1 had more farmers with housing in periods 1 and 2 than the other regions with only regions 3 and 5 surpassing it in latter periods. Region 3 was similar to region 5 while region 2 was similar to region 4 in the number of farmers with housing. About 58% of farmers in the entire five regions had housing in 5 periods. The first diagram in Figure 1 showed that 30% of farmers had housing in period 1 hence the upward trend. Generally, the housing treatment was applied widely and frequently in all regions.

The time distribution pattern of the number of farmers using vaccination shows a general increase with period in all the regions. Regions 2, 3 and 4 had generally highest number of farmers doing the vaccinations. Generally, most application was in done in later periods 3, 4 and 5.

Period 5 in regions 2 and 5 recorded the largest number of applications with about 50% of farmers doing vaccination in period five. Close to 30% of the farmers did vaccination in period five in all five regions. Region 3 had almost the same number of applications in every period. However, the pattern of the vaccination uptake in region 5 was completely different from those in the other four regions with only a few farms having done vaccination in periods 1-4 while period 5 had a large number of farms vaccinating. This was probably due to a late realisation of its importance by the farmers but there was also an element of organised group vaccination at this period.

The pattern of the numbers of farmers taking up deworming treatment in Fig 2 shows that more farmers applied deworming in later periods giving an upward trend of the number of farmers deworming over the periods. About 25 percent of farmers had vaccination in period 1, and about 40% in period 5. Periods 3 – 5 generally seem to be the time most applications were done. Regions 1 and 4 had similar patterns and both had the least application rates generally.

The pattern for the number of farmers taking up feed supplementation at each period and in each region provided by Fig 2 shows there was a small upward trend in the number of farmers who supplemented their chicken flocks from period 1 to 5 in each region with period 1 registering at least 10 farmers. Region 4 had the least number of farmers in each period compared to the other regions. Close to 50% of farmers generally, had supplementation at each period.

The two sets of diagrams provide an understanding of the treatment application in terms of number of times it was done, period of application and number of farmers involved. They also provide information on important regional differences if any, on application of the treatments.

The feed supplementation and the housing interventions seemed to have been applied early in the study and in the rest of the later periods by majority of the farmers, although they have rather different patterns because housing has non-decreasing levels. There is little variation between periods in the take up of the two interventions. Similarly, there were little regional differences in these interventions though region 4 was low on both. These two treatments were applied by use of locally available resources and hence many farmers found it possible to take them up from the early periods across the regions.

Summaries of the total numbers of treatment applications and the average levels of treatment application in 5 regions, over the entire 5 periods are provided in Table 4 and Table 5 respectively. These summaries support the arguments presented about the treatment levels and number of farmers.

Table 4. Total numbers of treatment applications in regions 1 – 5.

Region	Treatment			
	Housing	Vaccination	Deworming	Feed Supplementation
1	109	24	56	142
2	90	55	83	126
3	113	59	77	154
4	78	47	57	106
5	107	30	75	135
Total	497	215	348	663
Proportion	50%	21%	35%	66%

Table 5. Average total level of treatment application in 5 periods in regions 1 – 5.

Region	Number of farms	Treatments[1] mean total values			
		Thse	Tvac	Tdwm	Tspl
1	37	2.8	0.7	1.4	3.9
2	33	2.7	1.7	2.5	3.8
3	33	3.1	1.6	2.1	4.4
4	26	2.6	1.6	2.0	3.7
5	40	2.6	0.7	1.9	3.4
standard deviation range		2.0 – 2.4	0.8 – 1.3	0.9 – 1.3	0.7 – 1.5

Treatments[1]:Thse = Total level of housing; Tvac= Total level of vaccination; Tdwm = Total level of deworming; Tspl = Total level of feed supplementation. Maximum level is 5.

So the understanding by farmers about some basic nutritional science and the fact that most of the required nutrients could be found among local materials, might have greatly influenced the observed response by farmers in the application of feed supplementation treatment.

In general terms, feed supplementation had not only a high level of use by all farmers in each period, but also a high number of farmers taking it up early in the study. This observation is an indication of positive farmer response to our prior training and sensitisation sessions, where emphasis was put on the importance of feed supplementation to meet birds' nutritional requirements using locally available feed resources. This was a feasible innovation for anyone who recognised inherent livelihood opportunities in the research process. Strict emphasis was particularly placed on the need to feed young chicks with high protein rich feedstuffs. So the understanding by farmers about some basic nutritional science and the fact that most of the required nutrients could be found among local materials, might have greatly influenced the observed response by farmers in the application of feed supplementation treatment.

The vaccination and deworming treatments tended to have more variation between periods and regions. The majority of farmers in regions 3 and 5 applied the two treatments in period 5.

The pattern in region 5 is very different from the other 4 regions for the vaccination, which differed mainly on the number of farmers. Vaccination in particular needed greater technical and monetary intervention than other treatments and was applied by farmers in different villages and regions at different periods of time.

Application of deworming had a resonance with that for vaccination in that both were generally done up to a total of 3 times, and in the later periods. This was due to the fact that this was 'new science' for most of the farmers and application of both treatments required investment in external inputs, which most farmers had difficulty affording early in the project. Most farmers seemed to have taken time also to understand and probably appreciate the importance of applying vaccination and deworming. With time, and because of persuasion from the research team, some farmers were able to take them up in later periods of the process. The deworming was particularly baffling to a majority of the farmers who had no prior knowledge of likelihood for infestation of their chicken flocks by internal worms and the implications for the flock's performance.

4. Conclusions

One of the objectives of the study was to have the farmers participate fully and actively in the research process as a novel approach to technology transfer. Such farmers would benefit directly from the research by appreciating its significance. They would also understand better what a technology entails and be able to apply the same within their personal circumstances and situations. There was also the hope that other non-participating farmers would be influenced by and learn from the farmers who were involved in the research. Looking at the patterns of distribution of levels of treatments uptake and the numbers of farmers applying a technology over the periods, a great deal has been done towards the achievement of the stated objectives. Farmer's enthusiasm in the research process was created and was a major driving force that helped to sustain the impetus.

Farmer participatory research can therefore be seen, from the perspective of the current study, to be a tool for technology testing and transfer at the very point it is needed and designed to support. This is a quick and effective means of generating and disseminating information. The weakness of the tool however, is that it is dependent on development of enthusiasm among its clientele and is difficult to control and minimise random variation for ease of statistical analysis and investigations. A hundred and seventy three farms out of the 200 originally selected had records on treatments and this to me is exciting as it is an indication of strong farmer participation in the research process through implementation activity. There were a similar number of farms across the regions (except in region 4, which had only half the original number of farms selected) which suggests little regional variation in support for these processes.

The use of available local resources enhanced early uptake of housing and supplementation by farmers. This point to the potential need for the provision of credit inputs to enable farmers to secure other resources required to implement project activities, particularly early on. Creation of enthusiasm and interest among target groups require strengthening their capacity to be able to undertake and implement project activities.

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References

Dolberg, F., (2008). Poultry production for livelihood improvement and poverty alleviation. O. Thieme and D Pillings, eds. Poultry in the 21st century: Avian influenza and beyond. Proceedings of International Poultry Conference held 5-7 November, Bangkok, FAO Animal Production and Health Proceedings, No. 9.

Fanworth, C., Sudell, M., Nzioki, A., Shivutse, V., & Dan, M. (2013). (eds).Transforming gender relations in agriculture in Sub-Saharan Africa. *Swedish International Agricultural Network Initiativ*e (SIAN), Stockhom Environmental Institute, Sweden.

FAO, (2008). Poultry in he 21st century: Avian influenza and beyond. O. Thieme and D Pillings eds. Proceedings of International Poultry Conference held 5 – 7 November, Bangkok, *FAO Animal Production and Health Proceedings, No. 9*. Rome FAO. (Available at ftp://ftp.fao.org/docrep/fao/011/i0323e/i0323e.pdf).

FAO, (2010). *Smallholderpoultyr production: Livelihoods, food security and socio-cultulral significance*. K. N. Kryger, K. A. Thonsen, M. A. Whyte and M. Dissing. (available at www.fao.org/docrep/013/al.674e/al674e00.pdf)

FAO, (2011). *Women in Agriculture: Closing the gender gap for development.* The state of food and agriculture, 2010-2011. FAO of UN, Rome, Italy. [Online] Available: http://www.fao.org/publication/sofa/2010-11/en.

Gonsalves, J., Becker, T., Braun, A., Camplan, D., Chavev, H., Fajber, E., Kapiriri, M., Rivacamirade, J., Vernooy, M. (edts) (2005). Participatory research and development for sustainable agriculture and natural resource management: A sourcebook Vol 1: Understanding research and development. International Potato Centre – Users' Perspectives with Agricultural Research and Development, Laguna, Philippines and International Development Research

Centre, Ottawa, Canada.

Gueye, E. F. (2000). The role of family poultry in poverty alleviation, food security and the promotion of gender equality in rural Africa. *Outlook on Agriculture. 29*(2), 129-136. http://dx.doi.org/10.5367/000000000101293130

Kitalyi, A. J. (1998). Village chicken production system in rural Africa: Household food security and gender issues. *FAO Animal Production and Health Paper, 142*. Rome, FAO. [Online] Available: ww.fao.org/docrep/003/w8989e/w8989e00.htm

Ndegwa, J. M., (1992a). Digestibility and Metabolic Energy determination of ground and unground sesame (Sesamum indicum) seeds in broiler diets. Msc Thesis, 1992, Wageningen Agricultural University, Wageningen, The Netherlands.

Ndegwa, J. M. (1992b). Use of sesame seeds (Sesamum indicum) in broiler feeds. Proceedings, IX World Poultry Congress - Young professionals program. October 1992. Amsterdam, The Netherlands.

Ndegwa, J. M., Mbugua, H. C. W.,Owango, M. O., & Mburu, B. M. (eds) (1994). *Proceedings of second Poultry Research Priority setting Workshop*. Naivasha, 15-16 November. Kenya Agricultural Research Institute.

Ndegwa, J. M., & Kimani, C. W., (1997). Rural poultry production in Kenya: Research and development strategies. In: Proceedings of 5th Kenya Agricultural Research Institute (KARI) scientific conference, October, 1996. KARI, Nairobi.

Ndegwa, J. M., Kimani, C. W., Siamba, D. N., Mburu, B. M., Mukisira, E. A., & de Jong, R., (1999). Characteristics of rural poultry production in different agroecological zones in Kenya. In Proceedings of the 6th biennial Kenya Agricultural Research Institute (KARI) scientific conference 9-13 November 1998, pp 540 - 547. Nairobi, Kenya. KARI.

Ndegwa, J. M., Norrish, P. Mead, R., Kimani, C. W., Wachira, A. M., (2000). A research process and methodology focusing on indigenous Kenyan chickens. A paper presented at the Symposium of the International Network for Family Poultry Development (INFPD) at the XXI World's Poultry Congress. 20 – 24 August, 2000. Montreal, Canada. [Onl;ine] Available: http//www.fao.org//ag/againfo/subjects/en/infd/documents/newsletters/Infd111.pdf and http://www.fao.org/docrep/019/aq634e/aq634e.pdf - The Bangladesh model and other experiences in family poultry development. International Network for Family Poultry Development (INFPD) May-July 2002.

Ndegwa, J. M., Norrish, P. Mead, R., Kimani, C. W., Wachira, A. M. (2001a). The growth performance of indigenous Kenyan chicken fed diets containing different levels of protein during rearing. *Tropical Ainamal Health and Production, 33*(5), 441-448. http://dx.doi.org/10.1023/A:1010552008639

Ndegwa, J. M., D. D. Shephered1, Norrish, P.1 Mead, R., Kimani, C. W., Wachira, A. M., Siamba D. N., & Githinji, M. M., (2001b). Participatory strategic approach to development of improved indigenous poultry systems in East Africa. A paper presented at the International

Development Conference, Rotorua, New Zealand, 2-6 April (2001). [Online] Available: http://www.fao.org/docrep/019/aq634e/aq634e.pdf - 'The Bangladesh model and other experiences in family poultry development'. International Network for Family Poultry Development (INFPD) May-July 2002 and published in Global Journal of Agricultural Research Vol 1 No 2 pp 14 – 28 also [Online] Available: (http://www.eajournals.org/journals/global-journal-of-agricultural-research-gjar/vol-1-issue-2-september-2013/)

Ndegwa, J. M, Norrish, P. Mead, R., Kimani, C. W., Wachira, A. M., (2002). Hatching characteristics of eggs artificially incubated from six reciprocal crosses of indigenous Kenyan chickens. *Tropical Agriculture* (Trinidad), Vol. 9 No 1.

Ndegwa, J. M, Norrish, P. Mead, R., Kimani, C. W., Wachira, A. M. (2005). Growth characteristics of indigenous chickens lines and a cross with Rhode Island Red in Kenya. Tropical Agriculture (Trinidad)) Vol 82 No 1

Ndegwa, J. M., (2006). Participatory research approaches in development of improved management practices in indigenous chicken production system with smallholder farmers in Kenya. PhD. Thesis, University of Reading, UK.

Ndegwa, J. M, Norrish, P. Mead, R., D. D. Shephered, Kimani, C. W., Wachira, A. M., (2012). Growth characteristics of six reciprocal crosses of Kenyan indigenous chickens Journal of Agricultural Science Vol 4 No.6.Pp 160-170.

http://dx.doi.org/10.5539/jas.v4n6p160

Ndegwa, J. M. (2013) (ed). Improving indigenous chicken production in Kenya – A livelihood strategy. LAP Lambert Academic Publishing https://www.lap-publishing.com/

Ndegwa, J. M, Norrish, P. Mead, R., D. D. Shephered, Kimani, C. W., Wachira, A. M., (2014). Investigating eggs hatchability in indigenous chicken system with smallholder farms in Kenya in a participatory research using analysis of variation. *Journal of Applied Biosciences 80*, 7000-7013. http://dx.doi.org/10.4314/jab.v80i1.6

Okali, C., Sumberg, J. and Farringto, J., (1994). Farmer participatory research. Rhetoric and reality. Intermediate Technology publications London, UK: Overseas Development Institute.

Okong'o, Kabuage, L., Mbugua, P. N. and Ndegwa, J. M., (1998). The effect of cooking grain amaranth (Amaranthus hypochodriacus) on its utilisation by broiler and indigenous chickens. In Proceedings of Rural Poultry Workshop. Kakamega, July 1998. Kenya

Pica-Ciamarra, V. and Dhawan, M. (2010). Small-scale poultry farming and poverty reduction in South Asia: From good good practices to good poilicies in Bangladesh, Bhutamn and India. New Delhi, South Asia pro-poor Livestock policy Programmes. [Online] Available: http//:sapplpp.org/lessonslearnt/smallscale-poultry-farming-and-poverty-reduction-in-south-asia)

SA PPLPP, (2011). Proceedings of the Workshop in Bangladesh on "Implementation of the National Livestock Development Policy (2007) and National Livestock Development Policy

(2008): Impact on Small-scale Livestock Rearers". [Online] Available: http//:sapplpp.org/files/repository/information-hub/workshop%20proceedings20%28Babgladesh%205thApril%202011.pdf.

Thieme, O., Sonaiya, E. B., Alders, R., Saleque M. A., & De Besi, C., (2014). Family poultyr development – Issues, Opportunities and Constraints. Animal Production and Health Working Paper No. 2. Rome (http//:www.fao.org/docrep/i019/i595e/i3595e.pdf).

Tuitoek, J. K., Chemjor, W., Ndegwa, J. M., & Ottaro, J. M., (1999). Morphological characteristics and protein requirements of indigenous Kenyan chicken. In Proceedings of the 6th biennial Kenya Agricultural Research Institute (KARI) scientific conference

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Extra-gonadal Sperm Reserve and Daily Sperm Production of Male Rabbits Fed Diets Supplemented with Cerium Oxide

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Abstract

In an 8-week feeding experiment, 32 growing buck rabbits (*Oryctolagus cuniculus*) of an average weight of 1366.56±37.54g, were used to assess the effects of inclusion of different dietary concentrations of Cerium oxide (CeO), a Rare Earth Element, at 0, 50, 100 and 150 ppm on fertility. The animals were randomly allotted to the four dietary groups, each consisting of eight animals per treatment. The Extra-gonadal Sperm Reserve (the sperm stored in the caput, corpus and cauda epididymis), the testes weights and the daily sperm production (DSP) were estimated. The results revealed that the extra-gonadal Sperm Reserves (ESR) were significantly ($P<0.05$) increased by dietary cerium oxide at 100 ppm inclusion. Sperm reserves were higher in bucks fed dietary cerium oxide compared with those fed control diet and the highest value recorded at 100 ppm level of inclusion. The results also showed that the testes weights and the daily sperm production (DSP) per testes of the buck rabbits were significantly ($P<0.05$) increased. The testes of the animals fed diets containing 50-150 ppm dietary cerium oxide had good and normal testicular generation and proper process of spermatogenesis. Therefore, feeding diets supplemented with cerium oxide to buck rabbits to be used for breeding would positively influence sperm production.

Keywords: Cerium oxide, Fertility, rabbits, Rare earth elements

1. Introduction

The ban of all antibiotic feed additives by the European Union in early 2006 necessitated a strong demand for new, efficient, safe and inexpensive feed additives which would better promote growth (Redling, 2006). Quite a number of feed additives are already known as replacements for antibiotics as feed additives but rare earth elements (REEs) might be the new generation of growth promoters.

Rare earth elements are the 15 lanthanide elements with atomic numbers 57 (lanthanum) through 71 (lutetium), which are in group III A of the periodic table. Chinese literature has reported amazing results achieved by supplying REE in animal diets (Redling, 2006).

The performance enhancement effects of REE supplemented diets could be achieved in a great variety of farm animals as well as in aquaculture (Xiong, 1995). It was reported that proper concentrations of REE in diet can improve animal growth performance without any form of interference with the quality of products (Adu, 2005, Redling, 2006 and Akinmuyisitan, 2015).

Moreover, it was reported that REE may also increase milk production in dairy cows and egg production in laying hens (Redling, 2006) and at the same time improved fertility in hens (Wu *et al.,* 1994). However, based on the results obtained from Western countries feeding experiments, the effects of dietary REE vary with the animal species. Concentration and type of rare earths as well as the compositions of individual rare earth elements have also been shown to be important factors influencing performance enhancing effects of REE on animals (He *et al*., 2003; 2006; Redling, 2006). Also, it is generally agreed that the efficiency of growth- promoting agents highly correlates with keeping, housing, hygiene and feeding conditions (Wenk, 2004) as well as the genetic variations in animals. This might lead to differences in enzyme activities and keeping conditions, which may affect the composition of microbial populations within the gastrointestinal tract (Redling, 2006). Not only the effectiveness but also the safety of REE application has been assessed in China, prior to their commercial utilization (Wenk, 2004).

This study was designed to investigate the effects of different concentrations of dietary rare earth element (Cerium oxide) on the extra-gonadal sperm reserve and daily sperm production of male rabbits in male rabbits.

2. Materials and Methods

2.1 Experimental Site and Animals

The study was carried out at the Rabbit unit of the Teaching and Research Farm of the Federal University of Technology, Akure, Nigeria.

Thirty-two growing male rabbits of about 3 months old (12 weeks) of an average weight of 1366.56±37.54g were used and individually housed in wire-meshed cages in an in-door pen and were fed *ad libitum* at 0800 and 1600 hr for two weeks of physiological adjustment period. Kepromec Oral (Ivermectin®) manufactured by Kepro, B.V. of Holland was administered through drinking water against potential ecto- and endo-parasites for two days at recommended dosage by the manufacturer before the commencement of the study. The procedures for the experiment was approved by the institution's animal care and use committee.

2.2 Experimental Diets

Four experimental diets were formulated: control (diet 1) with non-inclusion of REE, diets 2, 3 and 4 had 50, 100 and 150 ppm inclusion of REE (Cerium oxide) respectively, as shown in Table 1. The animals were randomly assigned into one of the four diets (eight per treatment) after the 2 weeks of physiological adjustment period. The diets were isocaloric, isonitrogenous and satisfied the nutrient requirements of the animals as recommended by National Research Council (NRC, 1998). The bucks were provided with fresh, clean water and appropriate feed throughout the feeding period.

Table 1. Gross composition (%) of growing rabbit test diets

	Diet 1	Diet 2	Diet 3	Diet 4
Ingredients	**Control**	50 mg CeO	100 mg CeO	150 mg CeO
Maize	32.10	32.10	32.10	32.10
Wheat offal	41.80	41.80	41.80	41.80
Ground nut cake	3.50	3.50	3.50	3.50
Palm kernel cake	20.00	20.00	20.00	20.00
Oyster shell	1.50	1.50	1.50	1.50
Bone meal	0.25	0.25	0.25	0.25
Lysine	0.15	0.15	0.15	0.15
Methionine	0.05	0.05	0.05	0.05
Vitamin Premix	0.20	0.20	0.20	0.20
Salt	0.45	0.45	0.45	0.45
Cerium oxide (ppm)	-	50	100	150
Calculated Nutrient				
Crude Fibre (%)	10.83	10.83	10.83	10.83
Crude Protein (%)	10.38	10.38	10.38	10.38
ME* (MJ/kg)	2906	2906	2906	2906
Ether Extract	4.52	4.52	4.52	4.52

ME*: Metabolisable Energy

2.3 Determination of Testicular and Epididymal Sperm Reserve

At puberty, all the experimental rabbits were slaughtered and their reproductive systems were carefully dissected, trimming off adhering tissues; the testes and the epididymis were carefully collected and weighed using a sensitive electronic balance. A portion of the right testes, whole left testes and the epididymis were homogenized and separated with a blender in 0.154MNaCl (physiological saline) at the rate of 10ml/g testes. The suspensions were then mixed and sieved through a double layer of sterile gauze into clean glass test tubes and the sperm concentrations therein were determined by direct haemocytometric count after proper dilution (1:39, v/v) in 0.154 NaCl (Egbunike *et al.,* 1975; Adu and Egbunike, 2010).

2.4 Estimation of Daily Sperm Production

The daily sperm production (DSP) was estimated from the gonadal sperm reserves. The estimation of DSP from testicular homogenates is based on the fact that the nuclei of elongating spermatids are resistant to physical destruction at some point during spermatogenesis. The DSP of the bucks were calculated with the formula proposed by Amann (1970) as follows:

DSP = <u>Testicularsperm count</u>

Time divisor (3.43)

Where 3.43 is a constant divisor for rabbit in calculating DSP (Adu and Egbunike, 2010)

Statistical analyses

The design used for this experiment was Completely Randomized Design (CRD). Collected data were subjected to statistical analysis using ANOVA procedure of SAS (2008). The significant treatments were compared using Duncan's multiple range test of the same software.

3. Results

3.1 Extra-Gonadal Sperm Reserve

The extra-gonadal sperm reserve of bucks fed varied levels of dietary cerium oxide is as shown in Table 2. The testicular weight, epididymal weights and extra-gonadal sperm storage potentials of the rabbits were influenced ($P<0.05$) significantly in this study. The table showed that the extra-gonadal sperm reserves of the bucks were significantly ($P<0.05$) influenced by varied levels of dietary cerium oxide. It was observed that the sperm reserve in the left testes was higher than that of the right testes.

All the parameters determined were also significantly ($P<0.05$) influenced except the weight of the right cauda. Sperm reserves in the left, right and paired testes increased significantly ($P<0.05$) at 100 ppm level of inclusion (diets 3). The values ranged between 1.37-1.70/g for the right testis, 1.57-1.78/g for the left testis and 2.94 - 3.48/g for the paired testis as against 1.35, 1.43 and 2.78/g in control diet for the right, left and paired testis respectively. For the right and total caput sperm reserve, there was significant improvement with the values ranging between 1.92 - 2.11×10^9 for the right caput, 3.98-4.45×10^9 for total caput compared with 1.76 and 3.71×10^9 in control diets for the right and total caput respectively and the highest values observed at 100 ppm level of cerium oxide inclusion. For the left caput, the level of significance was at 100 and 150 ppm levels of inclusion with the values 2.34 and 2.19×10^9, respectively compared with 1.95×10^9 for control diet.

The sperm reserve in the corpus was significantly influenced and the values ranged between 3.44 -3.97×10^9 for the left corpus, 6.64-7.67×10^9 for total corpus as against 3.47 and 6.76×10^9 in control diets for the left and total corpus respectively; the level of significance was also at 100 ppm level of cerium oxide inclusion (diet 3) while that of the right corpus ranged from 3.20 - 3.70×10^9 and the highest value was observed at 100 ppm level of cerium oxide inclusion.

The cauda sperm reserve was similar across the dietary treatments and the highest values were at 100 ppm level of cerium oxide inclusion. The total epididymal weight was significantly ($P<0.05$) higher in bucks fed 100 ppm dietary cerium oxide (diets 3) compared with the control diet.

It was observed that the sperm reserves were higher in bucks fed dietary cerium oxide compared with those fed control diet and the highest value recorded at 100 ppm level of inclusion of dietary cerium oxide throughout, in all the parameters determined.

Table 2. Extra-Gonadal sperm reserve ($\times 10^9$) of bucks fed dietary cerium oxide

	Diet 1	Diet 2	Diet 3	Diet 4	±SEM
Parameters	Control	50 ppm	100 ppm	150 ppm	
Right (/g testis)	1.35^b	1.42^b	1.70^a	1.37^b	0.12
Left (/g testis)	1.43^b	1.61^{ab}	1.78^a	1.57^{ab}	0.19
Paired (/g testis)	2.78^b	3.03^b	3.48^a	2.94^b	0.29
Right (/testis)	2.17^c	2.57^{ab}	2.74^a	2.39^b	0.14
Left (/testis)	2.41^b	2.69^a	2.83^a	2.58^{ab}	0.16
Paired (/testis)	4.61^c	5.26^{ab}	5.57^a	4.97^{bc}	0.27
Right caput	1.76^c	1.94^b	2.11^a	1.92^b	0.09
Left caput	1.95^b	2.04^b	2.34^a	2.19^a	0.10
Total caput	3.71^c	3.98^b	4.45^a	4.11^b	0.17
Right corpus	3.29^b	3.63^a	3.70^a	3.20^b	0.15
Left corpus	3.47^b	3.57^b	3.97^a	3.44^b	0.23
Total corpus	6.76^{bc}	7.20^b	7.67^a	6.64^c	0.29
Right cauda	2.29	2.47	2.60	2.25	0.22
Left cauda	2.57^{ab}	2.76^{ab}	2.91^a	2.48^b	0.24
Total cauda	4.86^{ab}	5.23^{ab}	5.51^a	4.74^b	0.46
Total epididymal	15.33^b	16.40^{ab}	17.63^a	15.49^{ab}	0.56

abc: Means on same row with different superscripts differ significantly ($P<0.05$)

SEM- Standard Error of Mean

3.2 Testicular Weights and the Daily Sperm Production

Table 3 shows the testicular weights and the daily sperm production (DSP) of buck rabbits fed varied levels of dietary cerium oxide. The testicular weights (right and paired testes) increased ($P<0.05$) significantly at 50 ppm concentration of cerium oxide compared with the control diet except that of the left testis that was not influenced ($P>0.05$) significantly. The weights of the right and paired testes of buck rabbits fed dietary cerium oxide were higher than the control and the weights of the right testes ranged between 1.86-2.23 g across the dietary treatment as against 1.81g for control diet while the weights of the paired testes ranged from 4.00 - 4.67 g for diets 2 – 4 compared with 3.89 g for control diet.

The results also showed that DSP per testes of the buck rabbits were significantly ($P<0.05$) increased at 100 ppm level of inclusion of cerium oxide. The daily sperm production in the right testis ranged from 0.41 - 0.51($\times 10^7$), 0.47 - 0.53($\times 10^7$) for the left testis and 0.87-1.03 ($\times 10^7$) for the paired testis compared with 0.40, 0.42 and 0.82 ($\times 10^7$) for the control diet respectively.

Table 3. Daily sperm production of bucks fed varied levels of dietary cerium oxide

	Diet 1	Diet 2	Diet 3	Diet 4	
Parameters	Control	50 ppm	100 ppm	150 ppm	±SEM
Weight (g)					
Left testis	2.09	2.44	2.12	2.14	0.22
Right testis	1.81^{b}	2.23^{a}	1.90^{ab}	1.86^{ab}	0.24
Paired testis	3.89^{b}	4.67^{a}	4.01^{ab}	4.00^{ab}	0.45
Daily Sperm Production					
Right ($x10^7$/g testis)	0.40^{b}	0.42^{b}	0.51^{a}	0.41^{b}	0.03
Left ($x10^7$/g testis)	0.42^{b}	0.48^{ab}	0.53^{a}	0.47^{ab}	0.06
Paired ($x10^7$/g testis)	0.82^{b}	0.90^{b}	1.03^{a}	0.87^{b}	0.09
Right ($x10^9$/testis)	0.64^{c}	0.76^{ab}	0.81^{a}	0.71^{b}	0.04
Left ($x10^9$/testis)	0.72^{b}	0.80^{a}	0.84^{a}	0.76^{ab}	0.05
Paired ($x10^9$/testis)	1.36^{c}	1.56^{ab}	1.65^{a}	1.47^{bc}	0.08

abc: Means on same row with different superscripts differ significantly ($P<0.05$)

SEM- Standard Error of Mean

4. Discussion

The result of this study is in line with the report of Wu *et al.* (1994) that reported an improvement in fertility of hens fed dietary REEs and Shao *et al.* (1998) that reported that REE had significant positive effect on embryo development of carp. This is an indication of possible interaction of dietary rare earth element with the hormones of reproduction. The increase in testes weight observed in this study confirms the possible impacts of REE on sperm production. This is line with the assumptions of Amman (1970) and Møller (1989) that increase in relative testis size reflects increased investment in sperm production, since there is evidence of correlation between testis size and the number of sperm produced per unit time and the report of Møller (1989) that testicle size is a good indication of sperm producing ability. Gage and Freckleton (2003) also described the mammalian testes as infallible predictors of spermatozoa production. The increase in DSP observed in rabbits fed diets 2, 3, and 4 over the control diet is an indication that cerium oxide influenced spermatogenesis positively. This is a pointer to possible effects of REE on hormones primarily involved in sperm production such as the follicle stimulating hormones, luteinizing hormone and testosterone.

ESR represents the sperm stored in the caput, corpus and cauda epididymis. Egbunike and Elemo (1978) reported a close relationship between organ weight and sperm reserve. The significantly higher ESR and the testicular weights of the rabbits fed diets supplemented with cerium oxide may be attributed to the influence of dietary cerium oxide on sperm production in rabbits, as sperm production and storage are related (Egbunike and Elemo, 1978).

It can be concluded that dietary REE is capable of enhancing fertility in rabbits by significantly increasing the extra-gonadal sperm reserve as well as the daily sperm production at 100 ppm and testes weight at 50 ppm. Ji *et al*. (1985) found no increase in chromosome abberation rates of marrow cells after oral application, but, when compared to low doses at high doses, chromosomal translocation of the spermatocytes increased significantly.

This study revealed that the testes of animals fed diets containing 50-150 ppm cerium oxide have good and normal testicular generation and proper process of spermatogenesis.

Therefore, this study has clearly demonstrated that feeding diets supplemented with cerium oxide to buck rabbits to be used for breeding would positively influence sperm production.

References

Adu, O. A. (2005). Performance enhancing effect of Rare Earth Elements in growing rabbits. *Tropical Animal Production Investigations, 7 (1)*: 93-98

Adu, O. A. & Egbunike, G. N. (2005). Spermatogenesis and daily sperm production of rabbits fed diets with different levels of copper sulphate. *Journal of Agriculture, Forestry and Social Sciences, 3*(2), 126-131.

Adu, O. A. & Egbunike, G. N. (2010). Semen quality, Fertility and Reproductive organ weights of pubertal Boars fed dietary copper. *Journal of Applied Agricultural Research. 2*, 61-67.

Akinmuyisitan, I. W., Gbore, F. A., & Adu, O. A. (2015). Reproductive Performance of Growing Female Rabbits (*Oryctolagus Cuniculus*) fed diets supplemented with Cerium Oxide. *Journal of Medical and Bioengineering. 4 (3)*, pp. 239-243

Amann, R. P. (1970). Sperm production rates. In The testis, vol. 1 (eds Johnson A. D., Gomes W. R., Vandemark N. L.), pp. 433-482. New York, NY: Academic Press. http://dx.doi.org/10.1016/b978-0-12-386601-1.50013-5

Egbunike, G. N., Holtz, W., & Smidt, D. (1975). Reproductive capacity of German improve boars. Gonadal and extra-gonadal sperm reserves. *Zuchthygiene*. *10*:184-191. http://dx.doi.org/10.1111/j.1439-0531.1975.tb00301.x

Egbunike, G. N., & Elemo, A. O. (1978). Testicular and epididymal sperm reserves of crossbreed European boars raised and maintained in the humid tropics .*J. reprod. Fert*. *54*. 245-248.

Gage M. J. G., & Freckleton, R. P. (2003). Relative testis size and sperm morphometry across mammals: no evidence for an association between sperm competition and sperm length. *Proc. R. Soc. Lond. B* 270*,* 625-632. http://dx.doi.org/10.1098/rspb.2002.2258

Ji Y, Cui M, Wang Y., & Zhang X (1985). Toxicological study on safety evaluation of rare earth elements used in agriculture. In *Xu G and Xiao J. (Eds.)* New frontiers in rare earth science and applications. *Proceedings of the 1st International conference on rare earth development and applications*. Beijing, September 10-14. pp. 700-704, Science Press, Beijing

He, M. L., Wang, Y. Z., Xu, Z. R., Chen, M. L., & Rambeck, W. A. (2003). Effect of dietary rare earth elements on growth performance and blood parameters of rats. *Journal of Animal Physiology and Animal Nutrition*, *87*, 229-235.

He, M. L., Wehr, U., & Rambeck, W. A. (2006). Oral administration of a low dose of rare earth elements improved the performance of broilers. *J. Anim Phys. Anim. Nutr*. 153-243. http://dx.doi.org/10.1046/j.1439-0396.2003.00432.x

Møller, A. P. (1989). Ejaculate quality, testes size and sperm production in mammals. *Funct. Ecol. 3,* 91-96. http://dx.doi.org/10.2307/2389679

National Reasearch Council, (1998). Nutrient requirements of domestic animals. *In: Nutrient requirements of rabbits* (9^{th} Ed). National Academy of Sciences. Washington. DC.

Redling, K. (2006). Rare earth elements in agriculture with emphasis on animal husbandry. *Diss. Ludwig-Maximilians-Universität, München.*

SAS Institute Inc. (2008). SAS / STAT User's Guide.Version 9.2 for Windows.SAS InstituteInc; SAS Campus Drive. Carry, North Carolina, U.S.A.

Shao, H., Liu, H., Jiang, Z., Zong, Z. & Liu, W. (1998). Effect of Rare Earth Elements on egg embryo development of carp. *Fresh Water Fishery*, *28*(4), 20-21

Wenk, C. (2004). *Erwartungen und Möglichkeiten von Pflanzenextrakten in der Schweineernährung. In Schweinehaltung, 04.255, Sursee/Oberkirch, Schweiz*. pp. 24

Wu, J., Zhang, Z., & Yan, J. (1994) An initial study on effect of adding rare earth element on productivity of egg laying breeder hens,"Ning Xia Sci. Technol. *Farming Forest, 4*. 36-38.

Xiong, B. K. (1995). Application of Rare Earths in Chinese Agriculture and their perspectives of Development. In *Proceeding of the Rare Earths in Agriculture Seminar, 20. September*, pages 5-9, Canberra, ACT Australia.

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Cuba's Agricultural Transformations

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Abstract

The Cuban government has implemented a series of agricultural transformations since 2007 to increase the country's agricultural self-sufficiency and reduce its dependency on food imports. These include the transfer (in usufruct) of State-owned land to non-State producers (e.g. cooperatives and private farmers), moderate price reforms, the decentralization of decision making, and the gradual relaxation of existing forms of agricultural commercialization. As a result of these measures, the area planted, as well as physical output and agricultural yields (in selected non-sugar crop categories) have shown mixed results, but still remain below desired levels. There are three (3) fundamental unresolved aspects that have prevented Cuba's agricultural sector from achieving the desired outcomes: (1) the need to achieve the "realization of property," (2) the recognition and acceptance of the market as a complementary economic coordination mechanism, and (3) the absence of a systemic focus to achieve the successful completion of the agricultural production cycle. These unresolved aspects should be addressed through: (1) the consolidation of input markets, where producers can obtain essential inputs at prices that correspond to the prices they can

obtain for their output, (2) greater autonomy to allow agricultural producers to freely decide when, where, and to whom they could sell their output, after social contracts have been fulfilled, (3) the diversification of the forms of agricultural commercialization to permit greater participation by non-State economic actors, (4) allowing agricultural producers to freely hire the labor necessary to sustain and increase production, and (5) providing agricultural producers with the financing and technical assistance necessary.

Keywords: Agricultural transformations, Cuba, Cuban agriculture.

JEL Classifications: P15, P20, Q15, Q18.

1. Introduction

In its recent efforts to transform (or "update") its economic model, Cuba has understandably focused on its agricultural sector. Even though it only accounts for approximately 5% of gross domestic product (GDP), agriculture represents a relatively large share of the Cuban economy (some 20%) due to its direct linkages with other sectors and multiplier effect (Nova González, 2006, 2013a, 2013b). Despite of the expansion of tourism and services, Cuba still remains an agricultural country, and agriculture touches every aspect of the country's economic and social life.

The agricultural sector plays an important role in the Cuban economy due to various factors. First, an important group of industries or sectors, such as sugar (including derivative products), food, tobacco and beverages, which account for approximately 6.5% of the country's GDP, depend heavily on the raw materials or inputs supplied by the agricultural sector. Second, related activities, such as the transportation and commercialization of agricultural products, and food processing, which account for about 10% of GDP, are also dependent on the agricultural sector (Nova González, 2008). In total, close to 20% of Cuba's GDP is directly or indirectly related to the agricultural sector (Nova González, 2013b).

Cuba's agricultural sector also plays an important role as a source of employment; approximately 21% of the country's economically active population works in agriculture. If related activities, such the transportation, storage, and commercialization of agricultural products, are included, the agricultural sector's share of total employment increases significantly (Nova González, 2014). Close to 4 million Cubans, or 80% of the labor force, is either directly or indirectly related to agriculture (in terms of employment and economic activities) (Nova González, 2008).

The agricultural sector also plays an important role as a supplier of renewable energy (Nova González, 2008). This is primarily accomplished through generation of electricity, biofuels, and biogas produced by the sugar agro-industry. Sugarcane plantations can absorb carbon dioxide (CO_2) and emit oxygen (O_2). It is estimated that over the course of one year a hectare planted with sugarcane can absorb about 60 tons of carbon dioxide (CO_2) and emit approximately 40 tons of oxygen (O_2), resulting in the so-called "forest effect" (Nova González, 2008).

Finally, as a consumer of raw materials, intermediate capital goods, and finished products, Cuba's agricultural sector has strong linkages with almost every sector of the economy. These linkages, and high levels of coordination and integration, contribute to the aforementioned multiplier effect (of the agricultural sector) and to its positive spillovers, magnifying the economic and strategic importance of agriculture in the Cuban economy.

Since the collapse of the Socialist Bloc and the disintegration of the Soviet Union in the early 1990s, Cuba's agricultural sector has been affected by declining output levels, low labor productivity, worker absenteeism, insufficient administrative coordination, excessive bureaucratic controls, and increasing de-capitalization caused by shortages of investment and foreign exchange receipts (Hagelberg, 2010; Spadoni, 2014). Cuban agriculture has also been impacted by adverse weather conditions, particularly several devastating hurricanes and a severe drought (2006-2008) and the effects of the U.S. trade embargo (González-Corzo, Mesa-Lago, 2012; 2013; Nova González, 2013; Spadoni, 2014).

After Raul Castro's official ascent to power on February 24, 2008, a series of policy measures have been implemented to prioritize and reactivate this vital sector of the Cuban economy. The most significant include: the approval of Decree Law No. 259 in 2008, which facilitates the transfers of idle State-owned lands to private producers and agricultural cooperatives, the transfer of some of the functions performed by the Ministry of Agriculture (MINAGRI) to the Ministry of Interior Trade (MINCIN), the creation of a limited number of State-operated establishments to sell basic agricultural inputs (e.g., seeds, fertilizer, work gloves, machetes, axes, etc.) to small agricultural producers, experiments with "suburban agriculture" to connect local producers and consumers and reduce fuel, transportation and storage costs, and increases in the prices paid by *Acopio*, the State-run agricultural procurement agency, to private farmers and cooperatives producing milk, beans, rice, and other products.

This paper analyzes Cuba's agricultural transformations since the process of "updating" its socialist economic model was initiated in 2007. The first section presents a detailed account of the principal agricultural reform measures implemented from the inception of the "economic updating" process. This is followed by a comprehensive analysis of the structure and performance of Cuba's non-sugar agricultural sector, with a particular emphasis on key metrics such as planted areas and areas under production, physical output, and agricultural yields. Finally, the last section explores the principal elements of Cuba's emerging agricultural model and its prospects for the future.

2. Agricultural Transformations (2007 – Present)

Falling agricultural output, low yields, declining labor productivity, high levels of waste and inefficiency, the rising costs of food imports, and the deterioration of the trade balance, have placed food production at the forefront of the economic challenges confronting Cuba at the present time (Hagelberg, 2010). According to official statistics, Cuba spent $2.0 billion on imported food and agricultural products in 2013, representing 13.6% of the country's total merchandise imports for that year (Oficina Nacional de Estadísticas e Información, 2014). As it experienced the worst economic crisis since the collapse of the Eastern European Socialist Bloc and the disintegration of the Soviet Union in the early 1990s, and confronted with a more favorable international environment, mainly as the result of its close economic ties with Venezuela, China, and Canada, and its extended diplomatic relations with virtually every country in the Western Hemisphere and other regions of the world, Cuba has implemented a series of policy measures to transform its agricultural sector.

One of the first steps taken in this direction consisted of paying higher prices to producers of certain agricultural products. This process was initiated in 2007, when the State procurement agency, *Acopio*, increased the prices it paid milk producers as well as the percentage paid in convertible pesos (CUC) per liter produced and delivered. In 2007, the State increased the prices that its procurement agency, *Acopio*, paid to agricultural producers for a selected group of products. Rice prices, for example, increased from 1,931 Cuban pesos (CUP) per ton in 2007 to 6,304 CUP by the end of 2013 (Spadoni, 2014). Similarly, the price paid by *Acopio* to agricultural producers for potatoes rose from 544 pesos per ton to 652 pesos per ton between 2007 and 2013 (Spadoni, 2014); and the prices paid to milk and beef producers increased from 900 pesos per ton to 5,218 pesos per ton, and from 2,450 pesos per ton to 8,900 pesos per ton, respectively, during the same period (Spadoni, 2014). Higher prices have incentivized agricultural producers to improved their output deliveries (or sales) to *Acopio*, resulting in notable fuel savings and improved distribution to the State-operated retail store network (Nova González, 2010).

The resulting increase in producers' incomes resulting from this measure increased producers' capacity to obtain essential inputs to further increase production. (Nova González, 2010). These price increases allowed *Acopio* to recover a part of this production, which previously had other destinations and producers have been encouraged to sell their product to *Acopio*. This measure constitutes a direct stimulus to producers, and incentivizes them to indirectly contribute to certain savings in fuel and loss reductions because of timely deliveries made to *Acopio*. This procedure has been implemented in 89 municipalities, of which 66 are fully self-sufficient. However, it has resulted in certain unintended consequences, which have contributed to reductions in deliveries to industry, resulting in the under-utilization of the country's industrial capacity (Nova González, 2010)

Acopio also increased the prices it pays to meat and poultry producers. Payments in convertible pesos (CUC) to meat and poultry producers have increased their purchasing power, allowing many of them to obtain essential agricultural inputs in recently-created hard currency stores for this purpose (there are stores in 70 of the 168 existing municipalities). Unfortunately, these stores tend to offer a limited variety of inputs of about 64 products, supply has been unpredictable and unreliable, and prices tend to be relatively high.

The second significant policy measure implemented to transform Cuba's non-sugar agricultural sector was the transfer of idle State-owned land to cooperatives and individual producers after the approval of Decree-Law 259 in July 2008. The implementation of this measure is somewhat paradoxical since there is a significant amount of idle lands (1,758, 962 hectares), a valuable human capital, a significant number of research centers and experimental stations, with proven results, and available technology, but since the collapse of the Soviet Union and the disintegration of the Socialist Camp in the early 1990s, the Cuban economy has been forced to import significant volumes of food, many of which can be produced domestically under more favorable conditions.

Decree-Law 259 clarifies important aspects of Cuba's most recent "agrarian reform," the conditions of *usufruct* under which idle State-owned lands will be transferred to cooperatives and individual producers, the terms of economic ownership related to this property form, and its relation to legal ownership (Nova González, 2010). It also helps to clarify important aspects, which until recently, remained unclear or undefined such as the period of time for which the *usufruct* is established, which helps define its economic ownership and legal ownership, and the collection of taxes and rents by the State.

In addition, the Decree-Law 259 incorporates some elements that were not taken into consideration in previous agricultural reform measures, such as the duration of transfers to natural persons (10 years, renewable leases, regardless of the type of crop harvested), and the transfers of land to legal entities such as cooperatives (Nova González, 2010). One interesting feature that distinguishes Decree Law 259 from previous legislation is that the terms of the *usufruct,* or lease agreements, are standardized for specific periods regardless of the types of crops produced, the modes of production used to generate this output, and whether or not the crops are considered short-cycle or long-cycle, and the type of livestock raised by producers (Nova González, 2010).

The degree of investment intensity related to agricultural production varies according to the type of crop produced, or the type of livestock raised. Some products and forms of livestock are more labor and capital intensive than others, and due to their seasonal nature require different quantities of labor and physical and financial capital Pursuant to Article 15 (of Decree Law 259), once finalized, the terms of the *usufruct* allow producers to receive payment or compensation from the State for *bienhechurias*, or infrastructure or physical improvements to the land and facilities used for production, with the exception of housing built by individual producers or cooperatives. This constraint or limit provides a distorted incentive to make the minimum investment required, prevents the agricultural producers permanently settling in their newly acquired lands (leased from the State), and explains why most of them despite the positive advances made by Decree Law 259, consider themselves as transient (non-permanent) producers. In reality, as Nova González (2009, 2010) indicates, the successful transformation of Cuba's agricultural sector requires the *recampesinización*, or the re-population of the countryside; without significant and long-lasting increases in the quantity of farmers, technicians, and administrative and managerial personnel dedicated to agriculture, there is no guarantee and stability of a sustainable agricultural production (Nova González, 2009, 2010).

Cuba's newly decentralized agricultural model must recognize that agricultural producers require certain facilities to store and preserve the essential inputs, animals, seeds, supplies, and equipment, among others. To stimulate the migration of labor from other areas of the economy into agriculture, policies that provide economic incentives for investment in physical infrastructure and promote long-term commitments to agriculture are being contemplated. To ensure the success of this decentralized model of agricultural production, where regional and local producers are expected to develop strong linkages with the land in which they work, and consumers and suppliers in their respective "markets," producers and administrative and managerial personnel need to live near or on the locations where production takes, a sense of permanence and consistency must be encouraged and developed, and the linkages between producers and the lands in which production takes place must be strengthened over time (Nova González, 2010).

By the end of 2009, some 920,000 hectares of idle State-owned lands had been transferred to more than 100,000 applicants, representing 52% of the total (Nova González, 2010). Until January 2010, there had been 121,711 applications, of which 98% are natural persons, of which approximately 79% were previously landless (Nova González, 2010). At the present time, it is estimated that 35% of the land delivered has been planted or cultivated (Nova González, 2010). Considering the original conditions of the majority of this land, and the wide range of challenges, constraints, and difficulties that non-State agricultural producers still face, this is indeed a remarkable accomplishment.

Yet, despite the notable increases in the number of applications from both cooperatives and individual producers, the transfer of idle State-owned lands to non-State producers has been characterized by a series of bureaucratic hurdles and impediments, which still present serious difficulties. According to the provisions of Decree Law 282, nine (9) documents are required for processing of application for the transfer of land in *usufruct* (Nova González, 2010). To file a complaint or appeal, applicants are required to complete and submit thirteen (13) documents, and from the time the applicant files the application for the transfer of land with the municipal director of the *Centro Nacional del Control de la Tierra* (National Center for Land Control), the office has thirty (30) days to review the application, and draft or prepare the required documentation, and up to sixty (60) days to conduct the necessary surveys and medical examinations of the livestock to be transferred from State ownership to the non-State sector (Nova González, 2010).Once the necessary documents are drawn, the municipal director of the National Center for Land Control presents them to the municipal delegate of agriculture in the term of three (3) days, and the latter has thirty (30) days to review and approval of grant of the requested transfer in *usufruct* or requested (Nova González, 2010).

Theoretically, it can take at least sixty-three (63) days, from the beginning of the application to lease idle lands or livestock from the State for a predetermined period of time, under the conditions previously described, until the formal documents are approved and issued, assuming that process transpires normally and does not require additional field surveys or measurements, and other bureaucratic steps or procedures. In such cases, the time needed to clear existing bureaucratic hurdles and effectively transfer the land or livestock from the State to the cooperative or private sectors can theoretically take ninety-three (93) days or even longer.

Another important measure in Cuba's road towards a more flexible and decentralized agricultural model was the transfer of the collection activities, assigned to the State-owned procurement agency, *Acopio,* to the Ministry of Domestic Trade (*Ministerio del Comercio Interior*, MINCIN). For many experts in Cuban agriculture, this is considered as a road already traveled. In 1976, procurement was transferred from the Ministry of Agriculture (*Ministerio de la Agricultura,* MINAGRI), but then returned to it after the "Rectification Process" (RP) in 1986. Transferring *Acopio's* functions to the MINAGRI would be a more logical and appropriate step to improve the operational and administrative efficiency of Cuba's cumbersome system of agricultural procurement (Nova González, 2010).

At the present time, Cuba's agricultural procurement and marketing system is hindered by a highly regulated market, the distortions related to monetary dualism, and insufficient output, particularly by the cooperative sector (which includes the *Unidades Básicas de Producción Cooperativa*, UBPCs, and the *Cooperativas de Producción Agropecuaria*, CPAs). Despite recent efforts, the marketing function, which includes the distribution and exchange of agricultural products, is characterized by delayed payments, insufficient collection capacity on the part of *Acopio*, and the lack of material incentives and credit financing to stimulate and incentivize production (Nova González, 2010).

Another key measure in the transformation of Cuba's non-sugar agricultural sector has been the decentralization and the restructuring of the functions of the ministries responsible for the administration, implementation, and oversight of the country's agricultural policies. The municipality as an increasingly autonomous economic unit is as the center of this new strategy. The newly-considered model of decentralized decision making identifies the municipality as the principal actor responsible for making rational economic decisions and implementing the required strategies within its territorial boundaries. At the present time, each municipality has established a Municipal Delegation of agriculture (169 in total), which is primarily responsible for managing the transfers of idle State-owned lands and State-owned livestock to the non-State sector, to promote and stimulate the development of three (3) "core" modalities of production: (1) urban agriculture, (2) suburban agriculture, which covers a span of about 10 km from the periphery of cities and urban centers, and (3) and productive or conventional poles (Nova González, 2010). During the testing phase of this model in 2010, the MINAG selected 16 municipalities plus the special municipality of *Isla de la Juventud*, a total of 17, to carry across the combination of these three scenarios. Participation was extended to all the entities that produce food in the municipality, whether or not under the responsibility of the Ministry of Agriculture (UBPCs, CCS, CPAs, State-owned farms, etc.) (Nova González, 2010).

In addition, the Ministry of the Economy and Planning (MEP) has also selected five (5) municipalities that are supporting financially and decentralized forms of economic management, for investigation on solutions on the substitution of imports, export generated funds, on the food and employment problem (Nova González, 2010). The MEP also implemented a series of internal reforms to simply the State apparatus and structures that deal or are in some ways related with the production, distribution, and consumption of agricultural products. The first step in this direction was the unification of the Ministry of the Food Industry (*Ministerio de la Industria Alimenticia*, MINAL) with the former Ministry of Fisheries after the approval of Decree-Law 287 and Decree-Law 294 in 2011.

Decree-287 also transferred some of the functions of the Sugar Ministry (MINAZ) to the Ministry of Agriculture (MINAG) and to the Ministry of the Economy and Planning (MEP). MINAG was assigned regulatory and supervisory functions such as managing land dedicated to sugar production, enforcing industrial and environmental regulations, and overseeing the commercialization of refined sugar and sugar derivatives. The MEP is now responsible for managing State investments in the sugar sector, and the Ministry of Trade and Foreign Investment (MINCEX) is responsible for implementing export policies and managing foreign investment in agriculture.Decree-law 294 replaced the Ministry of Sugar (MINAZ) with a holding company, *Grupo Azucarero AZCUBA*, responsible for managing all economic and investment activities relates to the sugar Agro-Industry. *AZCUBA* is a diversified holding company, comprised of twenty-five specialized subsidiaries, organized to manage sugar production and exports.

The approval of Agreement 6853 on June 24, 2010 represented another important step in the transformation of Cuba's non-sugar agriculture sector. This policy measure authorizes the commercialization (or trade) of agricultural products in roadside kiosks (or "points of sale") operated by agricultural cooperatives or state enterprises. Producers or their representatives are authorized to sell their excess output, after their quotas to the state have been delivered (or met) (Gaceta Oficial de Cuba, 2010). Agricultural producers or their representatives are required to pay taxes and/or fees for the use of these kiosks (or "points of sale) as stipulated by Resolution 206 issued by the Ministry of Prices and Finance. According to Resolution 206, sellers in the kiosks (or "points of sale") established by Agreement 6853 are required to pay a sales tax of 5%, based on their daily gross sales, plus a fee of 2% of the value of their reported gross sales for the use of the kiosks and related facilities, and self-employed workers (who work on these kiosks) are required to make social security contributions (González-Corzo, 2013)

The approval of Agreement 6853 (2010) represents a step in the right direction. However, certain provisions limit its potential. First, the entities or administrative units that administer the kiosks (or "points of sale") are a State-owned entity, which implies that the State will continue to play a significant role in the administration of the important sales venues. Second, producers that use these venues to commercialize their agricultural products must first fulfill their delivery quotas to the State at prices and amounts established by the latter. These conditions limit the autonomy of participants in the kiosks (or "points

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of sale") in terms of determining output prices and quantity, and are likely to contribute to imbalances between supply and demand.

The decentralization of Cuban agriculture was further expanded with the approval of Resolution 90 by the Central Bank of Cuba (BCC), Resolution 122 by the Ministry of Agriculture (MINAG), Resolution 369 by the Ministry of Finance and Prices, and Resolution 121 by the Ministry of Tourism (MINTOUR) in 2011. These policy measures facilitated the decentralized commercialization of a selected group of agricultural products and Tourism Enterprises; authorized non-state producers such as cooperatives and private farmers to sell part of their output directly to such enterprises; and created a new entity, FINTOUR, S.A., to provide credit financing to tourism enterprises engaged in direct commercialization with participating agricultural producers (González-Corzo, 2013).

The approval of Decree-law 289 and Resolution 99 in 2011 formalized the extension of agricultural credits (from state-owned Banks) to non-state agricultural producers, representing another step towards a more flexible agricultural model. Decree 289 establishes the legal framework for the provision of agricultural credits to non-state production units, including self-employed workers, as well as for individuals wishing to obtain credit finance for home improvements and repairs. Decree-law 289 allows self-employed workers and private farmers earning more than 50,000 pesos (CUP) to open a business account; it also lifted existing ceiling of 3,000 pesos (CUP) on bank loans to natural persons, and eliminated the 100 convertible peso (CUC) limits on payments by State Owned Enterprises (SOES) to self-employed workers, who provided goods and services to SOES, on a contractual basis (González-Corzo, 2013).

Resolution 99, approved by the Central Bank of Cuba (BCC) in November 2011, authorized the extension of bank-based credit financing (up to 500 pesos-cup) to non-state agricultural producers (e.g. cooperatives and private farmers). Resolution 99 allows non-state agricultural producers to obtain credit financing to purchase and repair equipment, procure inventory, and obtain other essential inputs, including the costs of replanting and reconditioning previously-planted fields (González-Corzo, 2013). Depending on the borrower's circumstances and the nature (or purpose) of the loan, it can be amortized using any source of income, for periods of 18 to 60 months (González-Corzo, 2013).

The economic transformation of Cuba's agricultural sector was accelerated after the ratification of the "Guidelines" ("Lineamientos de la Política del Partido y la Revolución") after the 6th party Congress of the Communist Party (PPC) on April, 2011. As Nova González (2013) indicates, Cuba's Agricultural Sector confronts three (3) principal unresolved issues: (1) the need to achieve the "Realization of Property,"[1] the need to recognize (and accept) the existence and role of the market, and the inexistence of a systemic strategy through the productive cycle that would reflect its complex microeconomic and macroeconomic interrelations.

Several policies responses have been recommended and discussed to address or resolve these issues. These include: (1) the creation and development of input markets where agricultural producers can obtain essential inputs and supplies, (2) granting greater autonomy to agricultural producers, allowing them to decide how much output to produce, where to sell it

[1] The concept of the "realization of property" refers to the right of producers to have complete autonomy in determining output levels, choosing the final destination of their output, and determining its price; and having the ability to directly access input markets to obtain the essential inputs to close the productive cycle (Nova González, 2013).

and whom to sell it to, based on market conditions and social requirements, (3) facilitating diverse forms of agricultural commercialization as an alternative to the State monopoly, (4) allowing agricultural producers to freely hire labor, and (5) providing new and existing agricultural producers with adequate financial and technical support (Nova González, 2013). The Guidelines offer several proposals to address the aforementioned unresolved issues confronted by Cuba's agricultural sector. With regards to the creation of input markets where agricultural producers will be able to obtain essential inputs, the "Guidelines" indicate that such wholesale markets will be able to purchase or lease equipment, machinery, and other essential inputs, with the objective of increasing producer autonomy, limiting State intervention, and recognizing the participation of non-state forms of production (Nova González, 2013).

With regards to prices, the "Guidelines" explicitly state that the State will retain full discretion over price regulations, and prices will be established according to the plan (i.e. prices will be centrally-determined), taking into account the social and economic functions of the products and services for which prices will be centrally-determined by the State (Nova González, 2013). At the same time, mechanisms that allow the creation other prices by the Enterprise Sector will be approved, taking into account the interests of the nation, rather than those of the enterprise, as well as sectoral and territorial considerations (Nova González, 2013). The Guidelines state that prices will be centrally-established in accordance with efforts to "update" the country's economic model (Nova González, 2013).

The Guidelines contain several contradictory provisions that hinder the development of a more flexible system for the commercialization of agricultural products. Article 27, under "Economic Procurement Model," states that surplus agricultural production (i.e. production above the State established quotas) cannot be sold directly to the population through intermediaries; this provision hinders producer autonomy and limits their ability to achieve "The Realization of Property" (Nova González, 2013). Conversely, Article 183 proposes the transformation of the system of agricultural commercialization by simplifying the supply chain between producers and consumers, including the possibility of allowing producers to reach consumers through their own means (or resources) (i.e. via direct sales or commercialization) (Nova González, 2013). Along similar lines, Article 304 aims to restructure retail and wholesale agricultural commerce through more flexible arrangements in order to simplify the linkages between producers and consumers, taking into account economic conditions and the diversification of production and property forms (Nova González, 2013).

The Guidelines also provide for greater producer autonomy with regards to hiring labour by considering the expansion of employment in the non-state sector, as an alternative modality closely aligned with emerging production and property forms. In that respect, the Guidelines are closely synchronized with Resolution 32 and Resolution 33 of the Ministry of Labor and Social Security (MTSS), which authorized a new form of self-employed agricultural worker and regulate labor hiring practices by cooperatives and self-employed workers (Nova González, 2013).

Finally, with regards to providing new and existing agricultural producers with adequate financial support and training, Article 50 of the Guidelines identifies the implementation of policies to support those activities that stimulate national production and the provision of bank loans (or credit) to facilitate the expansion of the non-state sector as its principal goals (Nova González, 2013). Other policy objectives include applying a differentiated tax regime to stimulate agricultural production, the expansion of insurance programs to cover agricultural producers, and the development of specialized banking and financial services to meet their needs, including non-state producers who received land in usufruct after the approval of Decree-law 259 in 2008 (Nova González, 2013).

The approval of Decree-Law 300 on October 2012 expanded the principal provisions of Decree-Law 259 (2008) with regards to the transfers of idle State-owned lands to non-State producers (e.g., cooperatives and private farmers) in usufruct. Decree-Law 300 expanded the maximum number of hectares that could be transferred to non-State producers (in usufruct) to 67.1; it also permitted individual (or private) agricultural producers operating under this new modality to become affiliated with cooperatives other than the Credit and Services Cooperatives (CCS). Under Decree-Law 300 (2012), private farmers can also associate themselves with Cooperatives of Agricultural Production (CPA) or Basic Units of Cooperative Production (UBPCs); in addition, they are allowed to use alternative channels to procure essential inputs and distribute their output, once delivery quotas with the State have been fulfilled (González-Corzo, 2012).

In 2013, the Cuban government introduced several regulatory updates to further transform the agricultural sector. These primarily consist of policy measures to expand the sales of agricultural products to tourism enterprises, facilitate the direct commercialization of agricultural products (on an experimental basis) in the provinces of Havana, Mayabeque, and Artemisa, and restructure the Ministry of Agriculture (MINAG). The approval of Resolution 58 by the Ministry of Agriculture (*MINAG*), Resolution 352 by the Ministry of Finance and Prices, and Resolution 37 by the Ministry of Tourism (*MINTUR*) on September 2013 represent another step towards the transformation of the regulations governing the direct sales of agricultural products to tourism enterprises in Cuba. These measures supplement Resolution 122, which was approved in 2011. Their principal provisions include the authorization of direct sales of agricultural products in Cuban pesos (CUP) to tourism enterprises, without State intermediation, by all types of agricultural producers, including individual (private) farmers, and the expansion of authorized products to include: fresh cut flowers, gardening services, floral arrangements, dry spices, and eggs. According to Resolution 9 (June 2013), prices can be directly determined by buyers and sellers. Resolution 9 also establishes the implementation of a "transaction fee" of 9 Cuban pesos (CUP) for every convertible peso (CUC) generated from the direct sale of agricultural products to tourism enterprises (by ALL types of agricultural producers). In accordance with Decree-Law 112 (2012), *Casa Financiera, S.A.* and other financial and banking institutions will collect a 5% (sales) tax payment from tourism enterprises.

The approval of Decree-Law 318 and Resolution 673 by the Ministry of Agriculture (*MINAG*) on October 2013 authorized the creation, on an experimental basis, of non-agricultural cooperatives in some of the previous locations of the *Mercados Agropecuarios Estatales* (MAEs) [State Agricultural Markets] in Havana, Artemisa, and Mayabeque provinces. Nationwide expansion is planned by 2015. Their principal objective is to decentralize the commercialization of agricultural products by facilitating the creation of "*mercados de abastos*" (wholesale markets) where agricultural producers and or authorized intermediaries can offer their products at wholesale prices. The approval of Decree-Law 318 and Resolution 673 represents the implementation of *Lineamiento 181* (which basically proposed the calibration between supply and demand in agricultural markets), and *Lineamiento 183* (which focused on steps to improve the commercialization of agricultural products).[2] These

[2] The term "Lineamientos" refers to the "*Lineamientos de la PolíticaEconómica y Social del Partido y la Revolución*" – or the "Social and Economic Guidelines of the Party and the Revolution" (commonly referred to as the "Guidelines") –

measures are applicable to ALL types of agricultural producers in the State and Non-State sectors, including a new category of intermediary officially labeled as "*carretilleros*" (street cart vendors). The principal provisions of Decree-Law 318 and Resolution 673 include:

- The creation of Provincial Administration Councils responsible for implementing, and overseeing policies, determining the location of retail outlets and zones of operation for the "*carretilleros*," and regulating direct sales of agricultural products to Centers of Social Consumption such as hospitals, schools, daycare centers, dinning commons (*comedores*), etc.
- Beef, fresh milk, coffee, selected honey products, tobacco, and cocoa are excluded. Potatoes are subject to "social consumption requirements" (defined by the State).
- State producers (e.g., State farms, enterprises, etc.) are authorized to participate; the same applies to Non-State producers such as UBPCs, CPAs, CCSs, private farmers, and self-employed worker (a newly-authorized producer category).
- Authorized agricultural products may be distributed in the following outlets: *Mercados Agropecuarios Estatales (MAEs), Mercados de Oferta y Demanda (MOD), Mercados Arrendados (*a newly-created outlet type leased by the State to Non-State producers), *Puntos de Ventas (*stalls, or kiosks located in neighborhoods, rest stops on the highway, etc.).[3]
- Retail prices will be set by the Ministry of Finance and Prices for fixed price products; producers that operate in MAEs that have been converted to non-agricultural cooperatives can set their own prices, but these must be approved by the Ministry of Finance and Prices.
- As an initial part of the experiment, some MAEs will be converted into "*mercados de abastos*" – located in Havana City only- which would allow enterprises and other entities to buy agricultural products directly from State and Non-State producers.
- Cooperatives that participate in these markets will be exempt from taxes for the first three months; self-employed workers can also participate, but will receive a different tax treatment (as part of the efforts to prioritized cooperatives, which are considered a superior, and more socialized, property form).

The efforts to restructure the Ministry of Agriculture (MINAG) announced in early 2014 represent another key element of Cuba's agricultural transformations. These efforts are divided into three (3) phases. The first phase consists of updating the MINAG budget system. Phase two considers the creation of Provincial Enterprises (*Empresas Provinciales*) and during phase three it is expected that the Provincial and Municipal Administrative Councils will be phased out. The following measures are also planned: (1) transferring Provincial Enterprises to Provincial Administration, (2), the consolidation of 15 existing Agricultural Research Stations with similar institutions in the Ministry of Science, Technology, and the Environment (CITMA).

3. Recent Performance (2007 - Present)

approved by the 6th Congress of the Communist Party of Cuba (PCC) on April 18, 2011. The "Guidelines" are the framework that broadly delineates Cuba's economic policies since the 6th Party Congress.

[3] The retail agricultural outlets operated by the Youth Work Army (EJT) are excluded from Decree-Law 318, and will continue to operate as in the past.

Table 1 presents the distribution of land in Cuba at the end of 2013.

Table 1. Cuba: Land distribution based on tenure form, 2013 (thousand hectares)

			Non-State Sector			
	Total	State Sector	Total	UBPC	CPA	CCS and Private Farmers
Total	10,988.4	5,932.1	5,056.3	1,952.0	614.3	2,490.0
Agricultural Surface	6,342.4	1,851.7	4,490.7	1,677.5	521.5	2,291.7
Cultivated (or harvested) Surface	2,645.8	471.8	2,174.0	851.3	264.9	1,057.8
Non-agricultural Surface	4,646.0	4,080.4	565.5	274.5	92.8	198.3

Source: Oficina Nacional de Estadísticas e Información (2014).

As Table 1 indicates, Cuba's arable land (or total agricultural surface) (6.3 million hectares [ha]), represented 57.7% of the country's total land (10.9 million ha). Approximately 41.7% of the arable land was harvested (or under cultivation) in 2013. While the State sector holds 54% of Cuba's total land (5.9 million ha), only 29.2% of arable land is held by the State (1.9 million ha), out of which 25.4% (472,000 ha) were harvested (or under cultivation) at the end of 2013 (Table 1).

The non-State sector, which includes the Basic Units of Cooperative Production (*Unidades Básicas de Producción Cooperativa*, UBPC), Cooperatives of Agricultural Production (*Cooperativas de Producción Agropecuaria*, CPA), Credit and Services Cooperatives (*Cooperativas de Créditos y Servicios*, CCS) and private farmers (*privados)*, has seen its share of total land, arable land (or agricultural surface), and land under cultivation increase significantly since 2008 (Table 1). At the end of 2013, 46% of Cuba's total land (5 million ha), and 70.8% of the country's arable land (4.5 million ha) were held by the non-State sector. Close to half (48.4%) of the arable land (2.2 million ha) held by the non-State sector were harvested (or under cultivation), representing 84.6% of the country's area under cultivation (2.6 million ha) (Table 1).

Table 2 shows the areas planted and under production for selected crops in Cuba's non-sugar agricultural sector during the 2008-2013 period.

Table 2. Cuba: Areas planted and under production, selected crops, hectares.

CROPS	2008	2009	2010	2011	2012	2013	Chg.	% Chg.
Viandas[(a)]	279,752	352,452	363,041	295,844	271,957	297,326	17,574	6.3%
Roots and tubers	196,122	246,033	243,834	200,993	190,725	228,507	32,385	16.5%
Potato	9,789	12,480	8,671	7,365	6,375	4,941	-4,848	-49.5%
Boniato	58,934	78,496	79,792	45,638	47,522	48,273	-10,661	-18.1%
Malanga	26,581	27,027	19,795	16,242	15,305	16,400	-10,181	-38.3%
Plantains	83,630	106,419	119,207	94,851	81,232	68,819	-14,811	-17.7%
Bananas	23,413	33,034	27,152	28,474	18,135	13,638	-9,775	-41.7%
Plantains	60,217	73,385	92,055	66,377	63,097	55,181	-5,036	-8.4%
Vegetables	259,073	278,561	236,569	211,610	202,897	214,026	-45,047	-17.4%
Tomato	62,124	69,170	49,057	54,955	49,009	54,286	-7,838	-12.6%
Onions	11,056	11,586	9,766	10,713	9,175	11,620	564	5.1%
Pepper	6,969	7,227	5,797	5,618	6,311	7,825	856	12.3%
Cereals	284,736	419,732	402,037	351,364	356,261	375,996	91,260	32.1%
Rice	155,514	215,751	176,429	208,046	202,708	197,824	42,309	27.2%
Corn	129,222	203,981	225,608	143,318	153,553	178,172	48,950	37.9%
Legumes	95,306	150,584	112,712	123,914	123,434	119,775	24,469	25.7%
Beans	95,306	150,584	112,712	123,914	123,434	119,775	24,469	25.7%
Tobacco	23,048	24,861	20,256	13,631	16,130	12,906	-10,142	-44.0%
Citrus Fruits	45,635	47,921	43,149	33,391	26,155	20,290	-25,345	-55.5%
Oranges	30,628	31,907	26,046	18,988	13,500	11,222	-19,406	-63.4%
Grapefruit	13,207	12,424	13,075	11,093	9,895	7,605	-5,603	-42.4%
Lemon	898	1,116	879	836	754	656	-242	-26.9%
Other Fruits	83,058	91,662	96,890	80,781	79,439	83,472	414	0.5%
Mangoes	24,972	37,276	30,790	29,531	29,961	30,585	5,613	22.5%
Guava	10,116	13,035	11,660	8,525	8,704	10,093	-23	-0.2%
Papaya	4,406	5,427	7,979	5,800	5,824	6,186	1,781	40.4%
Cocoa	3,800	5,089	5,114	5,153	4,203	4,303	503	13.2%

[(a)] Includes Roots and Tubers and Plantains.

Source: Oficina Nacional de Estadísticas e Información (2014).

As Table 2 indicates, between 2008 and 2013, the areas planted and under production increased in five (5) out of the nine (9) categories of non-sugar agricultural crops reported by the National Statistics Office as follows: *viandas* (6.3%), cereals (32.1%), legumes (25.7%), other fruits (0.5%), and cocoa (13.2%). Conversely, during the same period, the areas planted and under production declined in the following crop categories: plantains (-17.7%), vegetables (-17.4%), tobacco (-44%), and citrus fruits (-55.5%) (Table 2).

Table 3 shows physical output levels for selected (non-sugar) crops in Cuba during the 2008-2013 period.

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Table 3. Cuba: Non-sugar agricultural production, selected crops, tons.

CROPS	2008	2009	2010	2011	2012	2013	Chg.	% Chg.
Viandas[(a)]	2,150,700	2,236,000	2,250,000	2,280,000	2,337,000	2,239,000	88,300	4.1%
Roots and tubers	1,392,500	1,565,600	1,515,000	1,445,000	1,452,000	1,580,500	188,000	13.5%
Potato	196,100	278,600	191,500	165,600	130,933	106,700	-89,400	-45.6%
Boniato	375,000	437,100	384,743	311,900	335,319	396,347	21,347	5.7%
Malanga	240,000	199,400	137,400	132,100	153,782	185,922	-54,078	-22.5%
Plantains	758,200	670,400	735,000	835,000	885,000	658,500	-99,700	-13.1%
Bananas	280,800	245,400	249,200	250,000	195,496	150,336	-130,464	-46.5%
Plantains	477,400	425,000	485,800	585,000	689,504	508,164	30,764	6.4%
Vegetables	2,439,300	2,548,800	2,141,035	2,200,000	2,112,000	2,406,500	-32,800	-1.3%
Tomato	575,900	750,000	517,040	601,000	557,100	678,000	102,100	17.7%
Onions	128,100	131,300	111,737	143,500	118,244	126,876	-1,224	-1.0%
Pepper	63,677	56,672	44,545	55,057	62,202	73,336	9,659	15.2%
Cereals	761,700	868,400	778,863	920,400	1,002,000	1,098,800	337,100	44.3%
Rice	436,000	563,600	454,400	566,400	641,600	672,600	236,600	54.3%
Corn	325,700	304,800	324,463	354,000	360,400	426,200	100,500	30.9%
Legumes	97,200	110,800	80,439	133,000	127,100	129,800	32,600	33.5%
Beans	97,200	110,800	80,439	133,000	127,100	129,800	32,600	33.5%
Tobacco	21,500	25,200	20,500	19,900	19,500	24,000	2,500	11.6%
Citrus Fruits	391,800	418,000	345,000	264,500	203,700	166,900	-224,900	-57.4%
Oranges	200,400	261,000	178,263	122,900	93,837	85,110	-115,290	-57.5%
Grapefruit	166,100	121,500	137,660	112,000	84,741	63,979	-102,121	-61.5%
Lemon	5,400	8,300	6,060	6,600	6,475	5,025	-375	-7.0%
Other Fruits	738,500	748,000	762,045	817,000	964,900	925,000	186,500	25.3%
Mangoes	228,700	269,300	203,595	185,000	286,385	285,526	56,826	24.8%
Guava	126,500	84,900	71,581	85,000	103,191	124,964	-1,536	-1.2%
Papaya	89,400	95,700	135,707	135,000	178,558	197,842	108,442	121.3%
Cocoa	1,100	1,387	1,709	1,510	2,027	1,425	325	29.5%

[(a)] Includes Roots and Tubers and Plantains.

Source: Oficina Nacional de Estadísticas e Información (2014).

Production in six (6) of the nine (9) reported categories of (non-sugar) crops increased as follows during the 2008-2013 period: *viandas* (4.1%), cereals (44.3%), legumes (33.5%), tobacco (11.6%), other fruits (25.3%), and cocoa (29.5%). These output levels, however, were significantly lower than in 1989, the last year before the onset of the "economic crisis of the 1990s" and the disintegration of the Socialist Camp and the Soviet Union in the early 1990s. By contrast, output declined in the following three (3) crop categories during the same period: plantains (-13.1%), vegetables (-1.3%), and citrus fruits (-57.4%) (Table 3). The variability of physical output in Cuba's non-sugar agricultural sector between 2008 and 2013 was attributed to several factors such as adverse weather conditions (e.g. drought, hurricanes), difficulties in obtaining essential agricultural inputs, existing limitations with regards to the "realization of property" (as discussed earlier), price controls, problems an inefficiencies related to the commercialization of agricultural products, insufficient warehousing and storage capacity, logistical difficulties associated with the transportation and cold storage of agricultural products, soil erosion and degradation, insufficient irrigation capabilities, and other administrative, organizational, and structural problems (Mesa-Lago, 2012; Nova González, 2013a; Spadoni, 2014).

Agricultural yields for selected (non-sugar) crops during the 2008-2013 period are shown on Table 4.

Table 4. Cuba: Agricultural yields, selected crops, tons per hectare

CROPS	2008	2009	2010	2011	2012	2013
Viandas[(a)]	7.69	6.34	6.20	7.71	8.59	7.53
Roots and tubers	7.10	6.36	6.21	7.19	7.61	6.92
Potato	20.03	22.32	22.09	22.48	20.54	21.59
Boniato	6.36	5.57	4.82	6.83	7.06	8.21
Malanga	9.03	7.38	6.94	8.13	10.05	11.34
Plantains	9.07	6.30	6.17	8.80	10.89	9.57
Bananas	11.99	7.43	9.18	8.78	10.78	11.02
Plantains	7.93	5.79	5.28	8.81	10.93	9.21
Vegetables	9.42	9.15	9.05	10.40	10.41	11.24
Tomato	9.27	10.84	10.54	10.94	11.37	12.49
Onions	11.59	11.33	11.44	13.39	12.89	10.92
Pepper	9.14	7.84	7.68	9.80	9.86	9.37
Cereals	2.68	2.07	1.94	2.62	2.81	2.92
Rice	2.80	2.61	2.58	2.72	3.17	3.40
Corn	2.52	1.49	1.44	2.47	2.35	2.39
Legumes	1.02	0.74	0.71	1.07	1.03	1.08
Beans	1.02	0.74	0.71	1.07	1.03	1.08
Tobacco	0.93	1.01	1.01	1.46	1.21	1.86
Citrus Fruits	8.59	8.72	8.00	7.92	7.79	8.23
Oranges	6.54	8.18	6.84	6.47	6.95	7.58
Grapefruit	12.58	9.78	10.53	10.10	8.56	8.41
Lemon	6.02	7.44	6.89	7.89	8.59	7.66
Other Fruits	8.89	8.16	7.87	10.11	12.15	11.08
Mangoes	9.16	7.22	6.61	6.26	9.56	9.34
Guava	12.51	6.51	6.14	9.97	11.86	12.38
Papaya	20.29	17.63	17.01	23.28	30.66	31.98
Cocoa	0.29	0.27	0.33	0.29	0.48	0.33

[(a)] Includes Roots and Tubers and Plantains.

Source: Oficina Nacional de Estadísticas e Información (2014).

Between 2008 and 2013, agricultural yields increased in seven (7) out of the nine (9) crop categories shown on Table 4. These were: plantains, vegetables, cereals, legumes, tobacco, other fruits, and cocoa. However, yields for *viandas* and citrus fruits decreased slightly during the same period.

4. Towards a New Agricultural Model

Despite representing only about 5% of GDP, due to its indirect economic contributions, positive externalities (or "spillover effects"), and strong linkages with the rest of the economy, agriculture plays a key role in the Cuban economy (Nova González, 2013a). Cuba's agricultural sector is also an important source of employment, a significant consumer of raw materials, intermediate, and finished goods, and one of the country's principal generators of renewable energy (Nova González, 2008).

Since the onset of the "economic crisis of the 1990s," following the disappearance of the Eastern European Socialist Bloc and the former Soviet Union, Cuban agriculture has been affected by declining production levels, higher external sector dependency, and increased hard currency expenditures to finance growing agricultural imports (Nova González, 2013a;González-Corzo & Nova González, 2013). Starting in 2007, the Cuban government has implemented a series of economic transformations to increase domestic agricultural production and reduced the country's dependency on agricultural imports and is food and agricultural vulnerability. These include structural and administrative transformations such as the transfers of idle State-owned lands (in usufruct) to non-State producers, moderate price reforms, the decentralization of decision-making and administrative functions, the consolidation of several Ministries responsible to agricultural policies and regulation, and gradual (experimental) transformations with regards to the commercialization of agricultural products (Mesa-Lago, 2012; Spadoni, 2014). So far, the most significant of these reform measures has been the transfer (in usufruct) of fallow State-owned lands to cooperatives and private farmers after the approval of Decree-Law 259 in 2008 and Decree-Law 300 in 2012 (Nova González, 2013a).

Official Cuba agricultural statistics show that there was mixed results in terms of the area planted and under production, and physical output between 2008 and 2013 (Tables 2 and 3). While both variables increased in some crop categories during this period, they decreased in others, indicating that the policy transformations initiated in 2007 had mixed effects. A simple linear regression conducted by the authors, using 2008-2013 data, to analyze the relationship between agricultural production (the dependent variable) and the area planted and under production (the independent variable) produced a correlation coefficient of 0.774 suggesting a strong (positive) linear relationship between these two variables. Our regression results also showed a coefficient of correlation (R2) of 0.599, indicating that close to 60% of the variation of the dependent variable (i.e. agricultural production) around the mean can be explained by the variation in independent variable (i.e. the area planted and under production). We believe that one of the key takeaways from these findings, which were statistically-significant at the 5% level, is that one of the palpable effects of Cuba's recent agricultural transformations seems to be the reallocation of land to the production of selected crop categories, as the country advances towards a new agricultural model.

Cuba's agricultural sector is comprised of State and non-State producers. The latter category includes the UBPCs, CPA, CCS, and private farmers. Under Cuba's new agricultural model, non-State producers account for a growing share of the country's agricultural output. While CCS and private farmers hold about 36% of the country's agricultural surface (or arable land), the produce close to 60% of its total agricultural output. According to Nova González (2013a), these non-State producers account for 56% of total cow milk production, compared to just 15% in the case of the State sector. Combined, the CCS and private farmers own more than 50% of the total cattle herd and 56% of the milk-producing cattle, and 59% of the total pork live stock in Cuba (Nova González, 2013a).

The importance of the non-State sector in Cuban agriculture has also grown in terms of its share of total employment, and overall contributions to and participation in the Cuban economy (Nova González, 2013a; Spadoni, 2014). Approximately 20% of Cuba's economy is directly or indirectly related to agriculture; an estimated 80% of the economically-active population is directly or indirectly involved in economic activities related to agriculture; and several key sectors of the economy, such as food processing, light industry, and transportation are strongly-connected to the agricultural sector (Nova González, 2013a).

There are three (3) fundamental unresolved aspects that need to be addressed, which have significantly limited the impact of the agricultural transformations initiated in 2007. These are: (1) the need to achieve the complete (or full) "realization of property," (2) the necessity to recognize and accept the existence of the market and its complementary role in the coordination of economic activities, and (3) the absence of a systematic approach across the entire agricultural production-consumption cycle to strengthen micro and macroeconomic linkages (Nova González, 2013a).

These unresolved aspects should be addressed or resolved through the gradual implementation of policies that facilitate the consolidation of input markets, where agricultural producers can obtain or procure essential inputs at prices that correspond to the prices they can receive for their output. Policies that allow agricultural producers to determine output levels and the final destination of their output, in accordance to market conditions and social requirements, should also be implemented. The diversification of the forms of agricultural commercialization, as an alternative to monopolistic or oligopolistic forms, should also be considered. This can be accomplished through the creation of "second degree cooperatives," created through the voluntary association of a group of production cooperatives to commercialize agricultural products on their behalf, and through the authorization of direct sales by such cooperatives to agricultural markets, the food processing industry, tourism enterprises, exporters, and other entities in the Cuban economy. The diversification of the existing forms of agricultural commercialization can also be achieved through the increased participation of private farmers, the expansion of retail "points of sale," and the inclusion of participants to include commercialization cooperatives and enterprises, individual producers (or private farmers), and the State procurement agency, *Acopio*.

Another step, or policy measure, to address the unresolved aspects that affect Cuban agriculture, is the transformation of labor (or employment) relations to allow producers to freely hire the amount of labor required to maintain and increase output. This requires, of course, greater levels of producer autonomy when it comes to hiring one of the most essential inputs in Cuban agriculture: labor. Finally, agricultural producers should be provided with the financing necessary to support their operations, and periodic technical assistance to improve their results and outcomes. The forms of financing provided to agricultural producers should include short-term and long-term micro-loans, equipment loans, input financing loans, crop revenue anticipation loans, and personal home improvement and construction, and farm improvement loans, (Coffrey, 1998; Morvant-Roux, 2008). Technical assistance to help no-State agricultural producers improve their results and outcomes should include some varied forms of government extension programs, value chain development programs, certification programs, agribusiness support programs, financial services and advisory support programs, and programs to support enabling institutions (The Initiative for Smallholder Finance, 2014).

The implementation of these policy measures will facilitate the "realization of property," under which agricultural producers would enjoy greater levels of administrative and operational autonomy and with respect to their production decisions and outcomes. Their implementation would also allow for the utilization of the market as a complementary, but regulated, economic coordination mechanism to achieve more rational levels of resource utilization, and higher levels of economic efficiency. Such process would favor the successful completion of the agricultural production cycle, under a systematic focus.

Given its long and successful participation in important clusters of non-sugar agriculture in Cuba, it is not surprising to find that under Cuba's new agricultural model non-State producers are allowed to play a larger role in the recovery and revival of this important sector of the economy. However, the expansion of the non-State sector should be conducted in gradual and regulated manner, particularly with regards to labor practices, the accumulation and transfer of assets, and health and safety standards. In this context, a strong but not antagonistic State, with the capacity to adapt and innovate, particularly on the regulatory front, but not completely malleable by the brutal forces of market capitalism, could play a vital role to ensure and promote agricultural self-sufficiency and national food security in Cuba.

References

Coffrey, E. (1998). *Agricultural finance: Getting the policies right* (Report no. 2). Food and Agriculture Organization of the United Nations (FAO). (1998). New York: United Nations.

Gaceta Oficial de Cuba. (2010). *Acuerdo 6853.* La Habana, Cuba. Gaceta Oficial de Cuba.

González-Corzo, M. (2013). Cuba's agricultural transformations: Moving towards market socialism?. In M. Font & C. Riobó (Eds.), Handbook of contemporary Cuba:

Economy, politics, civil society, and globalization (pp.97-110). Boulder, CO: Paradigm Publishers.

González-Corzo, M, &Nova González, A. (2013). U.S. agricultural exports to Cuba: Composition, trends, and prospects for the future. Choices, 28(4), 1-6.

Hagelberg, G.H. 2010. If it were just the "marabú: Cuba's agriculture 2009-2010." In J. F. Pérez-López (Ed.), Cuba in Transition, 20. Paper presented at the 20th Annual Conference of the Association for the Study of the Cuban Economy (ASCE), Miami, FL, July 29 – August 1 (pp. 32-45). Washington, DC: Association for the Study of the Cuban Economy.

Mesa-Lago, C. (2012). *Cuba en la era de Raúl Castro: Reformas económico-sociales ysus efectos.* Madrid: Editorial Colibrí.

Morvant-Roux, S. (2008). *What can microfinance contribute to agriculture in developing Countries?* In S. Morvant-Roux (Ed.). *Proceedings from the International Conference of the Fondation pour l'agriculure et la ruralité dans le monde (FARM)Conference* (pp. 1-20). Paris, France. Fondation pour l'agriculure et la ruralité dansle Monde (FARM).

Nova González, A. (2006). La agricultura en Cuba: Evolución y trayectoria (1959-2005). La Habana, Cuba: Editorial de Ciencias Sociales.

Nova González, A. (2008). El sector agropecuario en Cuba. *Nueva Sociedad*, *216*, 77-89.

Nova González, A. (2010). Agricultura. In O. E. Pérez Villanueva (Ed.), *Miradas a la economía cubana: II* (pp. 43-71). La Habana, Cuba: Editorial Caminos.

Nova González, A. (2013). Sector agropecuario y lineamientos. In M. Font & C. Riobó (Eds.), Handbook of contemporary Cuba: Economy, politics, civil society, and globalization

(pp. 81-96). Boulder, CO: Paradigm Publishers.

Nova González, A. (2013a). *El modelo agrícola y los lineamientos de la política económica* *y social en Cuba.* La Habana, Cuba: Editorial Ciencias Sociales.

Nova González, A. (2013b). Un nuevo modelo cubano de gestión agrícola. Temas, *77,* 84-91.

Oficina Nacional de Estadísticas e Información (ONEI). (2014). *Anuario Estadístico de Cuba, 2013*. La Habana, Cuba: Oficina Nacional de Estadísticas e Información (ONEI).

Spadoni, P. (2014). *Cuba's socialist economy today: Navigating challenges and change*. Boulder, CO: Lynne Rienner Publishers.

The Initiative for Smallholder Finance. (2014). *Technical assistance for smallholder farmers: An anatomy of the market* (Briefing 07). Washington, DC.

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New Insulation Fiberboards from Sunflower Cake With Improved Thermal and Mechanical Properties

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Abstract

New thermal insulation fiberboards were manufactured by compression molding from a cake generated during the sunflower biorefinery. Fiberboards were cohesive mixtures of a natural binder and lignocellulosic fibers from sunflower cake. The natural binder ensured the board cohesion, and fibers acted as reinforcing fillers. The influence of molding conditions, i.e. binder type and binder content, on board density, mechanical and heat insulation properties was examined. The medium-density board containing 20% starch-based binder was a good compromise between mechanical and heat insulation properties (78 mW/m K thermal conductivity). It could be positioned on walls and ceilings for thermal insulation of buildings.

Keywords: Sunflower, twin-screw extruder, lignocellulosic fibers, natural binder, compression molding, fiberboards, thermal insulation

1. Introduction

Twin-screw extrusion technology is an original and powerful solution for the biorefinery of sunflower (*Helianthus annuus* L.) whole plant. The latter is conducted in the presence of water, allowing the aqueous extraction of sunflower oil (Evon *et al.*, 2010a). A filtration section along the barrel allows an extract (filtrate) and a raffinate (cake) to be collected separately, and oil extraction yield attains 57%, under optimal operating conditions, with 14.3% residual cake dry matter oil content. Proteins and also pectins and hemicelluloses are co-extracted using the above conditions, thus protein extraction yield is 44%, and cake residual protein content is 7.3% of the dry matter.

To simplify conservation, cake is first dried because it has a relatively high moisture content of at least 62%. Structurally, it is porous with a majority of lignocellulosic fibers (around 58% of the dry matter), although there is also cell debris from breakdown of the kernels. The soluble molecules (proteins, pectins…) and lipids have been partly removed, whereas the structural plant molecules have not been extracted. Because the cake is a mixture of proteins and lignocellulosic fibers, it has been the subject of new valorizations. It can be thought of as a natural composite meaning that it can be processed by thermo-pressing into natural, cohesive, and value-added fiberboards, with the proteins acting as internal binder, and lignocellulosic fibers as reinforcing fillers (Evon *et al.*, 2010a, 2010b, 2012a, 2012b, 2012c, 2015).

Temperature, pressure and length of time of thermo-pressing all increase fiberboard bending mechanical properties (Evon *et al.*, 2010b, 2012b), and the highest flexural strength at break (11.5 MPa) and highest elastic modulus (2.2 GPa) are obtained with a cake having a dry matter residual oil content of 14.5%, using the following molding conditions: 500 mg/cm^2 cake quantity, 200 °C temperature for the two heated hydraulic press aluminum plates, 31.4 MPa pressure applied, and 60 s molding time (Evon *et al.*, 2010b). Fiberboard thickness is just 3.9 mm with quite a high density (1035 kg/m^3). A fiberboard with these flexural properties, could be used in the handling and storage industry as pallet inter layer sheeting, or for furniture manufacture and natural, multi-board containers, e.g. composters, vegetable gardening crates.

Another industrial application of fiberboards made from renewable resources is heat insulation of buildings (walls and ceilings), where the main advantages of vegetable fibers are abundance, low cost (the majority are agricultural residues), minimal environmental impact, independence from fossil resources, and their natural capacity for thermal insulation (Saiah *et al.*, 2010). Insulation boards can be made from maize husks and cobs (Sampathrajan et al;, 1992; Pinto *et al.*, 2011; Paiva *et al.*, 2012), a mixture of durian peels and coconut coir fibers (Khedari *et al.*, 2003, 2004), cellulose (Nicolajsen, 2005), wastes from tissue paper manufacturing and corn peel (Lertsutthiwong *et al.*; 2008), kenaf fibers (Ardente *et al.*, 2008), flax and hemp fibers (Kymäläinen & Sjöberg, 2008; Korjenic *et al.*, 2011; Benfratello *et al.*, 2013), cotton stalk fibers (Zhou *et al.*, 2010), jute fibers (Korjenic *et al.*, 2011), coconut fibers (Panyakaew & Fotios, 2011; Alavez-Ramirez *et al.*, 2012), sunflower pith (Vandenbossche *et al.*, 2012), date palm fibers (Chikhi *et al.*, 2013), etc.

The thermal conductivity of insulation boards is often influenced by their densities (Khedari *et al.*, 2003, 2004; Lertsutthiwong *et al.*; 2008; Zhou *et al.*, 2010; Panyakaew & Fotios, 2011; Vandenbossche *et al.*, 2012; Benfratello *et al.*, 2013; Chikhi *et al.*, 2013), and low-density materials have the lowest thermal conductivities. As an example, the thermal conductivity of an insulation board from sunflower pith is only 38.5 mW/m K at 25 °C with a board density of 36 kg/m^3 (Vandenbossche *et al.*, 2012). It is comparable to that of conventional insulation materials like expanded polystyrene (37.4 mW/m K with a board density of 50 kg/m^3), rock wool (35.6 mW/m K with a board density of 115 kg/m^3), and glass wool (35.4 mW/m K with a board density of 26 kg/m^3). Thermal conductivity is higher with medium-density materials: 46-68 mW/m K at room temperature for coconut husk insulation boards with board densities of 250-350 kg/m^3 (Panyakaew & Fotios, 2011), 81.5 mW/m K for a cotton stalk fibers insulation board with a board density of 450 kg/m^3 (Zhou *et al.*, 2010), 89.9-107.9 mW/m K for hemp fibers insulation boards with board densities of 369-475 kg/m^3 (Benfratello *et al.*, 2013), 103.6 mW/m K for a coconut coir insulation board with a board density of 540 kg/m^3 (Khedari *et al.*, 2003), and 150 mW/m K for a date palm fibers insulation board with a board density of 754 kg/m^3 (Chikhi *et al.*, 2013). Nevertheless, such boards are viable options for use in building insulation (walls and ceilings).

Heat insulation properties, of self-bonded fiberboards from cake generated during the biorefinery of sunflower whole plant in a twin-screw extruder are also promising, even if the corresponding board densities are quite high (904-966 kg/m^3) (Evon *et al.*, 2012c). Indeed, thermal conductivity at 25 °C is rather low for the three fiberboards tested, decreasing from 135.7 to 103.5 mW/m K as the board density decreased.

Furthermore, self-bonded fiberboards from such a cake with lower density (500-858 kg/m^3) and higher thickness (from 13.0 to 20.2 mm) reveal a significant improvement in their heat insulation properties (Evon *et al.*, 2014). Molding conditions, including mold temperature (140-200 °C), pressure applied (14.7-24.5 MPa) and molding time (40-76 s), greatly affect board density and thus the mechanical and heat insulation properties. And, all fiberboards produced from these conditions are cohesive, proteins and lignocellulosic fibers still acting respectively as binder and reinforcing fillers. Board density increases with increasingly extreme molding conditions, rising from 500 to 858 kg/m^3. The mechanical properties increase at the same time (from 52 to 660 kPa for flexural strength at break, from 5.9 to 49.4 MPa for elastic modulus, from 0.5 to 7.7 kJ/m^2 for Charpy impact strength, and from 19.2 to 47.1° for Shore D surface hardness). Conversely, heat insulation properties improve with decreasing board density, and the lowest thermal conductivity (88.5 mW/m K at 25 °C) is obtained with the least dense fiberboard, produced with a 140 °C mold temperature, a 14.7 MPa pressure applied and a 40 s molding time.

A medium mold temperature (160 °C) is needed to obtain a good compromise between mechanical properties (272 kPa for flexural strength at break, 26.3 MPa for elastic modulus, 3.2 kJ/m^2 for Charpy impact strength, and 37.3° for Shore D surface hardness), and heat insulation properties (99.5 mW/m K for thermal conductivity) (Evon *et al.*, 2014). The corresponding board density is medium (687 kg/m^3). And, because of its promising heat insulation properties, it could be positioned on walls and ceilings for thermal insulation of buildings. However, its insulation ability should be further improved.

A solution to improve significantly heat insulation properties of these fiberboards could be the use of natural binders, first solubilized in water and then mixed to the sunflower cake before compression molding plus drying. These external binders are with physical curing, the adhesion being achieved when water has evaporated. It then results in the appearance of bonds, usually of hydrogen type, between the biopolymer in the glue and the molecules (proteins, cellulose, hemicelluloses, etc.) contained in the materials to be joined. When used, natural binders favor both good cohesion and low density for the composite material, thus improving its thermal insulation ability. As an example, it is possible to manufacture insulating bio-based composites according to this technique, from sunflower stalks particles and chitosan (Mati-Baouche *et al.*, 2014). And, the size grading of particles, the ratio chitosan/sunflower particles and the stress of compaction influence the thermal and mechanical properties of these new materials. Composites with a thermal conductivity of only 56 mW/m K and a maximum stress of 2 MPa are obtained with a ratio of chitosan of 4.3% (w/w) and a size grading of particles higher to 3 mm. These thermal and mechanical performances are competitive with those of other insulating bio-based materials available on the market.

This study aimed to manufacture by compression molding at ambient temperature plus drying, new thermal insulation fiberboards with improved thermal and mechanical properties, from a mixture of an external binder in water solution and cake generated during the biorefinery of sunflower whole plant in a twin-screw extruder, and to evaluate the influence of molding conditions (binder type, and binder content) on their density, mechanical (flexural properties, and Shore D surface hardness) and heat insulation properties.

2. Materials and methods

2.1 Raw material

Twin-screw extruder thermo-mechanical fractionation was applied to a batch of oleic type sunflower (*Helianthus annuus* L.) whole plant (La Toulousaine de Céréales, France) (Table 1), harvested at plant maturity in September, pre-dried in a ventilated oven (50 °C, 48 h) and then crushed with a hammer mill (Electra VS 1, France) through a 15 mm screen. Powdered plant moisture content (batch of 250 kg) was 7.2±0.0% (French standard NF V 03-903).

2.2 Analytical methods

The moisture contents were determined according to French standard NF V 03-903. The mineral contents were determined according to French standard NF V 03-322. The oil contents were determined according to French standard NF V 03-908. The protein contents were determined according to French standard NF V 18-100. The three parietal constituents (cellulose, hemicelluloses, and lignins) were estimated using the ADF-NDF method of Van Soest & Wine (1967, 1968). Similarly, the water-soluble components were estimated by measuring the mass loss of the test sample after 1 h in boiling water. All determinations were carried out in duplicate.

Table 1. Chemical composition of the sunflower whole plant used for the experiment and of the cake obtained, after its thermo-mechanical fractionation in the Clextral BC 45 twin-screw extruder (% of the dry matter).

Material	Sunflower whole plant	Cake
Minerals	8.01±0.04	7.07±0.04
Lipids	24.11±0.04	17.40±0.13
Proteins	11.46±0.20	9.01±0.33
Cellulose	24.81±0.59	30.84±2.92
Hemicelluloses	8.10±0.30	5.36±0.26

Lignins	10.27±0.16	15.43±2.51
Water-soluble components	18.55±0.40	12.39±0.12

2.3 Particle size distribution

A 500 g test sample mass of sunflower cake was treated in a Retsch AS 300 (Germany) vibratory sieve shaker to determine particle size distribution. Sieve acceleration was 1.5 × *g*, and sieving time 10 min. For the tapped density of the cake, the measurement used a Granuloshop Densitap ETD-20 (France) volumenometer, and the corresponding apparent density, i.e. before compaction, was determined at the same time.

2.4 Natural binders

Three different natural binders were used in this study. All three have been chosen because of their commercial availability. The first one (S) was a starch-based binder supplied by Bostik (France) with the reference number 28474, and usually used as a glue for wallpapers. Its starch content was 85%. The second one (C) was a wood glue made of 96.6% casein, and supplied by Ipharos (France) under the name COLLASEUM Caseo Bois. The third and last one (G) was a bone glue made of gelatin (purity of about 90%), supplied by Briançon Production (France), and usually used in crafts, i.e. restoration of antique furniture, marquetry, etc.

2.5 Manufacturing of natural composites

The three natural binders were first solubilized at room temperature (20 °C) for 10 min under stirring at concentrations of 5.6, 8.8, 12.5, and 16.7% (w/v) in 500 mL distilled water, respectively. Binder solutions were then mixed manually for 5 min with 250 g cake, corresponding to binder contents (w/w) of 10, 15, 20, and 25%, respectively. The mixtures were molded at room temperature (20 °C) by compression inside an aluminium mold using a 5 ton capacity hydraulic press, producing 150 mm × 150 mm fiberboards. Pressure applied and molding time were 87 kPa and 30 s, respectively. Two insulation fiberboards were manufactured for all the molding conditions tested, including binder type, and binder content (Table 2). They were dried at 80 °C using a France Etuves XL2520 (France) ventilated oven to eliminate water added for binder dissolution, and they were then equilibrated in a climatic chamber (60% RH, 25 °C) for three weeks before any analyses. A first fiberboard was used to assess mechanical properties for bending, and a second one for measuring Shore D surface hardness and heat insulation properties.

Table 2. Molding conditions for the manufacture of the twelve fiberboards.

Board	S1	S2	S3	S4	C1	C2	C3	C4	G1	G2	G3	G4
Binder type	S	S	S	S	C	C	C	C	G	G	G	G
Binder content (%)	10	15	20	25	10	15	20	25	10	15	20	25

2.6 Mechanical properties for bending

Measurement of the flexural properties of the test specimens according to French standard NF EN 310 was undertaken using an Instron 33R4204 (USA) universal testing machine fitted with a 500 N load cell. Properties covered energy-to-break (E), breaking load (F), flexural strength at break (σ_f), and elastic modulus (E_f). An estimation of the energy-to-break for each specimen, using the area under the load deformation curve from zero to rupture, was calculated using the trapezium method. Fiberboard was equilibrated for three weeks in a climatic chamber (60% RH, 25 °C), and then 30 mm wide test specimens were cut and their thickness measured at three points and their length at two points, with a 0.01 mm resolution electronic digital sliding caliper. Thickness mean values (t) and length (l) were recorded to calculate the specimen volume, and they were all weighed to calculate mean apparent density (d). Test speed was 2 mm/min with 100 mm grip separation. All determinations were carried out four times.

2.7 Shore D surface hardness

Shore D surface hardness of the fiberboards was assessed using a Bareiss (Germany) durometer according to French standard NF EN ISO 868. All determinations were carried out 48 times (24 times for each side of the fiberboard).

2.8 Heat insulation properties

Thermal conductivity (λ) and thermal resistance (R) of fiberboards were determined at three temperatures (10 °C, 25 °C, and 40 °C) according to the ISO 8302 08-91 standard, using a Lambda-Meßtechnik GmbH Dresden EP 500 (Germany) λ-Meter hot plate apparatus. The area measured was 150 mm × 150 mm, and because of swelling in the climatic chamber, fiberboards had to be cut before measuring to obtain the required dimensions. The difference of temperature between the two plates was 5 K. Measurements were also made with the bulk cake using a polycarbonate box 1 mm thick and 50 mm high. Here, the solid, cake particles were evenly distributed in the box, and a ‘box effect’ correction made on the thermal conductivity measurements. The cake was equilibrated in a climatic chamber (60% RH, 25 °C) for three weeks before being tested. Both determinations were carried out once.

2.9 Statistical analyses

Determinations were conducted two times for board moisture content, four times for flexural properties and 48 times for Shore D surface hardness, and data are expressed as means ± standard deviations. The means were compared by the use of a single-factor analysis of variance (ANOVA) using the GLM procedure of the SAS data analysis software. The comparison between the different individual means was performed using the Duncan’s multiple range test at a 5% probability level.

3. Results and discussion

3.1 Cake production by twin-screw extrusion

A Clextral (France) BC 45 twin-screw extruder was used to conduct simultaneously at 80 °C the thermo-mechanical fractionation of whole plant and the aqueous extraction of sunflower oil, and the screw configuration was the same as that previously optimized (Evon *et al.*, 2010a). A filtrate was collected continuously from the filter section, and a cake was generated at the same time. Lipids and water-soluble components, mostly proteins but also pectins and hemicelluloses, were partly extracted during this process. Operating conditions used for cake production were 62.5 rpm for the screw rotation speed, 5.7 kg/h for the inlet flow rate of the sunflower whole plant, and 20.2 kg/h for the inlet flow rate of the water. The flow rate of the cake was 12.1 kg/h, and its moisture content was 67.8±0.2%. Immediately after production of this cake, and to facilitate conservation, it was dried in a ventilated oven, and the powder produced consisted of inhomogeneous particles (Figure 1 and Figure 2), whose chemical composition is shown in Table 1. It revealed an oil content (17.4% of the dry matter) quite comparable to that of a cake used in a previous study for the manufacture of self-bonded insulating fiberboards (17.6%) (Evon *et al.*, 2014), leading to an oil extraction yield, based on the residual oil content in the cake, of 46.4±0.4%. The corresponding protein extraction yield, based on the residual protein content in the cake, was 41.6±2.1%.

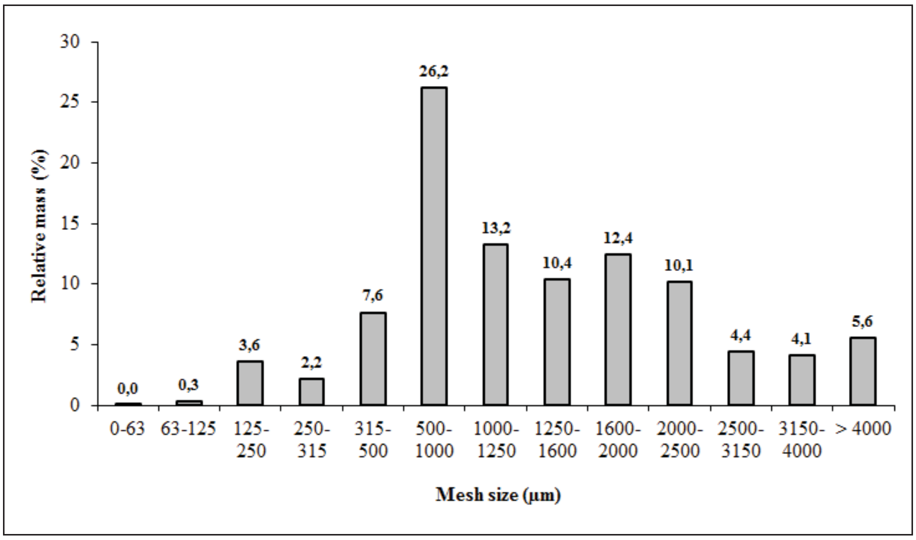

Figure 1. Particle size distribution in the cake.

Due to the fact that some lipids and proteins were partly extracted by water during the process, this meant that their residual contents in the cake decreased compared to initial whole plant values: from 24.1 to 17.4% of the dry matter, and from 11.5 to 9.0% of the dry matter, respectively (Table 1). Similarly, with hemicelluloses and water-soluble components, the same tendency was also observed: from 8.1 to 5.4% of the dry matter, and from 18.6 to 12.4% of the dry matter, respectively. On the other hand, cellulose and lignins were not extracted, because both these biopolymers are insoluble in water. Thus, in parallel, a significant increase relative to their initial values was observed: from 24.8 to 30.8% of the dry matter, and from 10.3 to 15.4% of the dry matter, respectively.

The particle size distribution inside the cake (Figure 1) revealed the presence of large particles (above 1 mm), mainly composed of lignocellulosic fibers originating essentially from the sunflower stalk and head, smaller particles (diameter between 500 and 1000 µm), and also fines (diameter inferior to 500 µm). The two last populations contained not only smaller fibers but also spherical particles, from the kernel breakdown process. And, it has to be mentioned that such continuity in particle sizes classically leads to good mechanical properties for composite materials. Apparent and tapped densities of the cake were also measured, and they were 214.5±2.7 and 233.3±1.3 kg/m^3, respectively. In conclusion, it was reasonable to suppose that lignocellulosic fibers would act as effective reinforcing fillers inside thermal insulation fiberboards. Moreover, because the cake oil content was higher than in previous studies (Evon *et al.*, 2010a, 2010b), residual oil in fiberboards would contribute to make them less water-sensitive and also more durable than truly deoiled agromaterials, in spite of their overall hydrophilic character.

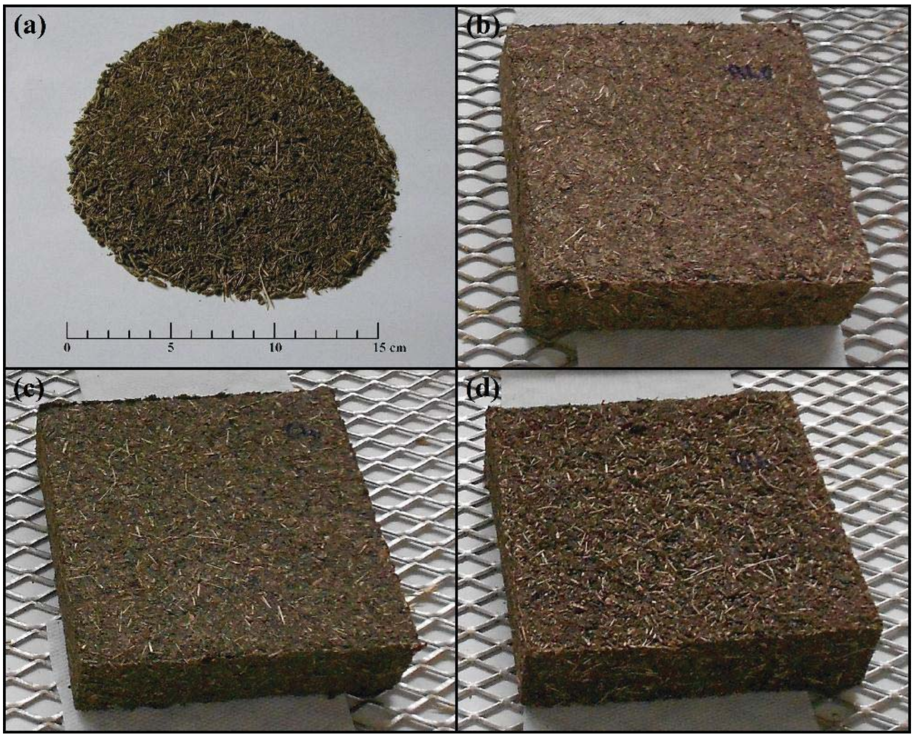

Figure 2. Photographs of the cake (a) and of the three fiberboards with 25% binder content (b, board S4; c, board C4; d, board G4).

3.2 Influence of molding conditions on mechanical properties of fiberboards

Twelve fiberboards were manufactured using different molding conditions (Table 2 and photographs in Figure 2). Conditions included binder type, and binder content. The three different natural binders tested were a starch-based binder (S), casein (C), and gelatin (G). The binder content, in particular, varied from 10 to 25% (w/w). Compression molding was conducted at room temperature (20 °C), and the pressure applied was only 87 kPa. It was significantly lower than for other studies producing self-bonded fiberboards from sunflower cake: from 14.7 to 24.5 MPa (Evon *et al.*, 2014), up to 31.4 MPa (Evon *et al.*, 2010b), from 31.4 to 35.3 MPa (Evon *et al.*, 2012c), and from 24.5 to 49.0 MPa (Evon *et al.*, 2012b). The objective for such a choice was to minimize the density of the materials obtained, in order to manufacture fiberboards with medium-density (from 250 to 450 kg/m^3). Molding time was only 30 s, which was quite similar to values used in two previous studies (30 s and 40 s) (Evon *et al.*, 2010b, 2014). Cake quantity for all the experiments was 1111 mg/cm^2, and this led to the manufacture of thicker fiberboards compared with other materials from sunflower cake described in previous studies (Evon *et al.*, 2010b, 2012b, 2012c, 2014): at least 34.8 mm (and up to 40.6 mm) after climatic chamber conditioning (60% RH, 25 °C) for three weeks (Table 3).

Table 3. Mechanical properties of the twelve fiberboards manufactured by compression molding.

Board	S1	S2	S3	S4	C1	C2
Drying at 80 °C						
Term (h)	36.0	39.5	46.0	51.4	24.3	33.5
Flexural properties						
H_{FB} (%)[1]	$8.0±0.0^{ef}$	$8.3±0.1^{cde}$	$8.6±0.2^{abc}$	$9.0±0.0^{a}$	$8.3±0.2^{de}$	$8.0±0.0^{ef}$
t (mm)	$34.8±0.5^{f}$	$37.1±0.6^{d}$	$38.7±0.7^{c}$	$40.6±1.2^{a}$	$38.3±0.8^{c}$	$37.3±0.5^{d}$
d (kg/m^3)	$338.3±7.6^{e}$	$346.4±6.2^{e}$	$357.9±10.9^{d}$	$375.3±14.3^{c}$	$266.1±4.7^{h}$	$339.6±2.0^{e}$
E (mJ)	$34.9±3.3^{fg}$	$67.4±5.3^{e}$	$127.3±9.9^{d}$	$326.1±37.0^{b}$	$8.3±0.7^{g}$	$50.6±6.0^{ef}$
F (N)	$44.8±5.3^{f}$	$70.7±7.7^{e}$	$104.0±9.2^{d}$	$199.3±13.6^{c}$	$8.9±0.7^{g}$	$49.0±4.0^{ef}$
$σ_f$ (kPa)	$184.6±21.7^{e}$	$256.9±27.9^{de}$	$347.0±30.7^{d}$	$604.4±41.3^{c}$	$30.4±4.5^{f}$	$176.3±14.4^{e}$
E_f (MPa)	$7.0±1.2^{e}$	$9.9±1.3^{d}$	$9.5±1.3^{d}$	$12.9±1.4^{c}$	$0.8±0.1^{f}$	$4.8±0.3^{e}$
Surface hardness						
Shore D (°)	$14.5±1.2^{gh}$	$15.5±1.3^{fg}$	$18.9±1.9^{cd}$	$24.6±3.3^{b}$	$6.7±0.9^{i}$	$13.0±1.4^{h}$

Board	C3	C4	G1	G2	G3	G4
Drying at 80 °C						
Term (h)	45.7	51.3	24.0	26.6	27.1	27.3
Flexural properties						
H_{FB} (%)[1]	$8.3±0.2^{de}$	$7.8±0.2^{f}$	$8.8±0.2^{ab}$	$9.0±0.5^{a}$	$8.8±0.2^{ab}$	$8.5±0.0^{bcd}$
t (mm)	$35.8±1.0^{e}$	$35.5±0.9^{e}$	$37.2±0.6^{d}$	$38.5±0.6^{c}$	$39.9±0.6^{b}$	$39.6±0.3^{b}$
d (kg/m^3)	$394.5±10.9^{b}$	$439.0±14.3^{a}$	$254.9±4.1^{i}$	$270.8±5.2^{h}$	$280.9±3.9^{g}$	$315.1±7.8^{f}$
E (mJ)	$238.0±24.2^{c}$	$356.7±35.3^{a}$	$2.0±0.4^{g}$	$1.8±0.2^{g}$	$3.3±0.5^{g}$	$12.2±1.3^{g}$
F (N)	$252.5±23.9^{b}$	$372.0±35.7^{a}$	$2.8±0.3^{g}$	$3.0±0.4^{g}$	$4.8±0.8^{g}$	$17.6±1.4^{g}$
$σ_f$ (kPa)	$987.0±93.5^{b}$	$1477.7±141.7^{a}$	$10.2±0.9^{f}$	$10.2±1.4^{f}$	$14.9±2.5^{f}$	$55.9±4.6^{f}$
E_f (MPa)	$25.6±2.0^{b}$	$34.4±3.7^{a}$	$0.3±0.1^{f}$	$0.5±0.0^{f}$	$0.5±0.2^{f}$	$1.8±0.2^{f}$
Surface hardness						
Shore D (°)	$17.9±1.4^{de}$	$20.3±2.1^{c}$	$4.8±0.4^{j}$	$13.8±1.8^{gh}$	$16.8±1.8^{ef}$	$27.4±2.3^{a}$

[1] H_{FB} is the moisture content of the fiberboard (%). Fiberboards were equilibrated in a climatic chamber (60% RH, 25 °C) for three weeks before moisture measurements. Means in the same line with the same letter (a-j) are not significantly different at $P < 0.05$.

No particular problem was observed for dissolution in distilled water of the three natural binders, including the highest concentration, i.e. 16.7% (w/v). In the same way, manual mixing of binder solutions with cake plus compression molding did not reveal any difficulty for all the molding conditions tested. The twelve fiberboards manufactured were carefully removed from the aluminium mold immediately after compression molding. And, they were then dried at 80 °C using a ventilated oven to eliminate water added for binder dissolution, i.e. 500 g. The drying duration depended on both binder type and binder content, varying from 24.0 to 51.4 h (Table 3). For starch-based binder and casein, it increased linearly with binder content: from 36.0 to 51.4 h, and from 24.3 to 51.3 h, respectively. In both cases, the increase in binder concentration in distilled water led to a significant increase in binder solution viscosity, and this contributed to slow more and more the water evaporation kinetics. Conversely, the gelatin solutions were all very fluid, including that corresponding to the highest concentration. And, this led to a slower increase in drying duration with the increase in gelatin content: from 24.0 h for board G1 to 27.3 h for board G4.

All fiberboards produced were cohesive mixtures of the natural binder and lignocellulosic fibers, in what could be considered as a natural composite. The natural binder contributed to ensure cohesion of the agromaterial, in addition to the entanglement of lignocellulosic fibers from sunflower cake also acting as reinforcement. Conditioning in the climatic chamber was conducted immediately after compression molding plus drying in order to assess the mechanical and heat insulation properties of fiberboards from equilibrated materials. And, moisture contents of equilibrated boards S1 to S4 increased progressively (from 8.0 to 9.0%) with increasing starch-based binder content, due to the natural hydrophilic character of starch (Table 3). Conversely, moisture contents of equilibrated fiberboards made from casein and gelatin were quite independent on binder content, and they were between 7.8 and 8.3%, and between 8.5 and 9.0%, respectively. And, higher moisture contents for boards G1 to G4 could be explained by their lower densities, compared to the other boards (Table 3). Indeed, during climatic chamber conditioning of fiberboards, water uptake was a little higher for these boards, due to their higher porosity.

The density of the equilibrated fiberboards was greatly affected by the molding conditions used, increasing with increasing binder content (Table 3). For boards using gelatin as binder, it varied from 255 to 315 kg/m^3. And, gelatin was the natural binder producing the least dense boards of the entire study. With the starch-based binder, fiberboards obtained were denser. Indeed, board density was 338 kg/m^3 for the 10% binder content (board S1), and it reached 375 kg/m^3 for the 25% binder content (board S4). The increase in board density with increasing binder content was much more significant with casein, ranging from 266 kg/m^3 for board C1 to 439 kg/m^3 for board C4. And, even if fiberboards made with 10 and 15% casein (i.e. boards C1 and C2, respectively) were less dense than their equivalents made from the starch-based binder (i.e. boards S1 and S2, respectively), it was the opposite for the two highest binder contents tested, i.e. 20 and 25%, respectively. Indeed, for the 20% binder content, density of board C3 was 394 kg/m^3 instead of 358 kg/m^3 for board S3. In the same way, for the 25% binder content, board density reached 439 kg/m^3 with casein (board C4), and it was only 375 kg/m^3 for board S4 that was made from the starch-based binder. And, board C4 was the densest fiberboard of the entire study.

The mechanical properties of fiberboards were also clearly influenced by the molding conditions, and could be correlated to their densities. Indeed, the higher the fiberboard density, the higher its mechanical properties (Table 3). Regarding flexural properties, the energy-to-break, the breaking load, the flexural strength at break and the elastic modulus increased progressively from 2.0 to 356.7 mJ, from 2.8 to 372.0 N, from 10.2 to 1477.7 kPa, and from 0.3 to 34.4 MPa, respectively, with increasing fiberboard density (Table 3 and Figure 3). Similarly, the Shore D surface hardness increased from 4.8 to 27.4°. Thus, the most fragile fiberboard was also the least dense board, and it was board G1. Conversely, the densest fiberboard (C4), was also the most mechanically resistant board of the entire study.

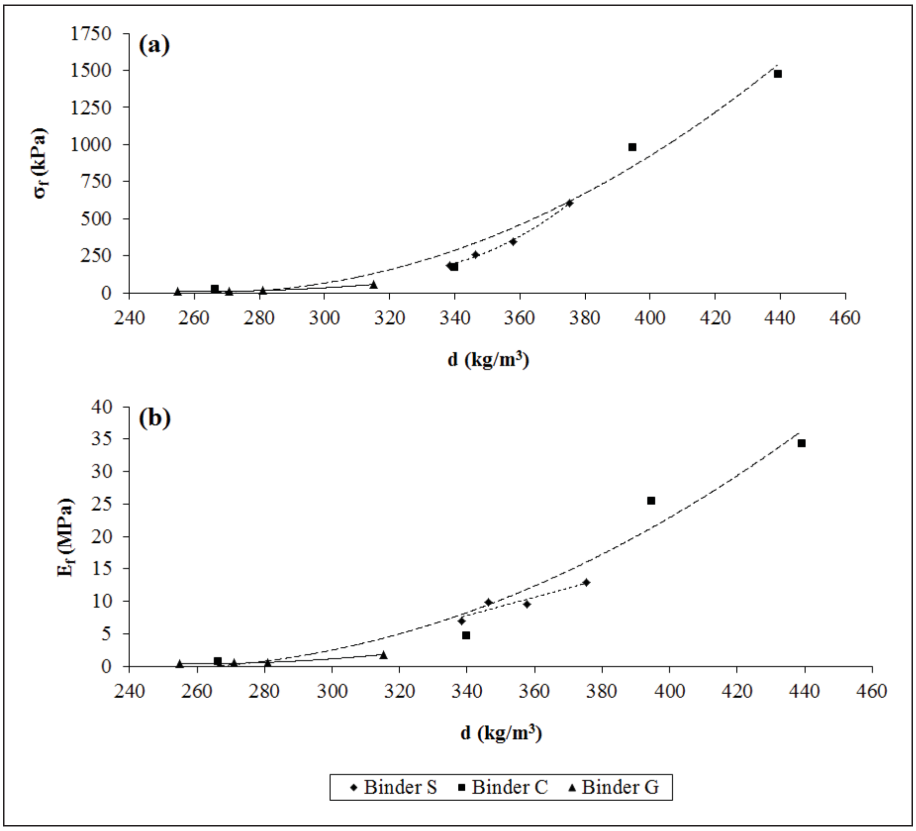

Figure 3. Flexural strength at break (a) and elastic modulus (b) of the twelve fiberboards manufactured by compression molding, as a function of their density.

In conclusion, an improvement in fiber wetting and binding efficiency was logically observed with the increase in binder content for the three natural binders tested, leading to an increase in flexural properties of fiberboards. However, gelatin revealed a very low binding ability, leading to boards G1 to G4 particularly fragile mechanically, including board G4 manufactured from the highest binder content, i.e. 25%. This was probably due to the temperature sensitivity of gelatin during water evaporation (drying at 80 °C using a ventilated oven), leading to its partial thermal degradation. Conversely, the starch-based binder and casein led to much higher mechanical properties. And, if the starch-based binder led to more mechanically resistant fiberboards for the two lowest binder contents (i.e. 10 and 15%), it was casein that generated the best mechanical properties for bending for the two highest binder contents (i.e. 20 and 25%).

3.3 Influence of molding conditions on heat insulation properties of fiberboards

The heat insulation properties of the twelve fiberboards were measured at three temperatures: 10 °C, 25 °C, and 40 °C. As generally observed for thermal insulation solids, the thermal conductivity of the twelve fiberboards tested increased with increasing temperature, with the thermal resistance logically and simultaneously decreasing (Table 4). The same tendency was also observed for measurements made on the bulk cake. Consequently, the capacity for thermal insulation of all the materials tested, decreased noticeably with increasing temperature. The thermal conductivity of the bulk cake and of the twelve fiberboards was also clearly influenced by their density, and it tended to increase with increasing density (Figure 4a). Similar characteristics have been observed on several occasions, in particular for insulation boards made from durian peel and coconut coir (Khedari *et al.*, 2003, 2004), wastes from tissue paper manufacturing and corn peel (Lertsutthiwong *et al.*, 2008), cotton stalk fibers (Zhou *et al.*, 2010), coconut husk and bagasse (Panyakaew & Fotios, 2011), sunflower pith (Vandenbossche *et al.*, 2012), hemp fibers (Benfratello *et al.*, 2013), date palm fibers (Chikhi *et al.*, 2013), and sunflower cake from whole plant (Evon *et al.*, 2014). At the same time, the thermal resistance logically decreased (Figure 4b), and these trends were observed at all three temperatures. However, here we will focus on the 25 °C results, considered as ambient temperature.

Table 4. Thermal conductivity (λ) and thermal resistance (R) at three temperatures (10 °C, 25 °C, and 40 °C) of the bulk cake and of the twelve fiberboards manufactured by compression molding.

Board	Bulk cake	S1	S2	S3	S4	C1	C2	C3	C4
λ (mW/m K)									
10 °C	58.0	71.8	72.6	74.8	79.0	66.0	69.4	78.3	82.3
25 °C	62.0	74.4	75.7	77.6	83.4	67.6	72.1	79.1	84.8
40 °C	64.1	77.0	79.7	81.4	89.6	70.1	76.1	82.1	89.4
R (m^2 K/W)									
10 °C	0.897	0.485	0.511	0.517	0.514	0.581	0.537	0.457	0.431
25 °C	0.839	0.468	0.490	0.499	0.487	0.567	0.517	0.452	0.418
40 °C	0.812	0.452	0.466	0.476	0.453	0.547	0.489	0.436	0.397

Board	G1	G2	G3	G4
λ (mW/m K)				
10 °C	62.3	66.0	66.4	68.5
25 °C	64.0	69.5	71.0	73.1
40 °C	67.0	72.3	74.6	78.1
R (m^2 K/W)				
10 °C	0.598	0.584	0.601	0.578
25 °C	0.582	0.554	0.562	0.542
40 °C	0.556	0.532	0.535	0.507

Thermal conductivity was rather low for the twelve fiberboards (Table 4), due to their medium densities (from 255 to 439 kg/m^3) contributing to better heat insulation properties compared with previous results obtained with denser materials from sunflower cake, i.e. self-bonded fiberboards: from 64.0 to 84.8 mW/m K for thermal conductivity at 25 °C instead of 88.5-110.5 mW/m K with board density between 500 and 858 kg/m^3 (Evon *et al.*, 2014), and 103.5-135.7 mW/m K with board density between 904 and 966 kg/m^3 (Evon *et al.*, 2012c). Moreover, as already mentioned, it decreased with the decrease in board density for each natural binder tested (Table 4 and Figure 4a). It was 84.8 mW/m K for the most dense (439 kg/m^3) fiberboard of the entire study, i.e. board C4, and only 64.0 mW/m K for the least dense one (255 kg/m^3), i.e. board G1. The increase in porosity within the boards thus improved their thermal insulation capacity, and such values were in line with the thermal conductivities of other experimental medium-density insulation boards, made from coconut husk (Panyakaew & Fotios, 2011), cotton stalk fibers (Zhou *et al.*, 2010) or hemp fibers (Benfratello *et al.*, 2013), and considered as viable options for use in building insulation: 46-68 mW/m K (250-350 kg/m^3 for board densities), 81.5 mW/m K (450 kg/m^3 for board density) and 89.9-107.9 mW/m K (369-475 kg/m^3 for board densities), respectively. At the same time, the thermal resistance varied from 0.418 to 0.582 m^2 K/W (Table 4 and Figure 4b).

Because the heat insulation properties of the fiberboards improved with decreasing density (Figure 4), the fiberboard with the weakest thermal conductivity (board G1) also corresponded to the most fragile insulation board (Table 3). Conversely, the most conductive fiberboard (board C4) was also the most mechanically resistant insulation board. Consequently, the medium density (358 kg/m^3) fiberboard from trial S3, i.e. the board containing 20% starch-based binder, was a good compromise between mechanical properties (127 mJ for energy-to-break, 104 N for breaking load, 347 kPa for flexural strength at break, 9.5 MPa for elastic modulus, and 18.9° for Shore D surface hardness) and those for heat insulation (77.6 mW/m K for thermal conductivity at 25 °C, and 0.499 m^2 K/W for the corresponding thermal resistance). And, both properties were significantly improved compared with those obtained in a previous study for the optimal self-bonded insulating board also made from sunflower cake (15 mJ for energy-to-break, 12 N for breaking load, 272 kPa for flexural strength at break, 99.5 mW/m K for thermal conductivity, and 0.161 m^2 K/W for the corresponding thermal resistance) (Evon *et al.*, 2014). Fitted on walls and ceilings, this optimal fiberboard (board S3) could be used for the thermal insulation of buildings, even if it revealed much more important thermal conductivity compared with conventional materials like expanded polystyrene (37.4 mW/m K), rock wool (35.6 mW/m K), or glass wool (35.4 mW/m K) (Vandenbossche *et al.*, 2012). Measurements made on the bulk cake indicated that it was an even better insulation material (only 62.0 mW/m K for thermal conductivity at 25 °C, and 0.839 m^2 K/W for thermal resistance) (Table 4), which was certainly due to its very low bulk density (215 kg/m^3) and to its porous structure. It also would be suitable for the thermal insulation of houses as loose fill in attic spaces.

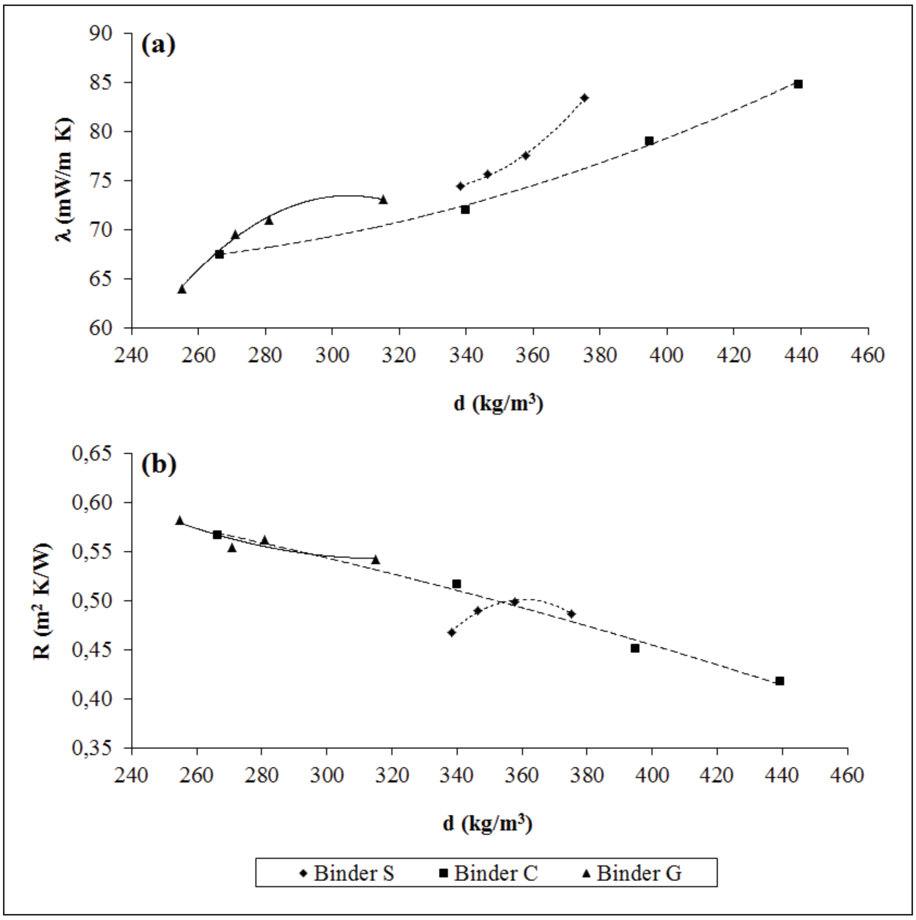

Figure 4. Thermal conductivity (a) and thermal resistance (b) at 25 °C of the twelve fiberboards manufactured by compression molding, as a function of their density.

To conclude, the optimal fiberboard, i.e. board S3, was a natural composite material like all the others, and the external binders used contributed to obtain panels with good cohesion and at the same time with lower density compared with a previous study (Evon *et al.*, 2014), thus contributing to better heat insulation properties. Moreover, the reinforcing fibers inside these panels originated essentially from sunflower stalks and heads, and these fibers are not now commercially available, the sunflower harvest concerning only the seeds. However, their promising ability for both reinforcement of composite materials and thermal insulation could, in the future, justify their harvest in the field at the same time as the seeds. Which in turn could generate an additional source of income for farmers.

4. Conclusion

New thermal insulation fiberboards were manufactured from a cake generated during the biorefinery of sunflower whole plant using a twin-screw extruder. All fiberboards were cohesive mixtures of an external natural binder and fibers from the cake. The binder contributed to ensure the board cohesion, and entanglement of fibers also acted as reinforcement. The molding conditions, i.e. binder type and binder content, had an important influence on board density and on mechanical and heat insulation properties. The density of the insulation materials varied from 255 to 439 kg/m^3. The heat insulation properties improved with decreasing density. The board containing 20% starch-based binder (358 kg/m^3 density) was a good compromise between mechanical and heat insulation properties. Thus, positioned on walls and ceilings, it could be used as thermal insulation in the construction industry. The heat insulation capacity of the bulk cake was even better. It also would be suitable for the thermal insulation of houses when used as loose fill in attic spaces.

References

Alavez-Ramirez, R., Chiñas-Castillo, F., Morales-Dominguez, V. J., & Ortiz-Guzman, M. (2012). Thermal conductivity of coconut fibre filled ferrocement sandwich panels. *Construction and Building Materials*, *37*, 425-431. http://dx.doi.org/10.1016/j.conbuildmat.2012.07.053

Ardente, F., Beccali, M., Cellura, M., & Mistretta, M. (2008). Building energy performance: A LCA case study of kenaf-fibres insulation board. *Energy and Buildings*, *40*, 1-10. http://dx.doi.org/10.1016/j.enbuild.2006.12.009

Benfratello, S., Capitano, C., Peri, G., Rizzo, G., Scaccianoce, G., & Sorrentino, G. (2013). Thermal and structural properties of a hemp-lime biocomposite. *Construction and Building Materials*, *48*, 745-754. http://dx.doi.org/10.1016/j.conbuildmat.2013.07.096

Chikhi, M., Agoudjil, B., Boudenne, A., & Gherabli, A. (2013). Experimental investigation of new biocomposite with low cost for thermal insulation. *Energy and Buildings*, *66*, 267-273. http://dx.doi.org/10.1016/j.enbuild.2013.07.019

Evon, P., Vandenbossche, V., Pontalier, P. Y., & Rigal, L. (2010a). The twin-screw extrusion technology, an original and powerful solution for the biorefinery of sunflower whole plant. *Oléagineux Corps gras Lipides*, *17*, 404-417. http://dx.doi.org/10.1051/ocl.2010.0339

Evon, P., Vandenbossche, V., Pontalier, P. Y., & Rigal, L. (2010b). Thermo-mechanical behaviour of the raffinate resulting from the aqueous extraction of sunflower whole plant in twin-screw extruder: manufacturing of biodegradable agromaterials by thermopressing. *Advanced Materials Research*, *112*, 63-72.
http://dx.doi.org/10.4028/www.scientific.net/AMR.112.63

Evon, P., Rigal, L., Pontalier, P. Y., & Vandenbossche, V. (2012a). Procédé de fabricationd'un matériau solide à partir d'une plante oléagineuse et matériau solide obtenu. *French Patent FR 2 967 689*.

Evon, P., Vandenbossche, V., & Rigal, L. (2012b). Thermo-pressing of cake meal from sunflower whole plant, one only operation for two actions: expression of residual oil and molding of biodegradable agromaterials. In: *Proceedings of the 18th International Sunflower Conference*. Mar del Plata, Argentina; pp. 937-942.

Evon, P., Vandenbossche, V., & Rigal, L. (2012c). Manufacturing of renewable and biodegradable fiberboards from cake generated during biorefinery of sunflower whole plant in twin-screw extruder: Influence of thermo-pressing conditions. *Polymer Degradation and Stability*, *97*, 1940-1947. http://dx.doi.org/10.1016/j.polymdegradstab.2012.01.025

Evon, P., Vandenbossche, V., Pontalier, P. Y., & Rigal, L. (2014). New thermal insulation fiberboards from cake generated during biorefinery of sunflower whole plant in a twin-screw extruder. *Industrial Crops and Products*, *52*, 354-362.
http://dx.doi.org/10.1016/j.indcrop.2013.10.049

Evon, P., Vinet, J., Labonne, L., & Rigal, L. (2015). Influence of thermo-pressing conditions on the mechanical properties of biodegradable fiberboards made from a deoiled sunflower cake. *Industrial Crops and Products*, *65*, 117-126. http://dx.doi.org/10.1016/j.indcrop.2014.11.036

Khedari, J., Charoenvai, S., & Hirunlabh, J. (2003). New insulating particleboards from durian peel and coconut coir. *Building and Environment*, *38*, 435-441. http://dx.doi.org/10.1016/S0360-1323(02)00030-6

Khedari, J., Nankongnab, N., Hirunlabh, J., & Teekasap, S. (2004). New low-cost insulation particleboards from mixture of durian peel and coconut coir. *Building and Environment*, *39*, 59-65. http://dx.doi.org/10.1016/j.buildenv.2003.08.001

Korjenic, A., Petránek, V., Zach, J., & Hroudová, J. (2011). Development and performance evaluation of natural thermal-insulation materials composed of renewable resources. *Energy and Buildings*, *43*, 2518-2523. http://dx.doi.org/10.1016/j.enbuild.2011.06.012

Kymäläinen, H. R., & Sjöberg, A. M. (2008). Flax and hemp fibres as raw materials for thermal insulations. *Building and Environment*, *43*, 1261-1269. http://dx.doi.org/10.1016/j.buildenv.2007.03.006

Lertsutthiwong, P., Khunthon, S., Siralertmukul, K., Noomun, K., & Chandrkrachang, S. (2008). New insulating particleboards prepared from mixture of solid wastes from tissue paper manufacturing and corn peel. *Bioresource Technology*, *99*, 4841-4845. http://dx.doi.org/10.1016/j.biortech.2007.09.051

Mati-Baouche, N., De Baynast, H., Lebert, A., Sun, S., Lopez-Mingo, C. J. S., Leclaire, P., & Michaud, P. (2014). Mechanical, thermal and acoustical characterizations of an insulating bio-based composite made from sunflower stalks particles and chitosan. *Industrial Crops and Products*, *58*, 244-250. http://dx.doi.org/10.1016/j.indcrop.2014.04.022

Nicolajsen A. (2005). Thermal transmittance of a cellulose loose-fill insulation material. *Building and Environment*, *40*, 907-914. http://dx.doi.org/10.1016/j.buildenv.2004.08.025

Paiva, A., Pereira, S., Sá, A., Cruz, D., Varum, H., & Pinto, J. (2012). A contribution to the thermal insulation performance characterization of corn cob particleboards. *Energy and Buildings*, *45*, 274-279. http://dx.doi.org/10.1016/j.enbuild.2011.11.019

Panyakaew, S., & Fotios, S. (2011). New thermal insulation boards made from coconut husk and bagasse. *Energy and Buildings*, *43*, 1732-1739. http://dx.doi.org/10.1016/j.enbuild.2011.03.015

Pinto, J., Paiva, A., Varum, H., Costa, A., Cruz, D., Pereira, S., Fernandes, L., Tavares, P., & Agarwal, J. (2011). Corn's cob as a potential ecological thermal insulation material. *Energy and Buildings*, *43*, 1985-1990. http://dx.doi.org/10.1016/j.enbuild.2011.04.004

Saiah, R., Perrin, B., & Rigal, L. (2010). Improvement of thermal properties of fired clays by introduction of vegetable matter. *Journal of Building Physics*, *34*, 124-142. http://dx.doi.org/10.1177/1744259109360059

Sampathrajan, A., Vijayaraghavan, N. C., & Swaminathan, K. R. (1992). Mechanical and thermal properties of particle boards made from farm residues. *Bioresource Technology*, *40*, 249-251. http://dx.doi.org/10.1016/0960-8524(92)90151-M

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Van Soest, P. J., & Wine, R. H. (1967). Use of detergents in the analysis of fibrious feeds. IV. Determination of plant cell wall constituents. *Journal of AOAC International*, *50*, 50-55.

Van Soest, P. J., & Wine, R. H. (1968). Determination of lignin and cellulose in acid detergent fiber with permanganate. *Journal of AOAC International*, *51*, 780-784.

Vandenbossche, V., Rigal, L., Saiah, R., & Perrin, B. (2012). New agro-materials with thermal insulation properties. In: *Proceedings of the 18th International Sunflower Conference. Mar del Plata*, Argentina; pp. 949-954.

Zhou, X. Y., Zheng, F., Li, H. G., & Lu, C. L. (2010). An environment-friendly thermal insulation material from cotton stalk fibers. *Energy and Buildings*, *42*, 1070-1074. http://dx.doi.org/10.1016/j.enbuild.2010.01.020

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Impact of Border Strip and Flood Method of Irrigation on Wheat Cultivation in the Malaprabha Command Area of Karnataka

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Abstract

A study conducted in the Malaprabha command area revealed that border strip method of irrigation was found better in terms of yield, income and water savings in cultivation of wheat. The crop yield was higher in border strip method of irrigation (28.50 q/ha) over flood (20.90 q/ha). The net returns was also higher in border strip method of irrigation (Rs. 20851.01/ha) over flood (Rs. 8024.92/ha). The highest cost of irrigation was found in flood method of irrigation (Rs. 2898.47/ha) compared to border strip method of irrigation (Rs. 2051.13/ha). The highest water consumption was seen under flood method of irrigation (12.04 ha cm) followed by border strip method of irrigation (8.41 ha cm).

Keywords: Border strip method of irrigation, cost of irrigation, flood irrigation, income, water savings, Wheat, yield

1. Introduction

Land and water are the basic resources for progress in agriculture and economic development of the country. The demand for these two resources has been continuously increasing, since the Country's population is also on rise since five decades, growing population needs to be fed. Hence scientists have already assessed that the water is going to be a major natural critical resource constraint in enhancing the agricultural production.

Malaprabha command comprises the area of a dam across the river Malaprabha, near

Navilutheertha in Belgaum district to provide irrigation to an extent of 2,20,028 hectares in Belgaum, Bagalkot, Gadag, and Dharwad districts. Potential created up to the end of May 2010 was 2,13,537 hectares. Cumulative financial and physical progress upto the end of March 2011 were Rs. 1172.36 crores and 2, 13,537 ha respectively. There are two different water management practices being practiced by peasants in cultivation of wheat in the Malaprabha command area, such as flood and border strip method of irrigation. Out of them first one is traditional and other is scientific. Flood irrigation is an ancient method of irrigation and has so many problems with respect to water loss and yield reduction. Thus to overcome the problems of traditional water management practices, the adoption of scientific water management (border strip method of irrigation) practice gains greater attention.

Wheat is a world's number one cereal in area. Wheat is a crop highly responds to irrigation. Hence the water should be applied optimally through scientific irrigation methods. The water use should aim at securing the maximum crop production per unit of water and sustaining soil health. Thus the present paper aims to analyse the impact of scientific water management practice in the cultivation of maize over the traditional water management practice.

2. Research Methodology

The present study was conducted in Malaprabha Command Area of Karnataka. Hebsur, Kumargoppa, Kanakikoppa, Guralikatti, Hunasikatti, Mugnur and Naragund villages of Malaprabha command area were purposively selected since the interventions on scientific water management practices were implemented in these villages under RKVY project.

The major traditional irrigation method followed by the farmers in the cultivation of wheat in the study area was flood method whereas; scientific method was border strip method of irrigation which was recommended by the project officials. Thus from each village five farmers practicing each methods were selected randomly, thus the total sample size was 70 and method wise sample size was 35.

Budgeting technique was followed for estimating the cost, returns, water savings, profits of crop grown in various water management practices and average income from wheat crop.

3. Results and Discussion

Inputs used per hectare of wheat cultivation in the study area are presented in Table 1 indicates that, the average per hectare utilization of human labour was highest in the case of border strip method of irrigation (78.53 man days/ha) followed by flood method of irrigation (74.15 man days/ha). With respect to bullock labour, the highest consumption was seen in the case of flood irrigation (8.35 pair days/ha) followed by border strip method of irrigation (7.23 pair days/ha). The highest tractor labour was utilized in border strip method of irrigation (6.85 hours/ha) followed by flood method of irrigation (5.43 hours/ha). Most of the farmers in both the methods of irrigation used bullock labour because use of bullock labour worked out to be cheaper than tractor labour use. The study is in conformity with the results of Pavankumar (2011). The average per hectare utilization of seeds was highest in the case of flood method of irrigation (129.43 kg/ha) followed by border strip method of irrigation (129.28 kg/ha). The average quantity of farmyard manure (FYM) applied per hectare was highest in the case of border strip method of irrigation (1.08 tonnes/ha) as compared to flood method of irrigation (1.05 tonnes/ha). The fertilizers applied per hectares was highest in case of border strip method of irrigation (257.18 kg/ha) followed by flood method of irrigation (252.16 kg/ha). Among the different inputs used, the average per hectare utilization of human labour was highest in case of both the methods of irrigation because most of the operations such as harvesting and weeding were human labour intensive. The study is also supported by Pavankumar (2011).

The highest yield was obtained in the case of border strip method of irrigation (28.50 q/ha) followed by flood method of irrigation (20.90 q/ha). The average quantity of wheat by product was also highest in the case of border strip method of irrigation (25.73 q/ha) followed by flood method of irrigation (20.50 q/ha). The study is also supported by the Manasa (2010).

Table 1. Input use pattern and output obtained in Wheat cultivation under different irrigation methods

(Per ha)

Sl. No.	Particulars	Units	Flood (n=35)	BSI (n=35)
1.	Human labour	Man days	74.15	78.53
2.	Bullock labour	Pair days	8.35	7.23
3.	Tractor labour	Hours	5.43	6.85
4.	Seeds	Kgs	129.43	129.28
5.	Farm yard manure	Tonnes	1.05	1.08
6.	Fertilizers			
	Urea	Kgs	118.72	129.16
	DAP	Kgs	133.44	128.02
	Complex	Kgs	-	-
	Total	Kgs	252.16	257.18
7	Cost of Irrigation	Rs.	2898.47	2051.13
8	Main Product	Qtls.	20.90	28.50
9	By-product	Qtls	20.50	25.73

Note: BSI- Border Strip Irrigation

The cost incurred and returns realized from wheat cultivation were calculated and are presented in Table 2. Among the different methods of irrigation, the total variable cost incurred per hectare in border strip method of irrigation was the highest (Rs. 29359.58/ha) followed by flood method of irrigation (Rs. 27842.29/ha) because in border strip method of irrigation the cost of human labour, bullock labour and tractor labour was higher as compared to flood irrigation method.

The distribution pattern of operational cost under various inputs revealed that the cost of human labour was highest in case of border strip method of irrigation (Rs. 12337.98/ha) followed by flood method of irrigation (Rs. 11653.28/ha). This is because in border strip method of irrigation, yield obtained was more than the yield obtained in traditional method which required more units of human labour for harvesting and post harvest activities where as bullock labour cost was highest in case of border strip method of irrigation which was Rs. 3075.75/ha followed by flood method of irrigation (Rs. 2803.18/ha). The cost of machine labour was highest in case of border strip method of irrigation (Rs. 4114.28/ha) followed by flood method of irrigation (Rs. 2714.28/ha). The cost of seeds was highest in case of flood method of irrigation (Rs. 1941.43/ha) followed by border strip method of irrigation (Rs. 1907.85/ha). The cost of FYM was highest in the case of border strip method of irrigation (Rs. 439.31/ha) followed by flood method of irrigation (Rs. 427.11/ha) and expenditure on fertilizers applied per hectare in the study area was also highest in case of flood method of irrigation (Rs. 3828.58/ha) followed by border strip method of irrigation (Rs. 3771.43/ha).

The irrigation method wise analysis indicated that the fixed cost incurred per hectare in case of border strip method of irrigation was high (Rs. 8186.53/ha) as compared to flood method of irrigation (Rs. 7952.63/ha). Among the different items of fixed costs, rental value of land was the highest in both the methods. In case of flood method of irrigation it was Rs. 4791.90/ha and in case of border strip method of irrigation it was Rs. 4831.55/ha. The other items like land revenue, depreciation charges and interest on fixed cost are of minor importance.

Among the two methods of irrigation the total cost incurred in the border strip method of irrigation was highest (Rs. 37546.11/ha) as compared to flood method of irrigation (Rs. 35794.91/ha) as the cost of human labour, bullock labour and machine labour was more which ultimately resulted in high cost of cultivation in border strip irrigation method. The gross returns and the net returns were high in case of border strip method of irrigation.

The irrigation method wise analysis of gross returns indicated that the gross returns obtained per hectare in border strip method of irrigation was high (Rs. 58397.12/ha) as compared flood method (Rs. 43819.83/ha). With respect to net returns also, the per hectare net returns obtained in border strip method of irrigation was high (Rs. 20851.01/ha) as compared to flood method (Rs. 8024.92/ha). Thus, cultivation of wheat crop in the study area found to be highly profitable in border strip method of irrigation as also supported by a high magnitude of returns per rupee investment (1.56) as compared to flood method of irrigation (1.22). The study is in conformity with the results of Manasa (2010).

Table 2. Cost and returns structure of Wheat cultivation under different irrigation methods

(Per ha)

Sl. No.	Particulars	Units	Flood (n=35)	BSI (n=35)
1.	Human labour	Rs.	11653.28	12337.98
			(32.56)	(32.86)
2.	Bullock labour	Rs.	2803.18	3075.75
			(7.83)	(8.19)
3.	Tractor labour	Rs.	2714.28	4114.28
			(7.58)	(10.96)

4.	Seeds	Rs.	1941.43	1907.85
			(5.42)	(5.08)
5.	Farm yard manure	Rs.	427.11	439.31
			(1.19)	(1.17)
6.	Fertilizers	Rs.	3828.58	3771.43
			(10.70)	(10.04)
8	Cost of Irrigation	Rs.	2898.47	2051.13
			(8.10)	(5.46)
9	Interest on working capital	Rs.	1575.98	1661.86
			(4.40)	(4.43)
	Total variable cost (A)	**Rs.**	27842.29	29359.58
			(77.78)	(78.20)
10	Irrigation charge	Rs.	100	100
			(0.28)	(0.27)
11	Land revenue	Rs.	30	30
			(0.08)	(0.08)
12	Rental value of land	Rs.	4791.90	4831.55
			(13.39)	(12.87)
13	Interest on fixed capital	Rs.	1905.20	1966.08
			(5.32)	(5.24)
14	Depreciation	Rs.	1125.53	1258.90
			(3.14)	(3.35)
	Total fixed costs (B)	Rs.	7952.63	8186.53
			(22.22)	(21.80)
	Total cost of cultivation (A+B)	**Rs.**	35794.91	37546.11
			(100)	(100)
15	Main Product	Qtls.	20.90	28.50
		Rs./q	1631.43	1602.86
16	By-product	Qtls	20.50	25.73
		Rs./q	474.29	494.29
17	Total Returns	Rs.	43819.83	58397.12
18	Net returns	Rs.	8024.92	20851.01
19	Returns per rupee investment		1.22	1.56

Note: A - Total variable costs

B - Total fixed costs

Figures in the parentheses indicate percentage to total

BSI- Border Strip Irrigation

Table 3 indicates that per hectare crop yield was highest in case of border strip method of irrigation (28.50 q/ha) followed by flood method of irrigation (20.90q/ha). The farm income was also found to be highest in case of border strip method of irrigation (Rs. 20851 /ha) followed by flood method of irrigation (Rs. 8024/ha). The per hectare water applied for the crop was lowest in case of border strip method of irrigation (8.41 ha cm) as compared to the flood method of irrigation (12.04 ha cm). The study is also supported by the Manasa (2010), Webber *et al* (2006), Shirahatti *et al* (2001) and Enda Antony and Singandhupe (2004).

Table 3. Impact of different irrigation methods on yield, farm income and water savings in wheat

(Per ha)

Sl. No	Particulars	Flood method			BSI			Per cent change (Flood & BSI)		
	Crop	Yield (q/ha)	Income (Rs. /ha)	Wa (ha cm)	Yield (q/ha)	Income (Rs. /ha)	Wa (ha cm)	Yield (%)	Income (%)	Wa (%)
1	Wheat	20.90	8024	12.04	28.50	20851	8.41	26.67	61.51	30.17

Note: Wa: Water applied

BSI: Border Strip Method of Irrigation

4. Conclusion and Recommendations

The objective of the intervention in the command area was to ensure better utilization of water available in the canal to grow the crops to improve the productivity and thereby increase the income and standard of living of farm families, who were dependent on the canal irrigation. Therefore, the farmers of the command area could cultivate crops under improved methods of irrigation which will not only save irrigation water, but at the same time generate more remunerative yields and more farm income.

Due to poor canal distribution network structures, owing to inadequate maintenance and repairs, the farmers were facing water shortages, in time and required quantity. Because of the shortage of water and no surety of water supply in time, the farmers were flooding the farms whenever they get water with more quantity of water which results in surface runoff and other soil related problems. Thus, on farm development, adoption of border strip method of irrigation and maintenance of canals needs to be taken up for more efficient use of water. There is necessity to convince the farmers regarding the efficiency of this water saving technology in the command area. It is necessary to give more stress on such aspects during the meeting of canal water users. Water used for irrigation was more in flooding in cultivation of wheat while it was reduced in improved method of irrigation (Border Strip Method of Irrigation), and also there was increase in yield, income and water savings in improved methods. So there is need to impart technical know-how to the farmers of the command area.

References

Anonymous, (2007). Report of the Steering Committee on Water Resources for Eleventh Five Year Plan (2007-2012), Government of India, Planning Commission

Enda, A., & Singandhupe, R. B. (2004). Impact of drip and surface irrigation on growth, yield and WUE of capsicum (Capsicum annum L.). J. Agric. *Water Mngt., 65,* 21-132.

Manasa, P. B. (2010). Water use efficiency in different irrigation methodsin tank commandsa management. M. Sc. (Agri.) Thesis, Univ. Agric. Sci., Dharwad, Karnataka (India).

Pavankumar. (2011). Economics of Bt. Cotton cultivation – a comparative analysis across different farm sizes in northern transitional zone, Karnataka. M. Sc. (Agri.) Thesis, Univ. Agric. Sci., Dharwad.

Shirahatti, M. S., Itnal, C. J., & Mallikarjunappa Gouda, D. S. (2001). Comparison of drip and furrow irrigated cotton on a red soil. Proc. Intl. Conf. on Micro and Sprinkler System, 659-656.

Webber, H. A., Madramootoo, C. A., Bourgault, M., Horst M. G., Stulina, G., & Smith, D. L. (2006). Water use efficiency of common bean and green gram grown using alternate furrow and deficit irrigation, *Agric. Water Mngt., 86*(3), 259-268.

Time Matters: Effectiveness of Steaming Times on Forage for Animal Consumption

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Abstract

The goal of this research is to determine the effectiveness of portable hay steamer equipment for horse owners averaging 1-15 head. Hay is a large portion of horses' diets, but it has a short shelf life. Dust from hay also becomes a problem due to respiratory diseases. There is a need for a healthier alternative for storing and feeding hay in order to promote optimum animal health. This study tests the effectiveness of four steaming times on the cleanliness of high-quality, Bermuda hay in the portable steamer. Swabs were taken from pre and post-steaming hay samples and incubated on nutrient agar plates at 37 degrees Celsius for 24 hours. After incubation, bacterial colonies were counted to compare the change in bacteria present from before and after the steaming process. Using a two-sample mean difference tests, we found steaming time had a significant impact on the cleanliness of hay.

Keywords: animal health, hay-steaming, Chronic Obstructive Pulmonary Disease (COPD)

1. Introduction

Hay is considered to be a large portion in the diets of horses due to the nutritional value of the forage (American Association of Equine Practitioners, 2002). Although hay is an important component, it has a short shelf life before quality begins to deteriorate or become susceptible to contaminants. Once a bale of hay sits for a period of time, bacteria will grow and mold will be apparent. Dust from hay also becomes a problem contributing to respiratory diseases (James, 2009). There is a need for a healthier alternative for storing and feeding hay in order to promote optimum animal health and well-being.

There are common respiratory diseases among species of animals similar to those in humans. A major factor contributing to the onset of illness or disease is the environment in which the animal lives. For most horses, the environment consists of a stable and pasture. Allergies developed in horses are often due to mold, dust, or airborne particles (Jean Hofve, 2007). Common sources of these include hay fed to the horse and straw used for bedding (Clarke, 1992). Mucus secretions induced by these particles will cause coughing and snorting, which will lead to inflammation and swelling. Airways may become partially blocked and smooth muscles constrict along the passage into the lungs resulting in excessive wheezing and coughing (Jean Hofve, 2007). Over time, this hypersensitive reaction reoccurs as a condition called Chronic Obstructive Pulmonary Disease, COPD (Blackman & Moore-Colyer, 1998).

COPD accounts for half of the lung diseases present in performance horses. COPD is also referred to as "heaves", "broken wind", and "equine asthma" due to the labored breathing seen in animals affected (PM, DI, & BC, 1995). "Farmer's lung" is a human disease often compared to COPD in horses due to their similarities, which also is associated with inhaling dust from moldy hay (Gregory & Lacey, 1963). In matters of quality, allergen-containing particles do not discriminate. All types of hay (even that of excellent quality) contain bacteria, mold, and fungal spores, which cannot be seen by the naked eye (Eduard, Lacey, Karlsson, Palmgren, & Blomquist, 1990). A damp and humid environment provides perfect conditions for bacteria to thrive, further contaminating the air. Figure 1 shows the distribution of mold spores in hay fed to animals in the United States. While in the stable, horses continually inhale particles, which can develop or worsen existing COPD (Jean Hofve, 2007).

Although hay is a vital feedstuff in animal nutrition, the pathogens it contains are hazardous to the health of animals (as well as owners) and must be managed. Improving ventilation of the stable or barn is limited in its effects on actually producing "cleaner air". Blackman and Moore-Colyer explain that improved ventilation does not eliminate the dust particles from the animal's breathing zone. In order to improve the quality of air, the source of the particles must be changed (Blackman & Moore-Colyer, 1998). Soaking hay for a short period of time in order to eliminate dust is a practice adopted by some horse owners. However, soaking hay nets have been observed to leach nutrients (Blackman & Moore-Colyer, 1998) and produce large amounts of wastewater (Warr & Petch, 1992). In a study comparing soaked hay to steamed hay, Blackman and Moore-Colyer described the use of steaming hay as an alternative to soaking due to its ability to reduce the amount of hazardous particles (Blackman & Moore-Colyer, 1998). A more recent study suggests that the HayGain Hay Steamer is effective at significantly reducing dust particles as well as producing a palatable product that does not alter an animal's feed intake (Moore-Colyer & James, 2009).

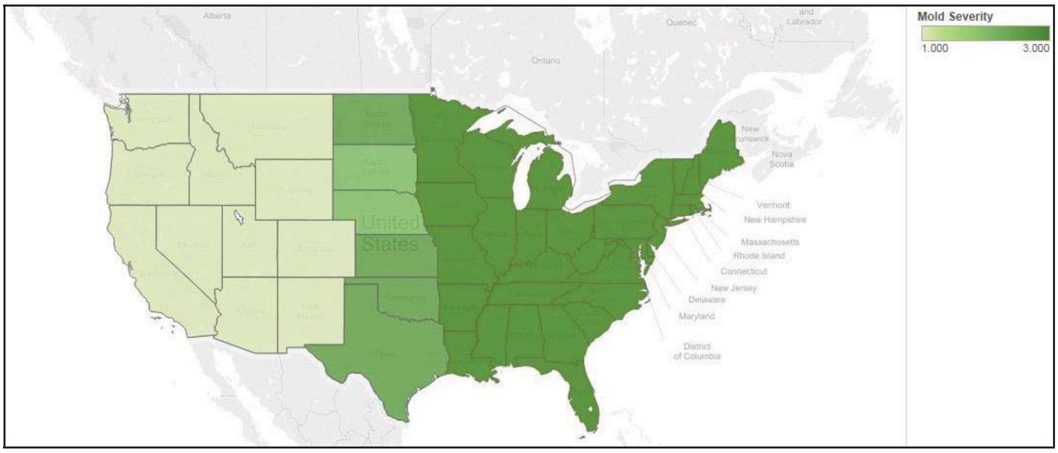

Figure 1. Mold distribution in the United States during summer months (Jean Hofve, 2007).

The goal of this research is to determine the overall effectiveness of portable hay steamer equipment for equine owners and the appropriate duration of steaming. The effectiveness of this product will impact the health of animals consuming sterilized hay. During this research, hay from two different bales was steamed using the HayGain portable hay steamer. Four trials were conducted with steaming times of: 45, 60, 75, and 90 minutes. Pre-steam and post-steam samples were collected. Bacteria colonies were counted and pre samples were compared to post samples to determine the effectiveness of the steamer at different time intervals. Elimination of the majority of bacteria colonies was expected after steaming.

2. Materials and Methods

Two bales of Bermuda hay were obtained from the same source to limit variability of different grades of hay. In order to compare water gain to bacterial growth in the bales of hay, the half-bales were weighed both before and after steaming. For the first trial, half of the first bale was weighed and the measure was recorded.

Maintaining a systematic, clean collection and plating procedure was of the utmost importance. This was achieved through various applications of aseptic technique to minimize contamination. Samples from the bale needed to be from different locations within the bale in order to observe effectiveness of steam throughout the whole bale. Three samples were taken from the half-bale by placing a sterile bag over the hand and reaching into the bale. Once the hay was grasped, the sterile bag was folded from the hand and sealed to reduce contamination from the steamer to the laboratory. The steamer was sanitized with alcohol solution applied by a clean washcloth. This ensures that bacterial growth, mold, or contamination was present in the hay and not the steamer itself.

The half-bale of hay was placed into steamer bags and secured. After the HayGain steamer signals to start, the bale was steamed for desired durations of 45, 60, 75 and 90 minutes, respectively. Following steaming, the bale was weighed and the weight was recorded. Three more samples were taken using the same procedure outlined previously. Samples were delivered to the lab within ten minutes of taking the sample because bacterial growth can be achieved in approximately 20-30 minutes given optimal growth conditions. Following each trial, the steamer was rinsed with water and sanitized with isopropyl alcohol prior to the next use to maintain the same conditions for each trial.

For both pre and post samples, nutrient agar plates were inoculated using aseptic technique. The nutrient agar provided favorable ingredients needed for a number of different bacteria to grow. Students working in the lab twisted the cap off of a test tube filled with sterile water, and passed the opening of the test tube over hottest part of Bunsen burner flame (approximately 2-3 seconds) to achieve sterilization. A sterile swab was dipped into the sterile water and the tube is passed back through the flame and capped. Wet swab was used to swab the sample in desired sample bag and streak ¼ of the nutrient agar plate. Swab was discarded in a disinfectant solution to control a safe working environment. An inoculating loop was flame sterilized to avoid contamination from the environment and used to pull a new streak from the original ¼ of the plate. This was repeated twice until the full surface area of the plate was streaked.

Dilution of the original sample by this method provided a clearer view of bacterial colonies in order to count them. The final ¼ of the streaked plate was marked and was used to determine the bacterial colony count. This process is repeated for 15 pre and post samples taken for four trials providing a total of 30 observations for each time trial. A temperature of 37ºC was chosen because this is approximately the internal temperature where growth would be likely to occur in horses' nostrils and lungs. Inoculated plates were incubated for 24 hours and colony counts were recorded. Pictures were taken to document results and data was entered into an Excel spreadsheet. Afterwards, all samples and plates were autoclaved to sterilize the materials, and were discarded safely.

2.1 Data

The four trials (45, 60, 75, and 90 minutes) produced 15 data points for pre-samples and 15 data points for post-samples. This yielded a total sample size of 120 observations. These observations are listed below in Table 1. This table provides the bacterial colony count for each trial, the mean colony count, and variance.

Table 1. Summary Colony Count Data for All Four Trials

45-Minute Trial		60-Minute Trial		75-Minute Trial		90-Minute Trial	
Pre Sample Mean	Post Sample Mean	Pre Sample Mean	Post Sample Mean	Pre Sample Mean	Post Sample Mean	Pre Sample Mean	Post Sample Mean
17.27	1.53	0.47	0.67	0.73	0.0	15.27	4.27
Variance	Variance	Variance	Variance	Variance	Variance	Variance	Variance
249.78	4.84	0.70	3.24	0.78	0.0	80.78	11.64

Two bales of Bermuda hay were used. The 45 and 90-minute trials used bale 1, while the 60 and 75-minute trials used bale 2. One aspect of the data that becomes immediately clear is the pre-sample data differs considerably across bales. To the naked eye, these bales appeared identical and were obtained through the same source. Pre-sample data indicated that the second bale had a considerably lower initial bacteria count.

From bale 1, the pre-sample mean bacteria count of the 45-minute trial was 17.27 and the 90-minute trial was 15.27. The mean bacteria count from bale 2 was considerably lower with a mean bacteria count for the 60-minute trial of 0.47 and the 75-minute trial was 0.73. Based on these figures, it is expected that in Tables 1 also showed a higher variance for those trials from bale 1 compared to bale 2. Notably, the 90-minute trial did include one significant outlier. While the mean bacteria count for this trial's pre-sample was 15.27, there was one observation that totaled 120.

Post-sample data showed a reduction in the mean post-sample bacteria count for all but the 60-minute trial. From bale 1, the mean post-sample bacteria count for the 45-minute trial was 1.53 and the 90-minute trial was 4.27. From bale 2, the mean post-sample bacteria count for the 60-minute trial was 0.67 and the 75-minute trial was 0.00. Again, we can see that the mean bacteria count associated with bale 2 was lower than that of bale 1. Within the trials, Table 1 showed the 60-minute had one unusual observation of 7.

2.1.1 Statistical Methods

Based on the sample means and variances from Table 1, there is a significant difference in the means between the pre and post sample. Specifically, we want to determine whether steaming results in a reduction in bacteria count. Our testing hypothesis is

$$H_0 : \mu_1 \leq \mu_2 \quad (1)$$

$$H_1 : \mu_1 > \mu_2$$

where μ_1 is the pre-sample population mean and μ_2 is the post-sample population mean.

The method by which we test this hypothesis is a two-sample difference of means test.

Equation 2 shows the exact equation used in this computation:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \tag{2}$$

This method is a t-test that compares the pre-sample mean $\bar{x}_1$ to the post-sample mean $\bar{x}_2$. In the denominator, we find the sample variance (s^2) and sample size (n^2) for the pre and post samples. The degrees of freedom used determine the critical values for this test statistic are

$$df = Min(n_1 - 1, n_2 - 1) \tag{3}$$

Compared to other similar methods of testing mean differences, this method does not assume equal variances. This method was selected because it is the more conservative test statistic formula because it involves minimal assumptions and is the preferred method when working with small sample sizes. While we minimize the assumptions made when calculating the test statistic, we do make simplifying assumptions for the degrees of freedom. According to Doane and Seward (2007), equation 3 is a suitable approximation to the Welch-Satterthwaite adjusted degrees of freedom. We perform this test for each of our four trials containing 15 pre and post observations.

2.1.2 Results

Longer durations of steaming do not appear to significantly reduce the population of bacteria in our experiment. Trial four was the longest duration of steaming in our experiment (90 minutes) and we can conclude at 90% confidence that the bacteria colony count was reduced. The results from the remaining trials largely indicate improved performance of the steamer. Trials one (45 minutes) and three (75 minutes) indicate significant reductions in bacteria colony counts. In both trials, we can conclude at 99% confidence that steaming reduced the bacteria count in the hay. Relatively, trial one had a greater reduction in bacteria than trial three. This can be explained by the fact that bale one had a much larger population of bacteria prior to steaming, while bale two was a much cleaner bale of hay with pre samples showing very little to no bacteria present prior to steaming.

While trial one displayed the greatest mean difference in colony count, the hay was sampled from the bale that contained a larger population of bacteria. Therefore, there is greater opportunity for improvement with regards to cleanliness in trials one and four. Conversely, trial two (60 minutes) was the only trial that did demonstrate a statistically significant reduction in bacterial growth. Bale two was used for this trial and therefore allows for more limited improvements in cleanliness. The post-steaming sample for trial two indicated that the bacteria count remained near zero following one hour of steaming. With regards to time, it appears from our limited number of trials that there is a diminishing return to the duration of steaming following 75 minutes.

In addition to changes in bacteria count within time trials, we compared the impact of different steaming times on the same bale of hay. With this test, we compared the reduction in bacteria found in trials two and three and found evidence at 95% that steaming produced a greater reduction in bacteria at 75 minutes than 60 minutes in bale 2. We also tested the change in bacteria count for the 60 and 90 minutes trials performed on bale 1. Surprisingly, we found evidence at 99% significance that the 60-minute trial produced a larger reduction in bacteria count than the 90-minute trial.

Table 2. Results of Two-Sample Mean Difference Test and Critical Values

	Mean	Variance	T-Statistic
45-Minute Trial			
Before	17.27	1.53	3.82
After	249.78	4.84	
60-Minute Trial			
Before	0.47	0.70	-0.39
After	0.67	3.24	
75-Minute Trial			
Before	0.73	0.78	3.21
After	0.00	0.00	
90-Minute Trial			
Before	15.27	80.78	1.45
After	4.27	11.64	
Critical Values: 1.345 (90%), 1.761 (95%), 2.624 (99%)			

3. Conclusions

By using a hay steamer, owners of livestock and equine can offer a healthier and safer alternative feed compared to hay exposed to quality decreasing variables. Hay quality changes due to methods of storage, time harvested, and other environmental variables. This experiment has shown that the portable hay steamer does have an impact on bacteria colony count which is beneficial to owners.

It is not economically feasible to discard hay due to mold or other undesirable qualities. Using a hay steamer offers an opportunity for owners to use stored hay that has been exposed to more variable conditions and gives a possible solution to help manage negative effects on the health of their animals due to mold. The use of a hay steamer is most beneficial when used on hay that is heavily populated with bacteria. The marginal benefit to using the steamer on fresh, clean bales is lower; however, the hay steamer can act as an insurance policy for the owner since one cannot tell the damage done by external factors on a microscopic level.

One issue that was not addressed in the current research is the scalability of steaming. Specifically, what is the quantity of hay to be steamed in each batch to ensure maximum efficiency of the steamer? Future research is needed to determine the points of maximum temperature in the steamer and calculate the amount of hay required to reach this capacity.

With the use of a hay steamer, animal owners can reduce costs associated with discarding hay and possibly increase performance and the health of their animals. Owners will not only be able to utilize their left over hay; but they will be able to utilize it in a simple, cost effective way. The hay steamer is most efficient at a short span of steaming time, 45-75 minutes. Longer steaming time does not improve efficiency past 75 minutes. There is very little labor involved in using the hay steamer and it is simple to use which makes it desirable to those who own smaller operations. By using a hay steamer, the owner can provide good quality hay, which will benefit the health of their animals as well as eliminate costs associated with wasted hay.

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References

Blackman, M., & Moore-Colyer, M. J. (1998). Hay for horses: the effects of three different wetting treatments on. *Animal Science*, 745-750.

Clarke, A. (1992). Environmental monitoring in relation to Current Therapy in Equine Medicine, 310-315.

Doane, D. P., & Seward L. E. (2007). Applied Statistics in Business and Economics, McGraw-Hill Irwin, 406-407.

Eduard, W., Lacey, J., Karlsson, K., Palmgren, U., & Blomquist, G. (1990). Evaluation of methods for enumerating microorganisms in filter samples from highly contaminated occupational environments. American Industrial Hygiene Association, 427-436.

Gregory, P. H., & Lacey, M. E. (1963). Mycological examination of dust from moldy hay associated with farmer's lung disease. Journal of General Microbiology, 75-88.

Hofve, J. (2007). Respiratory Conditions in Horses. [Online] Equina Wellness, Available: http://www.equinawellness.com/equine-respiratory.htm (July 30, 2015)

Moore-Colyer, M., & James, R. (2009). The effect of steam treatment on the total viable count, mold and yeast numbers in hay using the Haygain Hay Steamer. Cirencester, Gloucestershire: Royal Agricultural College GL 7 6JS. [Online] Available: https://www.smartpakequine.com/pdfs/products/haygaintheeffectofsteamtreatment.pdf (July 30, 2015)

PM, D., DI, R., & BC, M. (1995). Equine pulmonary disease: a case control study of 300 referred cases. Part 1: Examination techniques, diagnostic criteria and diagnoses. Equine Vet Journal, 416-421.

Warr, E., & Petch, J. (1992). Effects of soaking hay on its nutritional quality. Equine Veterinary Education, 169-171.

Food Security

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Abstract

Global food security is one of the most unrelenting issues for humanity, and agricultural production is not sufficient in accomplishing this. However, earlier analyses of agricultural food production barely ever bring out the contrasts associated with economic development and different climatic zones. The world population is increasing day by day and climate change will be causing more extreme weather, higher temperatures and changed precipitation. The crop contributes about 20 % of the total dietary calories and proteins globally. There is 1% annual growth in food demand in the developing regions. The developing regions (including China and Central Asia) account for roughly 53 % of the total harvested area and 50 % of the production. Although, unmatched productivity growth from the Green Revolution since the 1960s dramatically transformed world food production, benefitting both producers and consumers through low production costs and low food prices. One of the key challenges today is to replace today's food system with new ones for better sustainability. While the Green Revolution freed essential ecosystems from conversion to agriculture, it also created its own ecological problems. Moreover productivity increase is now slow or stagnant. Attaining the productivity gains needed to ensure food security will therefore require more than a repeat performance of the Green Revolution of the past. Future demand will need to be achieved through sustainable intensification that combines better crop resistance plants, adaptation to warmer climates, and less use of water, fuel, fertilizer, and labor. Meeting these challenges will require concerted efforts in research and innovation to develop and set up feasible solutions. Necessary investment will be required to realize sustainable productivity growth through better technologies and policy and institutional innovations that facilitate farmer adoption and adaptation. The persistent lessons from the Green Revolution and the recent efforts for sustainable escalation of food systems in South Asia and other developing nations will definitely providing useful insights for the future.

Keywords: Food security; Climate change, Hunger; Green revolution, Food nutrition

1. Introduction

In many under developed countries like in Indonesia, Cambodia, Bolivia and Nepal the daily undernourishment is a common form of hunger. In these countries and many LDC's (least developed countries) hunger is much more than an empty stomach. The recommended 2,100 kilocalories is an average person needs to lead a healthy life but the hunger victims live for weeks, even months less than the recommended 2,100 kilocalories.

However, hunger weakens the immune system, slowing down physical and intellectual actions. A hungry mind cannot think properly, a hungry body is no longer in active state, a hungry child loses all desire to play and study. As a result of hunger and deprived of the nutrition, hungry children are especially vulnerable and become too weak to fight off disease and may die from common infections like measles and diarrhea. Each year, almost 7 million children die before reaching the age of five; malnutrition is a key factor of these deaths.

Hunger and malnutrition are considered to be one of the greatest health risk worldwide even greater than AIDS, malaria and tuberculosis combined. According to an estimate by WFP (world food programme), there are 805 million undernourished people in the world today. The number of people do not get enough food to be healthy and lead an active life is about one in nine. Solving hunger is a "best buy" in today's tough economy. To solve hunger many nations are working together which also results in providing good nutrition, they are also increasing productivity and creating economic opportunities. On the other hand, studies have shown that countries lose millions of dollars in economic output as a result of child under nutrition. Also, peace and stability comes with solving hunger. When governments can no longer guarantee adequate food supplies, states are prone to fall. Instability on food markets can quickly translate into unpredictability on the streets. Lastly, solving hunger also helps in progress in many other areas of improvement, including health and education. Also, a well-nourished women have healthier, heavier babies with stronger immune system for life. A healthy and well-nourished child is also more likely to attend school.(WFP. *Food Security analysis*)

The best were seen in terms of chronic hunger in the 1980s and the 1990s, but progress fell down between 2000 and 2010. Asia is the continent with the hungriest. Sub-Saharan Africa is the region with the highest prevalence (percentage of population) of hunger. Poor nutrition causes nearly half (45%) of deaths in children under five 3.1 million children each year. One out of six children which is roughly 100 million in developing countries is underweight. In developing countries the proportion can rise to one in three. If women farmers had the same access to resources as men, the number of hungry in the world could be reduced by up to 150 million.66 million primary school-age children attend classes hungry across the developing world, with 23 million in Africa alone. WFP calculates that US$3.2 billion is needed per year to reach all 66 million hungry school-age children.(WFP)[2]remove all these numbers

To solve world hunger we should not favor western chauvinism or anti universalism; but should follow some universals—basic human rights, for instance—which are non-negotiable. In this paper I will discuss on global food problems. I will then argue on today's food system and food insecurity, failure of green revolution, economic pragmatism and industrialization &

role of coffee, corn, fertilizers in global food economy.

2. Modern Food system and Food security

The good news is that ,the latest news from FAO estimates indicate that global hunger reduction is in progress with about 805 million people were projected to be suffered from undernourishment in 2012–14, down more than 100 million over the last decade, and 209 million lower than in 1990–92. However during this period, the frequency of undernourishment has decreased from 18% to 11% globally and from 23% to 13.5 % for developing countries. Subsequently during 1990-92, 63 countries have touched the hunger target of Millennium Development Goal and 25 countries have achieved the more stringent WFS target. Of the 63 developing countries, 11 already had undernourishment levels below 5 percent (the methodological limit that can assure significance of the results different from zero) in 1990-1992 and have been able to keep it in that interval, and are therefore not the prime focus of the 2014 report. (FAO UN 2014)[3]

These data's demonstrate that the hunger target of the Millennium Development Goal of cut up the proportion of undernourished people in developing countries by 2015 is within reach. In some countries like Latin America and the Caribbean have made the greatest overall progress in increasing food security with unassertive progress in sub-Saharan Africa and Western Asia, which have been distressed by natural disasters and conflict. Continual political commitment with food security and nutrition as top priorities, is a prerequisite for hunger eradication. The studies of the State of Food Insecurity in the World 2014 report show that regions such as Africa and the Latin America and the Caribbean, as well as individual countries have strengthened their political commitment to food security and nutrition.

Hunger decline requires an assimilated approach, and needs to include: public and private investments to raise agricultural productivity; better access to inputs, land, services, technologies and markets; measures to promote rural development; social protection for the most vulnerable, including strengthening their resilience to conflicts and natural disasters; and specific nutrition programs, particularly to address micronutrient deficiencies in mothers and children under five.

However, the modern food economy finds that the system entrusted to meet our most basic need is failing. There is very harsh economic realities behind modern food and our system of making, marketing, and moving what we eat is less compatible with billions of consumers it was intended to serve. If we examine the global hunger and in an age of superabundance, one billion people, many of them in sub-Saharan Africa are excluded from the global food economy.

Although, during twentieth century, the modern food system was notable as a shrine to humanity's greatest conquest. Humans were at the stage of producing more food. This includes more grains, meat, fruits and vegetables than ever before with plenty of variety, safety, quality and convenience that preceding generations would have found puzzling. On the other hand, the same methods that released great quantity of food, great livestock operations and chemically intensive farming, have so degraded the productive capacities of our natural systems that it's not clear how we'll feed the nearly ten billion people expected by midcentury, or even how long current food production levels can be maintained. In developed countries where hunger has been banished, population now struggle with the less desirable costs of the modern food system for instance obesity, heart disease and diabetes.

In North America, Europe, and even emerging Asia, hundreds of millions of anxious consumers skim from one diet to the next, obsessing over bad carbs and good fats, additives and allergies, instead of being citizens in the wealthiest, most sophisticated cultures in human history. The very meaning of food is being transformed: food culture that once treated cooking and eating as central elements in maintaining social culture and tradition are slowly being seized by a global food culture. A food culture where cost and convenience are dominant, the social meal is obsolete, and the art of cooking is restricted only to coffee table cookbooks and on television shows. (Pollan, M.2007)[4]

Today's food crisis is basically economic, that food companies operate for financial gain. Somewhat, the crisis is economic as we see that our food system can only truly be understood as an economic systems. Like all economic systems, it has winner and losers, suffers periodic and occasionally deep instability, and is plagued by the same inherent and irreducible gap between what we demand and what is actually supplied. Food was our first form of wealth, and its production was our first economic enterprise, generating not only most of our employment and prosperity but many of the tools with which the larger economy would eventually be built. The success of the modern food sector has been its ability to make food behave like any other consumer product, but this the paradox of the food economy. According to my views, the source of most of its current problems for all that the food system has evolved like other economic sectors and food itself is fundamentally not an economic phenomenon. Food production may follow general economic principles of supply and demand; it may indeed create employment , earn trade revenues , and generate profits , sometimes considerable profits ; but the underlying product the thing we eat has never quite conformed to rigors of the modern industries. (Breeman.G, Dijkman.J and Termeer.C.2015)[5]

3. Green revolution, Economic pragmatism and Industrialization

In recent years, as world hunger reemerged as a cause celebre. As a cause for celebrities, world leaders have committed to cutting the number of food-insecure people in half by 2015, the so called Millennium goals. But many of the numbers are moving in the opposite direction, in part because as food production improves, human population increases even faster. Every year, the ranks of those who still cannot get enough to eat grow by seven million. But, either elitist or unpatriotic; but possibly be a combined sense of real responsibility for other human beings as human beings with a deeper sense of commitment to a political community. The crucial is global concern and the acceptance that we're all responsible for the human community, which is the essential idea of morality. The fact that people live in different ways; that free human beings will choose to live in different ways and will choose to express themselves in different ways. We should not neglect the power of one i.e. One world & One species. (Julian.B.2006)[6]

Although, as per many studies every twelve months across sub-Saharan Africa, malnutrition kills more than ten million people. Hundreds of millions more suffer a collapsing dietary regime and a medieval nightmare of exhaustion, sickness, and ravaged potential. Although sub-Saharan Africa is the poster child for persistent hunger, the affliction is by no means confined to this continent. While China has revamped its food system, India, once the leading light of an agricultural breakthrough known as the Green revolution, today struggles to handle its more than two hundred million hungry people, including the world's largest cohort of malnourished children. Even in United States, the wealthiest country in the world, one child in six still suffers from inadequate nutrition. All total nine hundred million people, one seventh of the population are malnourished and another one billion suffer chronic and often destructive deficiencies. (Roberts's, P.2008)[7]

Climate change is another factor in having devastating impact on food production in many least developed nations or LDCs and in Africa. Climate changes may cut yield in half by as early as 2020, according to the Intergovernmental Panel on Climate change. The various technological and commercial revolutions that transformed much of the rest of the global economy has largely bypassed the poorer countries. The early success at bringing Western style high yield agriculture to Africa, much of the so called Green revolution on that continent has faltered.

However from 1960, on Kenya's per acre maize yields increased by more than 3 percent a year, better than in the United States. Although maize isn't native to East Africa, it had been part of the regional culture and agriculture for centuries and settlers had developed numerous local varieties. African breeders now begin to cross their local crops with the higher yield varieties from Latin America with impressive results. The entire developing world in fact was poised for such a revolution. In Mexico, wheat yields almost tripled between 1950 and 1965, allowing a country that had once imported 60 percent of its wheat to become entirely self-sufficient. In 1968, the Pakistan and Turkey had harvested record wheat crops. The Philippines brought in a record rice harvest, while India's wheat crop was so unexpectedly massive it overwhelmed the nation's primitive storage infrastructure; hundreds of schools were closed and the classrooms used as temporary silos.

The ocean of grain spilling over the developing world by the early 1970s radically altered not only the food supply but the modern debate over hunger as well. Until perhaps one hundred years ago, governments had been more or less content to understand hunger as an unavoidable part of life. At the same time, there were renewed fears of a population explosion, especially in teeming Asia. Western government worried that endemic hunger would so destabilize Asian countries that they would be easy prey for Communists.

On the other hand, many economic pragmatists who argued that hungry countries shouldn't even try to farm but should focus instead on industrial development with western financing and use their new earnings to import their food. This evolution from agricultural revolution to industrialization was, in sense what had occurred in Europe, the United States, and Japan in the eighteenth and nineteenth centuries. Soon many experts believed industrialization could be replicated in poor countries or development states. In Asia, soaring farm output not only alleviated famine worries but unleashed the predicted wave of urbanization and industrialization. Africa at this time seemed to have caught the same wave of agriculture driven industrialization.

Many green revolution supporters, pointing to successes in Asia and Latin America, blame the African failure on poor execution by corrupt and inept African government, but also by outside players, especially the major donors, whose strategies shifted constantly with changing global politics. Other critics have focused on the revolutions underlying paradigm; its heavy reliance on expensive industrial inputs, they say, was grossly unsuited to the social and physical realities of African agriculture. And indeed, given the deep involvement of the Western input industry(fertilizer, pesticide, and oil companies among them DuPont, Dow, BASF and EXXON all helped distribute the new technologies) it has certainly occurred to some to ask whether the Green Revolution's primary goal wasn't just building food security but building new markets for American farm inputs. The truth lies somewhere in between. There is little doubt that African governments grossly mismanaged their farms programs: grain boards routinely manipulated grain prices for their own profit; government seed breeders didn't adequately localize the super seeds developed by international seed program. It is true that Green Revolution model did impose a set of industrial agricultural practices that didn't fit the realities of African farming. (Shiferaw. B.*et.al.*2013)[8]

The real peak of the Green Revolution was and is fertilizers. By conservative estimates, more than a third of the Green Revolution yield increase came directly from using more fertilizers. And yet as American and European farmers were also discovering that while fertilizers were a necessary ingredient for modern high yield agriculture, they were not sufficient to ensure its success. Although African farmers saw massive yield increases within the first few years of adopting the new techniques in a relatively short time ; something odd happened; yields fell unless farmers added steadily greater applications of nitrogen and other fertilizers. This effect was so dramatic that over the course of twenty years, a farmer would need to double his nitrogen applications simply to maintain his yields at their initial level. By adding synthetic fertilizers to lands rich in organic matter such as American Midwest and certain parts of Africa could indeed bring massive yield increases. The problem is that soil organic matter (SOM) can be depleted when farmers raise too many crops without replenishing nutrients with cover crops or manure or other fertilizers. Once SOM begins to fall, the soils capacity to hold and transport synthetic nutrients also falls, which means that farmers have to steadily add more nitrogen simply to maintain their yields. The loss of SOM also leaves soils hugely vulnerable to wind and water erosion and thus accelerates leaching of nitrogen.

Environmental groups worried that farm chemicals were damaging fragile soils; and had begun lobbying western governments to shift their financial support away from farm chemicals and towards "environmental sustainable" agriculture. During the same time market economists claimed that fertilizer subsidies themselves were slowing the development of local fertilizer industries within poor countries. Sub Saharan farmers are almost back to where they were fifty years ago no inputs, no mechanization and a preindustrial level of output. The only difference is that farmers are trying to feed a population roughly four times as large. Sub Saharan Africa as a whole now boasts both one of the highest population growth rates and one of fastest declines in per capita grain supply. By 2025 will need to triple the amount of grain it buys from foreign suppliers.

4. Role of Coffee, Corn, Fertilizers in Global Food Economy

For the LDC's to join global food economy, pay off their debt and generate much needed income and industry they have started exporting high demand crops like sugar, cocoa, coffee and palm oil. But the complex challenge is still there to pursue food security in a fast moving global food economy. Kenya's coffee industry grabbed this opportunity and after a frost destroyed much of the Brazilian coffee crop in the early 1990s, soaring coffee prices encouraged grower's countries like Kenya to expand rapidly. Within a few years, exports of Kenya's distinctive Arabica beans were earning quarter of a billion dollars a year. Unfortunately for Kenya, the same boom attracted other players including Vietnam. With its Robusta bean rehabilitated, Vietnam was poised to become the Wal-Mart of the coffee world, a low cost producer that made up in volume what it gave up on price. Money poured in to the Vietnamese coffee industry: $233million from the Vietnamese government, $16million from the World Bank, and another $100 million from European governments. Nestle which depends on Vietnam for roughly a quarter of its bean opened a research center there. Between 1990 and 2000 , Vietnam coffee production soared from fewer than a million tons to more than sixteen million tons , overtaking Colombia as the world's number two producer and generating hundreds of millions of dollars in yearly export income. In fact, with all these advantage that Vietnam was given in the coffee market, it was quite the opposite for Vietnam and any other coffee producer. Between 1997 and 2000 the composite Robusta-Arabica price fell from two dollars to around 48 cents, well below many farmers' production costs.(Kavallari.A, Fellmann.T, and Gay.H.2014)[9]

In Kenya, coffee earnings have fallen by more than 75% and other exporters have fared worse. In Uganda and Burundi, coffee accounted for more than half of all export earnings, while Ethiopia depended on coffee for two-thirds of its export revenues and lost more than $300 million between 1999 and 2001 alone. The post coffee aftermath has been eye-opening. According to figures from US AID more than half a million coffee laborers have lost their jobs worldwide. In Vietnam coffee plantation were simple abandoned leaving exposed soils to erode in the heavy seasonal rains. In some African countries, unemployed coffee farmers have turned to poaching endangered animals; among them chimpanzees and gorillas for the thriving bush meat market. In south and Central America many coffee farmers switched to coca from which cocaine is made while many more joined the exodus northward to America.

In the post-Green Revolution collapse, many experts have come to regard large-scale, export oriented agriculture as an overly blunt instrument in the war on hunger. Although agribusiness has flourished in some developing countries, where land is suitable and infrastructure is in place, the model simply does not fit as well in the least food secure places, such as India or sub-Saharan Africa. There, Farmers are often so small, so focused on feeding themselves and so poor that they cannot easily upgrade to a more remunerative crop.

However some observers warn that unless new initiatives are carefully planned and executed they will simply repeat old mistakes. Development experts are also more than little anxious about the surge of interest in high value agriculture such as fresh fruit and vegetables, which has transformed the countryside in many developing nations and revived hopes of an export-led discovery. Demand is especially keen for a producer like Kenya which has the climate to grow several turns of green beans and baby corn. All told, Kenya's horticultural sector is growing about 3 times as fast as the global food economy, and is generating nearly $200 million a year, the most of any product, making Kenya the second largest exporter in all Africa after South Africa. In Mexico, for example, corn is the traditional basis of Mexico's several million subsistence farmers, who consume roughly half of what they grow and who until fairly recently could sell their surpluses in local markets for a price that was kept high by bans on cheap imported corn. After the passage of the North America Free Trade Agreement (NAFTA) in 1995, however, that protectionist ban was phased out, opening Mexico to a rising volume of corn from farmers in Canada and the United states. But the opening of local food system to free market forces poses enormous risks as well. By removing grain boards and grain reserves, for example, developing countries have exposed themselves to some of the downsides of a free market economy. In 2002, officials with the International Monetary Fund advised the government of Malawi to sell off a large portion of its strategic grain reserves in order to pay off an outstanding loan just as the country was moving into a massive maize shortage that sent prices skyrocketing and caused several hundred starvation deaths.

5. Conclusion

In the conclusion, the food economy of the developing world is waiting to see what happens next. After decades of corruption and ineptitude, a steady progression of natural and medical disasters and continually shifting aid strategies the food systems of sub-Saharan Africa and other poor regions are on the knifes edge. In many cases, local officials and aid workers have identified critical factors in food insecurity and have launched targeted solutions that are bringing small but significant successes. The United Nations World Food Program now feeds some two hundred thousand Kenyan children in the Nairobi slums alone, often in school lunch programs .For the meantime the food economies are so fragile that even a small disruption such as drought, flood, and border conflict is sufficient to push the system into collapse. Kenya found itself deeper and deeper into a nation size poverty trap. Population continues to grow which pushes more people into less and less suitable lands, where their maize and other nontraditional crops are even more prone to failure. Daily nourishment levels fall, both in overall caloric intake and crucially, meat; whereas meat consumption has climbed by a third in Latin America and nearly doubled in Asia since 1970s, it has actually fallen in sub-Saharan Africa. All told, most of the gains in food security made during the 1960s and 1970s are being lost: infant mortality in sub-Saharan and India is soaring while life expectancy is dropping like a stone .In Kenya, life expectancy rose from 40 in1970 to nearly 60 by the mid-1990, but it has since fallen back to nearly 40 and drops a year with each year.(Drimie.S and McLachlan.M.2013)[10]

For decades, the operating assumption of the aid community was that no matter how dysfunctional a country's food system might be, it would eventually respond to the right combination of policies and technologies and join the global food system. Such an outcome may still be possible for a country like Kenya. But we also now understand that food insecurity comes not simply from bad government, fickle aid strategies and post colonialism but also from the pressure of a burgeoning population coming up against natural constraints such as poor soils, scare water and a changing climate. Environmental change and food insecurity has become synonymous with globalization and deterritorialisation. It is now taken as evidence of a globalized world, bound up in the economic practices of globalization, demonstrative of the ecological one-ness of the planet and demanding of some form of globalized governance in the face of a state in the throes of a crisis of capacity and legitimacy. The globalized politics of the food is also firmly embedded in and characterized by social, economic and political inequities in which those who are already marginalized are made disproportionately worse off in both a material and social sense. In this, it is possible to imagine the crisis in Kenya not as a vestige of our food history but as a vision of our food future. To solve food insecurity at a global level we must follow to exchange the views and ideas globally by listening to each other stories to figure out the particularities of the views and scenario, do not just depend on some metaphysical or theological views, and respect the humanity above than any cultural or political views. (Sundström.J.F.*et.al*.2014)[11]

But we should start, I think by recognizing that the issues like food insecurity are subject to disputation within every society as well as across societies. We need a global conversation that recognizes that we have these very different views and that seeks, first, simple understanding of each other's positions. Next, I think, come attempts to try to agree on fundamental rights: things we think every person is entitled to. Finally, if we're convinced that what a government or a society elsewhere is doing to some people is badly wrong and the conversation gets nowhere, it seems to me that sometimes we just have to try and help the victims like hunger or food security, especially if they ask for our help--whether or not we can get the agreement of the perpetrators. But often we won't be able to help (at reasonable cost) unless we do it through dialogue.

Nevertheless according to WHO, there is enough food in the world to feed everyone adequately; the problem is distribution; Future food needs can or cannot be met by current levels of production; National food security is paramount or no longer necessary because of global trade; Globalization may or may not lead to the persistence of food insecurity and poverty in rural communities.

The overall problem with the food insecurity is geographical location, public stewardship and economic strength in the risks presented by several biophysical threats to agricultural production in different kinds of countries. As these causes are far from evenly spread among the world's major food producers, diversified risk monitoring and international assessment of agricultural production will play a critical role in assuring global food security in 2050.(Charles, D.2013)[12]

References

Breeman, G., Dijkman, J., & Termeer, C. (2015). Enhancing food security through a multi-stakeholder process: the global agenda for sustainable livestock. http://link.springer.com/article/10.1007/s12571-015-0430-4/fulltext.html.

Charles, D. (2015). As Promised: Obama Wants To Overhaul Global Anti-Hunger Efforts. April 10, 2013.

Drimie, S., & McLachlan, M. (2015). Food security in South Africa—first steps toward a transdisciplinary approach. Springer. 5 February 2013. Available online: http://link.springer.com/article/10.1007/s12571-013-0241-4/fulltext.html. (Accessed on March 11, 2015).

FAO UN. (2014). The State of Food Insecurity in the World 2014. Available online: http: //www.fao.org/publications/sofi/2014/en/.(Accessed on March 10, 2015).

Future threats to agricultural food production posed by environmental degradation, climate change, and animal and plant diseases – a risk analysis in three economic and climate settings. Springer. 17 February 2014. Available online: http://link.springer.com/article/10.1007/s12571-014-0331-y/fulltext.html.

Julian, B. (2006). Cosmopolitanism: How to Be a Citizen of the World. A philosopher issues a call for a pragmatic, humane stance toward difference in a world of strangers. *An interview with Kwame Anthony.*

Kavallari, A., Fellmann, T., & Gay, H. (2014). Shocks in economic growth = shocking effects for food security? Springer. 3 August 2014. Available online: http://link.springer.com/article/10.1007/s12571-014-0368-y/fulltext.html.

Pollan, M. (2007). The Omnivore's Dilemma: A natural history of four meals. Edition 2007

Roberts's, P. The end of hunger .The end of food. Edition 2008

Shiferaw, B., Smale, M, Braun, H. J., Duveiller, E, Reynolds, M., & Muricho, G. (2013). Crops that feed the world 10. Past successes and future challenges to the role played by wheat in global food security. Springer. 28 April 2013. Available online: http://link.springer.com/article/10.1007/s12571-013-0263-y/fulltext.html (Accessed on March 11, 2015).

Sundström, J. F., Albihn, A., Boqvist. S, Ljungvall, K, Marstorp, H, Martiin, C, Nyberg, K, Holm, I. V., Yuen, J., & Magnusson, U. (2014).

WFP. (2015). Available online: http://www.wfp.org/hunger/stats. (Accessed on March 11, 2015)

WFP. (2015). Food Security analysis. Available online: http://www.wfp.org/food-security.

Assessment of the Fiscal Performance of Bee Keeping for Employment Generation and Poverty Reduction in Osun State, Nigeria

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Abstract

Beekeeping is a new venture in recent times that has the potential of improving the livelihoods of the Nigeria citizenry. A good proportion of youth and adults engaged in beekeeping. The study was embarked upon to investigate the fiscal performance of beekeeping as a possibility of reducing youth unemployment and alleviating poverty among the citizenry. Specifically, the study described the socio-economic variables of beekeepers income generating potentials of the enterprise, measured the economic efficiency and identified the constraints to honey beekeeping in the study area. A structured questionnaire was used to collect data from 120 respondents' purposively selected using a snowballing technique. The data collected was analyzed using Frequency counts and percentages, as well as profitability analysis and efficiency ratios. Results showed that honey beekeeping was carried out mostly by young, enlightened male respondents on a part-time basis. Most of them were members of the beekeeping association. The result also showed that the gross margin derived from Beekeeping was N16, 306, which constituted 93.68% of the total revenue. Also, the Expense Structure Ratio (ESR), Benefits Cost Ratio (BCR) Rate of Return, Gross ratio (GR) Economic Efficiency (EE) was 0.79, 2.30, 2.30, 0.69 and 2.30 respectively. All the efficiency ratios indicated that beekeeping was profitable and worth venturing. The major constraints to Beekeeping in the study area were disturbance by farmers through some farm practices such as clearing, spraying of insecticides, hunting, fetching of firewood and felling trees as well as by cattle ranchers and climate variability.

Keywords: Beekeeping, Employment Generation, fiscal performance, profitability, livelihood strategy

1. Introduction

Bees are the predominant and most economically important group of pollinators in most geographical regions. The Food and Agriculture Organization of the United Nations (FAO) estimates that out of some 100 crop species that provide 90% of food worldwide, 71 of these are bee-pollinated. In Europe alone, 84% of the 264 crop species are animal pollinated and 4 000 vegetable varieties exist" (UNEP, 2010). 'Honey is the natural sweet substance produced by Apis mellifera bees from the nectar of plants or from secretions of living parts of plants or excretions of plant-sucking insects on the living parts of plants, which the bees collect, transform by combining with specific substances of their own, deposit, dehydrate, store and leave in honeycombs to ripen and mature' (European Commission, 2001). The significance of Honey, as summarized by FAO (1990) shows that: honey has antioxidant and bacteria properties which improves digestive system and fight against diseases. It possesses carcinogen that prevents anti-tumour properties, regarded as anticancer. It is used as a natural cure for wounds, burns, and cuts. Honey has anti-bacteria properties that prevent infection and functions as anti-inflammatory agent thereby reducing swelling and pain. Honey also has anti- oxidant which reduces cholesterol thereby reducing heart diseases. Bee venom is used in treating arthritis and other inflammatory disorders. Honey can be used in treating digestive problems such as indigestion, stomach ulcer, and gastroenteritis. Honey can be used in increasing milk production and reducing acetonemia in cattle as well as making of rat and mice repellents. It is used widely in the manufacture of facial cleaners and hand lotion. The medicinal efficiency of honey has initiated a new and highly promising branch of medicine called "Apitherapy" with the term "API" from apis mellifera (honeybee). According to Amy and Echazarreta, (1996), the desirable features of honey on treating health challenges was the ease of administration for the treatment of wounds and the absence of antibiotic resistance as found with conventional antibiotics. It also lacks side effects in alleviating gastric pain and shortening the duration of diarrhea.

The high usefulness of bee and honey enhanced its production in large quantity in most parts of the world. For instance, FAOSTAT, (2012) indicated the top ten countries producing Honey worldwide and the quantities produced. The countries are China (400 000 tons), Turkey and the USA (80 000 tons each), Ukraine (70 000 tons), Argentina (60 000 tons), Mexico and Ethiopia (55 000 tons each), Russia and Iran (50 000 tons each) and India (40 000 tons) (FAOSTAT, 2012).

Although traditional beekeeping has long age history in Nigeria, however, Beekeeping as an enterprise is a relatively new enterprise in the nation. Currently, people are agitating for the diversification of the Nigeria economy and employment generation for the teaming youth populace. Beekeeping as an enterprise has proven the capability of being used for different purposes and thus can generate employment for the youths. More also, it has the potential of improving farmer's income and increase foreign exchange earnings of the country (Ojeleye, 1999). According to Adebo & Ajiboye (2014), the issue of poverty is still prevalent in rural Nigeria, and there is urgent need to proffer solutions to it. They recommend that youth empowerment programs should focus on commercial agriculture rather than subsistence agriculture. Beekeeping on a large scale could go a long way in reducing poverty and youth unemployment in Nigeria.

The knowledge of the import of beekeeping makes the Nigerian government through the Agricultural Development Programme (ADP) to boost its production. Parts of the efforts made by the government includes: extension agents' visitation to honey farmers; organization of regular workshops on beekeeping; provision of modern equipment, improving honey marketing through improved contact with consumers; introduction of modern honey production techniques and the integration of beekeeping into rubber plantation establishment in rubber research institute (RRI) of Nigeria (Ojeleye, 1999).

A good number of farmers and youth across the country and especially in Osun state have been involved in Beekeeping over the years. Most of them belong to the beekeeping association and participated in the training programs organized by the ADP. However, there is a dearth of information on the performance of the beekeeping enterprise as a livelihood strategy in Osun state; hence the study is set to provide answers to some questions. Some of which are: what are the socioeconomic characteristics of beekeepers in the Osun state of Nigeria? How do they see the beekeeping enterprise? Do they take it as a full-time or part-time job? What is the scale of beekeeping production? Is the enterprise profitable? What are the costs and revenue structure of the enterprise? Is the enterprise efficient? The answers to these questions would prove if beekeeping as an enterprise could be an effective livelihoods strategy for youth empowerment and poverty alleviation in Nigeria.

2. Methodology

The study was carried out in Osun State, Nigeria. A multi- stage sampling was used in selecting the respondents for the study. The first stage involves a random selection of four out of 18 Local Government Areas (LGAs) in Osun state. The second stage involves a random selection of six villages from each LGA. The last stage involves the selection of five beekeepers from each village using a snowballing technique. Thus, a total of 120 respondents were selected and utilized for the study. A structured interview schedule was used to collect data while descriptive statistics, budgetary technique, and efficiency ratio were used in data analysis. The budgetary analysis was calculated using the model expressed as follows:

$$NFI = GI – TC \quad (1)$$

$$TC = TVC + TFC \quad (2)$$

Where:

NFI = Net Farm Income (₦)/ Colony.

GI = Gross Income (₦)/ Colony.

TC = Total cost (₦)/ Colony.

TVC = Total variable costs (₦)/ Colony

TFC = Total fixed costs (₦)/ Colony

The profit (π) analysis equation is given as:

$$\pi = TR - TVC$$

Wherer π = Profit from the sales of honey and bee wax

TR = Total Revenue

TVC = Total Variable Cost

The Expense ratio is the measure of an investment fund's costs of operation as a percentage of its total asset. The expense ratio for beekeeping is calculated by dividing the fund's total cost of beekeeping by its total assets

The Benefit cost ratio is gotten by dividing the present worth of benefit by the present worth of cost. If the BCR is equal or greater than one then the business is beneficial

Benefit-cost ratio B/C = PW of benefit/PW of cost ≥ 1. (Rijiravanich, 2010).

The return on investment is calculated by subtracting the cost of investment from the gains from investment and divide by the cost of investment

$$ROI = \frac{\text{Gains from investment- cost of investment}}{\text{Cost of investment}}$$

Gross profit ratio (GP ratio) is calculated by dividing the gross profit from beekeeping by its net sales

$$\text{Gross profit ratio} = \frac{\text{Gross profit}}{\text{Net sales}}$$

The efficiency ratio of beekeeping is calculated by using noninterest expense divided by total revenue less interest expense.

3. Results and Discussion

a) Socioeconomic Characteristics of the Respondents

Data in Table 1 shows that the respondents belong to different age brackets. However, 90.1% of them were below 45 years of age and had few years of beekeeping experience. Almost all the respondents (98.5%) kept honey bees on a part- time basis to supplement other farm income. The system of beekeeping is contrary to what obtains in Turkey where beekeeping is the main source of income to over 68 percent of the beekeepers who own more than 160 colonies (Hasan & Karaman2010). The majority (62.5%) of the beekeepers were male, married and mostly literates. The domination of beekeeping by married men might probably be due to the skills required in handling bees and the fear of the female gender from being stung by the bees. More than half of the beekeepers claimed membership of Honey Producer Association of Nigeria. It is a reflection of governments' intervention in honey production in Nigeria as well as their educational status. In terms of the number of colonies owned. Table 1 also shows that 37.5, 50.0 & 12.50 percent of the respondents owned < 20, 21-40 and above

40 colonies respectively. The mean number of colony owned was 32.5.The average number of colony owned is relatively small when compared to Turkey. The average number of colony owned by a farmer in Turkey was 168.40 (Hasan & Karaman, 2010), and that of Vietnam was 200-300 Nguyen (2010). It could be affirmed that beekeeping in Osun state is relatively on a small scale. Despite the fact that Muhammad, et al. (2006) reveals that beekeeping has higher economic efficiency than most crops grown in the Adamawa state of Nigeria, beekeeping is still at low ebb in most states in the country (Muhammad et al, 2006 & Tijani *et al.,* 2011). The low production is a reflection of the fact that most of the people took beekeeping as a part time occupation and the low level of awareness of the livelihood's transformative potentials of the bee venture. Also, 14.17 percent of the respondents earn less than N100 000 from beekeeping, and 26.67percent earned between N101-200.00 naira from beekeeping. About 40 percent earned between N201 000.00- 300 000.00, 10 percent earned between 301 000.00-400 000 annually while a few (9.16%) earned above N400 000.00 from beekeeping annually. The mean annual income was N279 054.04. The annual income from Beekeeping compares relatively well with that of palm oil in Ekiti state whose mean annual income for 2011 was N 275 000 as indicated by Adebo *et al*., (2014). It was also above the annual income from rice maize, sorghum and sugarcane, groundnut and millet in Adamawa state as reported by Muhammad *et al.* (2006). Thus, it could be said that the earnings from beekeeping is relatively high and could sustain the livelihoods of farmers if the scale of production is increased. More also, Bradbear (2010) affirmed in his study that beekeeping is environmentally sustainable and a good livelihood practice for many people around the world.

Table 1. Socio-Economic Characteristics of the Respondents

Variable	Frequency	Percentage
Age		
20-29	21	17.5
30-39	57	47.5
40-49	30	25.0
50-59	10	8.33
≥ 60	02	1.67
Sex		
Male	99	82.5
Female	21	17.5
Marital status		
Single	30	20.0
Married	75	62.5
Widow/widower	15	10.0
Level of education		
No formal education	08	6.67
Primary education	21	17.5
Secondary education	20	16.67
Tertiary education	67	55.83
Non-formal education	04	3.33
Bee keeping experience		
≤4 years	42	35.0
5-9 years	51	42.5
10-14 years	25	20.83
≥15 years	02	1.67
Membership of Bee keeping Association		
Yes	68	56.67
No	45	37.50
No of colony owned		
≤20	45	37.5
21-40	60	50.00
>40	15	12.50
Annual income from Beekeeping (₦)		
<100 000.00	17	14.17
101 000.00- 200 000.00	32	26.67
201 000.00- 300 000.00	48	40.00
301 000.00-400 000	12	10.00
400 000.00	11	9.16

Source: Field Survey, 2013

b) Profitability Analysis

Data in Table 2 shows that the total variable cost for beekeeping in Osun state was 4173.20 while the total fixed cost was 1100.00. The total cost was 5173.20. The average total revenue resulting from the sale of honey and bee wax was N 17 406 while the Gross Margin and the Net farm income were 16 306.00 &12 132.80 respectively. The gross margin accounted for 93.68 percent of the total revenues. It shows that beekeeping is a profitable enterprise in Osun state, Nigeria. In a similar study carried out in Edo State by Atamonokhai (2002), the gross margin for honey from bee keeping accounted for 95.4% of the total revenue. The findings are supported by the reports of Tijani *et al.* (2011) Folayan & Bifarin (2013) and Famuyide *et al.* (2014). Their findings indicated that beekeeping is a profitable venture in Chibok Local Government area of Borno state as well as in Oyo and Edo states, Nigeria. In essence, beekeeping as a profitable venture could be used as empowerment and poverty reduction strategy in Nigeria.

Table 2. Estimated Costs and Returns per colony in Beekeeping

Item	Mean Value	Percentage
Gross revenue:	17 406.00	
Fixed input costs:		
Beehives	352.00	32.00
Bucket	198.00	18.00
Torch light	203.00	18.45
Ropes	347.00	31.55
TFC	1100.00	100.00
Variable input costs:		
Hired labour	1000.00	23.96
Baiting materials	1050.80	25.16
Control of pest and predators	250.00	5.99
Batteries	450.25	10.79
Corn stock	750.02	17.97
Matches	50.00	1.20
Contingencies	622.93	14.93
TVC	4173.20	100.00
TFC+TVC	5273.20	
GM	16 306.00	
Net farm income	12 132.8	
%GM/TR		93.68
% TVC/TC		79.14
%NP/TR		69.70

c) Efficiency of beekeeping

Data in figure 1 shows the Efficiency Ratio (ER) for beekeeping in Osun state. The Expense Structure Ratios (ESR) and Benefit Cost Ratio (BCR) were 0.21 and 2.3 respectively. The ESR of 0.21 implies that about 21% of the total cost was made up of fixed component. The low ESR gives room for honey beekeepers to adjust quickly to varying market conditions. Also, the Rate of Returns (ROR) was 2.3. The ROR of 2.30 shows that for every N 1.00 investment on beekeeping, the farmer earns N 2.30 profit. Likewise, the Gross Ratio (GR) of 0.69 and Economic Efficiency (EE) of 2.30 indicated that honey bee keeping was an economically viable enterprise worth venturing into in the study area.

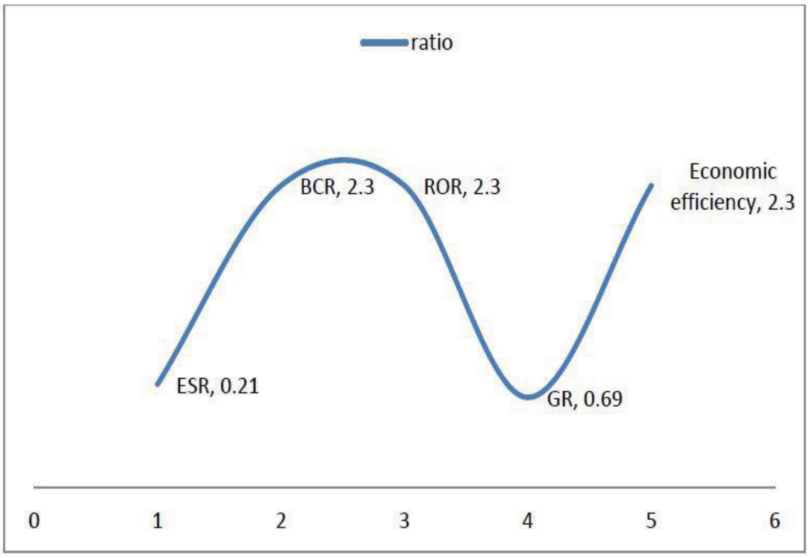

Figure 1. Efficiency Ratio of Honey Beekeeping in Osun State

Data in figure 2 shows that 2.3 percent of the respondents suffered from land tenure problems, 31.55 percent were disturbed by human activities. Also, 24.76 percent reported disturbance by cattle ranchers, 30.0 percent suffered from climate variability, and 18.32 percent were affected by pest and diseases while 8.74 percent suffered from reptiles attack. The major constraints to Beekeeping in Osun state were the disturbance by human activities and cattle ranchers as well as climate variability. All other factors recorded very low percentages. The villagers also disturbed the Bees through the agricultural activities when clearing, spraying of insecticides, hunting, fetching of firewood and felling trees.

The cattle ranchers disturbed the bees' farmland when feeding their cattle particularly during the dry season that coincides with the flowering period of plants. Their presence scares the bees thereby reducing the comb and honey produced. It supports the findings of Tirado (2013) that wild bees are threatened by many environmental factors, including lack of natural and semi-natural habitats and increased exposure to man-made chemicals. Also, Hasan & Karaman (2010) discovered that high chemical usage in the hives was one of the major constraints to beekeeping in Turkey. However, it differs from the findings of Tijani *et al.* (2011) who identified theft and lack of credit as major impediments to beekeeping in Chibok Local Government area of Borno state in Nigeria. Also, Climate variability affects beekeeping, especially extremely high temperature could be very destructive during brooding. It also supports the findings of Adebo & Sekumade (2013) that climate change constitutes major impediment to reducing farmers productivity in Ekiti and Ondo states of Nigeria

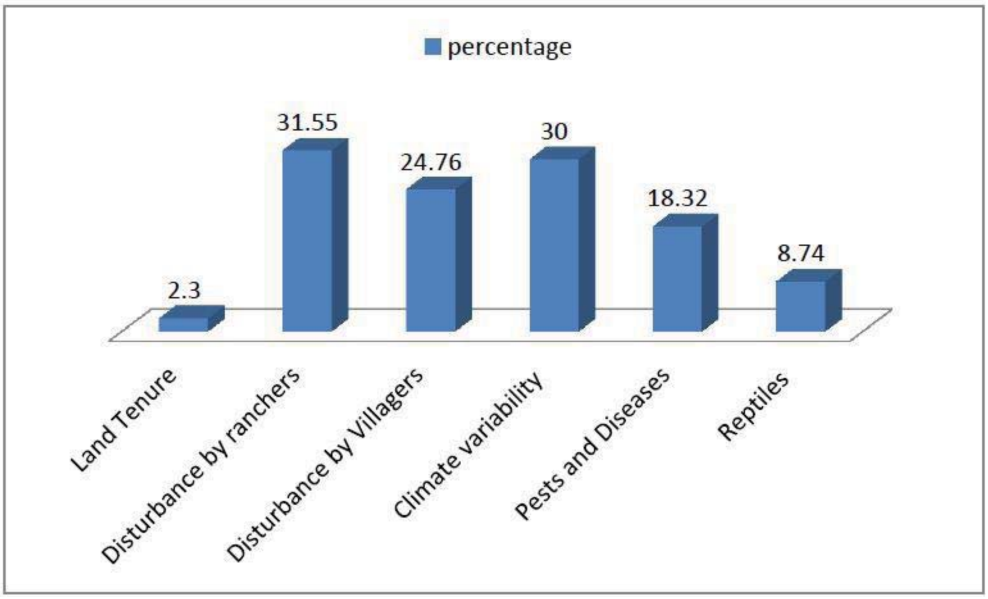

Figure 2. Constraints to beekeeping in Osun state

Source: Field survey, 2013

4. Summary, Conclusion and Recommendations

a) Summary

Beekeeping is a relatively new venture in Osun state, kept mostly on a part-time basis to supplement farm income. Beekeeping in Osun state is a male-dominated occupation, most of the producers are young, literate, and married. More than half of the beekeepers were members of Honey Producer Association of Nigeria. The mean number of colony owned per person was 24.2 while the mean annual income was N279 054.04. The annual income from Beekeeping compares relatively well with that of other crops and is relatively high to sustain the livelihoods of farmers if the scale of production is increased.

The average total revenue resulting from the sales of honey and bee wax was N 17 406 while the Gross Margin and the Net farm income were 16, 306.00 &12,132.80 respectively. The gross margin accounted for 93.68 percent of the total revenues. The Expense Structure Ratios (ESR) and Benefit Cost Ratio (BCR) were 0.21 and 2.3 respectively. The Rate of Returns (ROR) was 2.3. The ROR of 2.30 shows that for every N 1.00 investment on beekeeping, the farmer earns N 2.30 profit. Likewise, the Gross Ratio (GR) of 0.69 and Economic Efficiency (EE) of 2.30 indicated that honey bee keeping was an economically viable enterprise worth venturing into in the study area.

However, the major constraints to Beekeeping in Osun state were the disturbance by human activities and cattle ranchers as well as climate variability.

b) Conclusion

Beekeeping is not a major source of income for the producers. However, it is a profitable venture that could be used to could be used to generate employment and empower the youth. It is a veritable tool for poverty alleviation.

c) Recommendations

Based on the findings of the research, the study recommends that:

- Farmers should be encouraged to increase the scale of production of beekeeping to enhance more income.
- They should make full utilization of the Honey Producers Association in obtaining loans and acquiring skills necessary to hurl them from small to medium and large scale beekeepers
- Government policies on human and animal activities that could hinder bee production hould be enforced
- The government and non-governmental Organizations should pay Special attention on climate change and the strategies to reduce the impact on agricultural production and beekeeping in the state
- The female gender can be encouraged to engage in value addition to honey production to enhance their income

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References

Adebo, G. M., & Ajiboye, A. (2014). Comparative Analysis of Poverty Level among Rural and Urban Farmers in Ekiti and Ondo States. *Journal of Developing Countries Studies. The International Institute for Science, Technology and Education (IISTE), 4*(20), 23-27.

Adebo, G. M., & Sekumade, A. B. (2013). Climate Change and Adaptive Capacity of Women to Rural Water Supply in Ekiti State Nigeria. *Academic Research International*, *4*(2), 386-399.

Adebo. G. M., Ayodele. O. J., Olowokere, K. (2015). Palm Oil Production as a Poverty Alleviation Strategy among Small-scale Farmers in Ekiti State, Nigeria. *World Journal of Agricultural Research, 3*(2), 43-48

Amy, E., Jeffrey, Carlos, M. E. (1996). Medical uses of honey *Rev Biomed, 7,* 43-49.

Atamonkhai, E. K. (2002). Economic Analysis of Honey Bee-Keeping in Edo State, Nigeria. Unpublished Thesis at the Department of Extension Farm Management, Federal College of Agriculture, Akure, Ondo State.

Brabear, N. (2010). Beekeeping Development-Why is success so difficult to achieve? International conference on Beekeeping Development and Honey Marketing, Hanoi Vietnam, *24*

European Commission, (2001). Evaluation of the CAP measures related to apiculture Agriculture and Rural Development DG- Final Report**.** Directive 2001/110/EC

Famuyide, O.O., Adebayo, O. Owese, T., Azeez, F.A., Arabomen, O., Olugbire, O.O and Ojo, D (2014). Economic Contributions of Honey Production as a Means of Livelihood Strategy in Oyo State *International Journal of Science and Technology*, *3*(1).

FAO. (1990). Food and Agriculture Organization of the United Nations Publications, Rome

FAOSTAT. (2012). Trends in World Honey production. the amounts produced by country and provide a view of the recent trend in production.

Folayan, J. A., & Bifarin, J. O. (2013). Profitability analysis of honey production in Edo North Local Govt of Area of Edo State, Nigeria. *Journal of Agricultural Economics and Development, 2*(2), 60-64.

Hasan, V., & Süleyman, K. (2010). Socio-economic analysis of beekeeping and the effects of beehive types on honey production African Journal of Agricultural Research, *5*(22), 3003-3008. http://www.academicjournals.org/AJAR.

Muhammad, R. Ja'afar-Furo, A. S., & Yusuf El-Sahab, H. (2006). A Comparative Analysis of Beekeeping and Crop Production in Adamawa State, Nigeria Apiacta , *41*(2006), 44 -53

Nguyen, Q. T. (2010). Profitability of *Apis Mellifera* in Vietnam. University of Agriculture and Forestry, Thu Duc, Ho Chi Minh city, Vietnam

Ojeleye, B. (1999). Chemical Composition of Honey. *The Beekeeper Journal*, *1,* 4-5.

Rijiravanich, V. (2010). Benefit Cost ratio. Siam University

Tijanil, B. A., Ala, A. L. Maikasuwa, M. A., & Ganawa, N. (2011). Economic Analysis of Beekeeping in Chibok Local Government Area of Borno State,Nigeria. *Nigerian Journal of Basic and Applied Science*, *19*(2), 285-292.http://www.ajol.info/index.php/njbas/index

Tirado, R. (2013). A review of factors that put pollinators and Agriculture in Europe at risk. Greenpeace research laboratory technical report

UNEP (2010). UNEP Emerging Issues: Global Honey Bee Colony Disorder and Other Threats to Insect Pollinators. United Nations Environment Programme.

Preliminary Study, Risk Analysis and HACCP in Cold Chain System, Frozen Yellow Fin Tuna in Moluccas

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Abstract

The differences In cold chain system, Risk analysis and Hazard Analysis and Critical Crisis Point(HACCP) is a procedure for the identification, assessment and control of hazards in, and indirectly risks from, food. HACCP procedures focus on chemical, physical and microbiological hazards, Yellow Fin Tuna is the one of the most superior export fishery product of Moluccas, based on paper review and field observation in Molucass, this paper is a preliminary study to development HACCP framework of frozen Yellow Fin Tuna in Moluccas.

Keywords: Cold Chain System; Risk analysis and HACCP; Yellow Fin Tuna

1. Introduction

There are five main species of tuna; skipjack, yellowfin, bigeye, albacore and bluefin, global trade in all tuna materials and products has increased in the last 30 years. In 1976 just over 425,000 tonnes of tuna, with a value of US$391 million, was imported globally. By 2006 these figures had grown to over 1.8 million tonnes of tuna with a value in excess of US$3.6 billion.*(seafish.org,2009)*

Tuna production growth in Indonesia in the period 1989 - 2006 reached 4.74% per year with the export volume of 5.21% per year. Tuna export value in 2008 ranks second after the shrimp. Total production of the national tuna until October 2008 reached 130,056 tons with a value of 347.189 million USD, *(ministry of maritime affairs and fisheries RI, 2007).*

The potential of fish resources in Maluku is large enough that distributed in the Arafura Sea (792 100) tons with sustainable potential 633,600 tons / year), the Banda Sea (248 400 tons with sustainable potential 198,700 tons / year), and the Maluku Sea and surrounding areas (587 000 with the potential for sustainable 469,500 tons / year), while exports of frozen fish

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from Maluku for 2003 to 2007, only recently ranged from 220 570 tons - 321,885 tons *(Moluccas in number 2008)*, this means that export opportunities are great potential in the era of globalization and free trade now. If this sector is driven optimally, will greatly encourage local revenue.

This globalization of fish trade, coupled with technological developments in food production, handling, processing and distribution, and the increasing awareness and demand of consumers for safe and high quality food have put food safety and quality assurance high in public awareness and a priority for many governments*(Lahsen ababouch,2006)*

There are many factors that influence, but fundamental factor are: fulfillment quality standard and safety to consumed of international requirements and regional from importer countries. To guarantee this fulfillments requirement are needed adequate cold chain system.These issues make the development of cold chain system model for the prospects of development fishery and marine product exports of Indonesia especially frozen fish become important and strategic*(grasiano.W.L,et al,2010).*

In cold chain system ,Risk analysis and Hazard Analysis and Critical Crisis Point(HACCP) is a procedure for the identification, assessment and control of hazards in, and indirectly risks from food. HACCP procedures focus on chemical, physical and microbiological hazards. The number of cases of detention of tuna products in overseas markets between 2004-2006 can be seen in Table bellow.from the table, majority of turned out to reject cases, caused by histamine and heavy metal

Table 1. Detention cases of indonesian tuna products in international the market

Parameters	Year			Fisheries Commodity	Specific Compound
	2004	2005	2006		
Vetenary drugs	10	5	9	Shrimps,	Nitrofuran, Chloramphenicol
				Catfish	Malachite green
				Chanus Chanos	Malachite green
				Eel	Malachite green + Cristal Violet
				Milkfish	Malachite green
				Tilapia	Malachite green
Histamine	21	3	5	Tuna	-
Heavy metal	20	4	17	Swordfish, Tuna, Cuttlefish, Lobster, Shark, Butterfish, Marlin	Cover by develop knowledge through monitoring
CO2	4	21	3	Tuna	-
				Tuna	TPC
				Goatfish	Salmonella

(source: *Notification of RASFF of Indonesian Fishery roducts by EU Commission 2004 – 2006)*

In cold chain system, Risk analysis and Hazard Analysis and Critical Crisis Point(HACCP) is a procedure for the identification, assessment and control of hazards in, and indirectly risks from, food. HACCP procedures focus on chemical, physical and microbiological hazards.This problem triggers a manufacturer of fishery products including frozen yellow fin tuna exporter continue trying to fulfill the standards required both regional standards of export destinations and international standards (FAO, WHO.WTO).

Habitat biochemical products will also affect the hazard / risk aspect (biological aspect, the chemical aspect, physical aspect) so that the stages in the cycle that are considered critical cold chain will also vary depending on the product, resulting in a model approach to Risk Analysis and Hazard Analysis Critical Crisis will also be different. This paper is a preliminary study for the development of HACCP Yellow fin tuna in the Moluccas

2. Methods

This paper based on research literature,paper review and Field observations in Molucass

3. Result and Discussion

3.1 Concept of Risk Analysis

In general terms, risk is the potential occurrence of unwanted, adverse consequences associated with some action over a specified time period**.** Risk is the possibility that a negative impact will result from an action or decision and the magnitude of that impact. Workshop on Understanding and Applying Risk Analysis in Aquaculture, held in Rayong, Thailand from 8–11 June 2007, were find Seven "risk categories" have been identified in previous expert discussions, specifically at the FAO/Network of Aquaculture Centres in Asia-Pacific (NACA) :

- Pathogen risks
- Food safety and public health risks
- Ecological (pests and invasives) risks
- Genetic risks
- Environmental risks
- Financial risks
- Social risks

To more clearly,See table 2 and figure.1.bellow,

Table 2. Relationship between the seven risk categories and relevant frameworks

Framework	Pathogens	Food safety and public health	Ecological (pests and invasive species)	Genetic	Environmental	Financial	Social
FAO/WHO *Codex Alimentarius*		X					
Convention on Biodiversity (CBD)	X		X	X	X		X
International Plant Protection Convention (IPPC)	X		X	X	X		
World Health Organization (WHO)	X	X	X				
OIE *Aquatic Animal Health Code*	X		X				
WTO *Agreement on Sanitary and Phytosanitary Measures*	X	X	X	X	X		
FAO *Code of Conduct for Responsible Fisheries* (CCRF)	X	X	X	X	X		
ICES *Code of Practice on the Introductions and Transfers of Marine Organisms*	X	X	X	X	X		

Risk category	Hazard to aquaculture	Hazard from aquaculture
Pathogen risks	Disease outbreak causing loss of stock OIE-listed disease Food safety and public health concern Loss of consumer confidence	Disease outbreak in wild populations OIE -listed disease Food safety and public health concern
Food safety and public health risks	Bacteria Viruses Parasites Residual therapeutants Biotoxins (HABs)	Transfer of pathogen from aquaculture facility to wild Residual therapeutants
Ecological (pests and invasives) risks	Pest outbreak causing fouling Pest outbreak competing for space Pest outbreak predating on adult or juvenile stock	Escape of adult or juvenile stock into wild Release of non-target hitch-hiker into wild Release of species as /or associated with feed stock (e.g. microalgae, pathogens)
Genetic risks	Not applicable	Genetic introgression Loss of local adaptation Loss of locally adapted populations
Environmental risks	storm activity (including flooding) Predation Competition for food	Organic loading Inorganic loading Residual heavy metals Residual therapeutants Physical interaction with marine life Physical impact on marine habitat
Financial risks	Changing production costs Reduced production Equipment failure Poor quality broodstock Market demand fluctuations Increased regulatory costs	Volatility in the aquaculture industry affecting economy Global market instability Changes in transport costs due to "carbon-miles"
Social risks	Industrial action Skill shortage Civil unrest Excessive regulation	Poor workplace conditions Use of technology that replaces labour Pollution from farm Poor quality product Loss of resource access due to farm site

Figure 1. List of aquatic animal diseases notifiable to the World Organisation for Animal Health, 2009

To guarantee this fulfillments requirement are needed adequate cold chain system.These issues make the development of cold chain system model for the prospects of development fishery and marine product exports of Indonesia especially frozen fish become important and strategic*(grasiano.W.L,et al,2010)*

3.2 The Risk Analysis Process

Risk analysis is frequently used by decision-makers and management to direct actions that potentially have large consequences but also have a large uncertainty. Risk analysis is a structured process for determining what events can occur (identifying hazards), analyzing the probability that the event will occur (determining likelihood), assessing the potential impact once it occurs (determining consequence), identifying the potential management options and communicating the elements and magnitude of identified risks.

In simple terms, risk analysis is used to determine the likelihood that an undesired event will occur and the consequences of such an event. This is generally developed in a repeatable and iterative process (MacDiarmid, 1997; Rodgers, 2004;OIE, 2009) where we seek answers to the following questions:

• What can occur? (*Hazard identification*)

• How likely is it to occur? (*Risk assessment*: likelihood assessment through release assessment and exposure assessment)

• What would be the consequences of it occurring? (*Risk assessment* :consequence assessment and risk estimation; risk management: risk evaluation); and

• What can be done to reduce either the likelihood or the consequences of it occurring? (*Risk management*: option evaluation, Implementation,Monitoring and review).

3.3 Hazard Analysis Crisis Control Point (HACCP)

In the UK, the Food Safety (General Food Hygiene) Regulations 1995 implemented the European Union Directive 93/43/EEC relating to food hygiene. This places the emphasis for food safety activities on the identification of the critical operational steps and findingways of controlling them.The approach is defined in terms of five principles, developed according to HACCP:

1. Hazard analysis of given foodstuff,
2. Identification of all points or operation steps at which hazards may occur,
3. Identification of points critical to food safety (i.e.,CCPs),
4. Implementation of control and monitoring procedures at CCPs, and
5. Periodic review of food hazards, CCPs, control and monitoring to ensure continued effectiveness.*(Karl Ropkins)*

From the review that there are some thoughts on paper so important about haccp among them : As an approved valid food safety management system for lowering microorganism, Hazard Analysis and Critical Crisis Point (HACCP) system has been spread by FAO and WHO to help consumers obtain safety food

We have made good progress on our food safety strategy, which is based on the principles of preventing food safety problems, ensuring that industry and government are carrying out appropriate roles and responsibilities, and ensuring that we focus our regulatory activities on the most critical food safety risks*(Thomas J. Billy,2002)*

Well designed and structured premises with well designed and reliable equipment, will help in protecting ingredients and food products, maintaining hygienic conditions, improving cleanliness and cleaning efectiveness and controlling pest infestations. The design and layout of factories and equipment, is also important to eliminate, prevent or control hazards (e.g. temperature- or pressure-controlled areas) and reduce the amount of CCPs by efective control of the plant environment. However, food premises with congested and unhygienically designed food preparation rooms are frequently found *(Hasçiçek et al., 2004).*

Conducted a national study and found three types of barriers: resource management, employee motivation, and employee confidence. Employees are nervous about taking food safety certiWcation examinations and often are not comfortable with the change needed for implementation of a program like HACCP *(Giampaoli et al.2002)*

Found that Indiana school foodservice managers identified time to establish a HACCP program, time to run the program, and labor costs as being the three biggest obstacles. In addition, "lack of training funds, time to get used to running the HACCP program, and union problems" were other identified obstacles *(Hwang, Almanza, and Nelson ,2001)*

During the last three decades, HACCP has been progressively introduced and applied for the benefit of food industry Panisello & Quantick, 2001). The system can be considered as an efficient tool for both industry and health authorities to prevent foodborne diseases if it is based on understanding and proper implementation, because it is not HACCP system itself which makes food safe, but its correct application *(Motarjemi & Käferstein, 1999).*

In generally Process flow Diagram of Frozen Yellow Fin Tuna in Molucass can be see from figure 2 bellow:

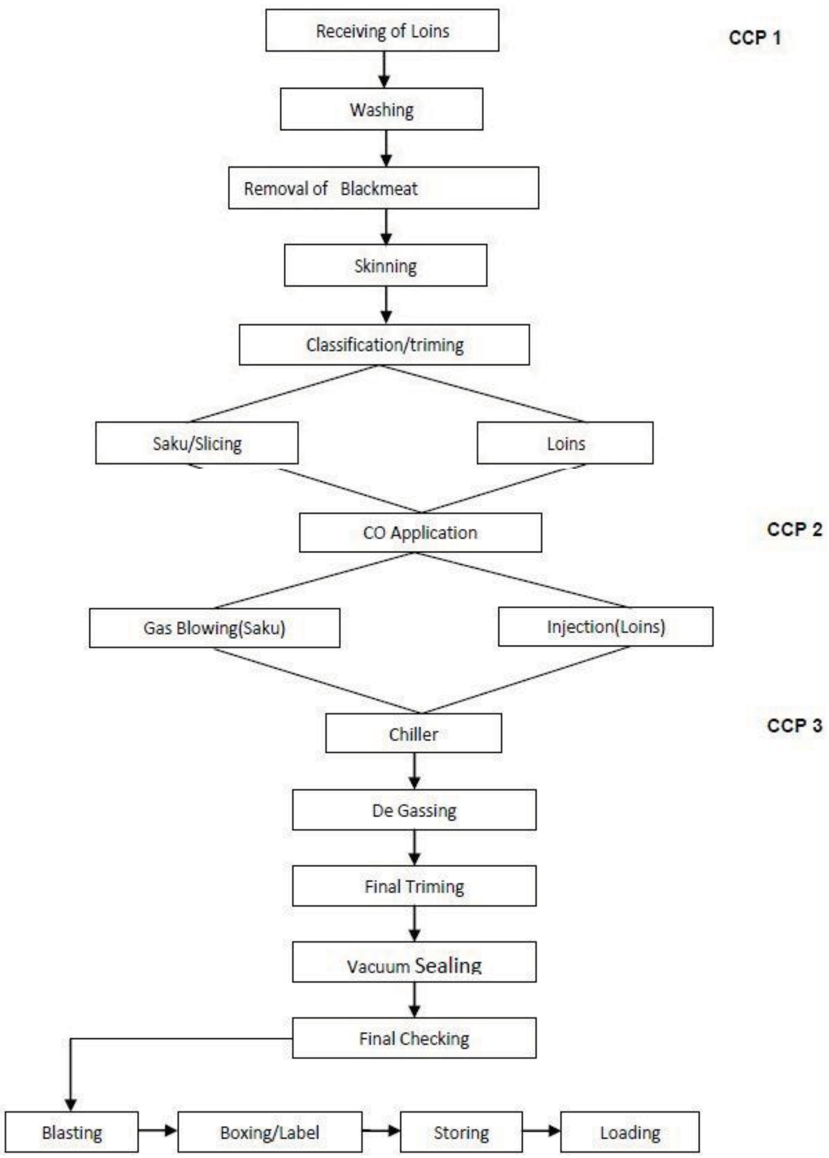

Figure 2. Process Flow Diagram Fresh-Frozen CO treated Yellow Fin Tuna n it's CCP (source : result of field studi)

Based on figure 2, we can find three Crisis Control Point(CCP):

CCP 1, quality of loins wich received very influential in the next process, a failure at this stage can cause to fish will be reject (suppliers delivered quarter loins with plastic in the plant by placing it in astyro box with adequate supply of ice ,Temprature is maintained $0^0 – 4{,}4^0$ C as required.

CCP 2, in CO Application process(these product are then segregated and arranged per item/line before placing inside the chiller.their are blown with CO only so as not to disintegrated the meat).

CCP 3, in chiller process(All product are then arranged inside the chiller and placed with production dates for traceability after curing,chilled/cured, the product for a maximum 48 hours to allow the carbon monoxide penetration.

Another hand,from field observations on fishing vessels, general process of Tuna fish handling on the ship,can be seen on figure.3 bellow,

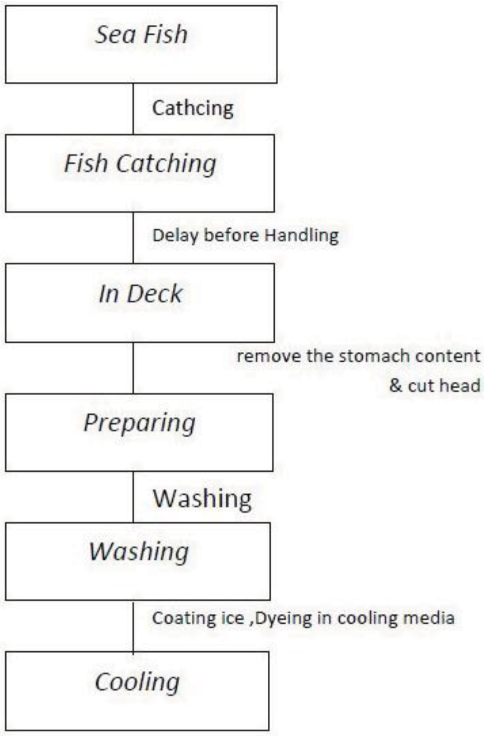

Figure 3. Handling Process in Fishery Ship (source: result of field study)

Figure 3 show, handling process on the ship, greatly effect to the quality of fish, especially in Crisis Control Point(CCP) 1(figure 2), to minimize the hazards ,table 3 below can see some point in the main hazards and actions that must be taken. Minimize the hazards will be improve the quality of tuna to be received

Table 3. Some point in the main hazards and action that must be taken to minimize CCP 1

MAIN HAZARDS	ACTIONS MUST BE TAKEN
• Long time in nets • Physical damage	• Improve fishing practices
• Direct sunlight,wind,heat • Fish Drying • The pressure in the heap of fish a lot	• Keep the fish stay cool and protected • Avoid a lot heap
• Spending the stomach contents and cutting fish head are bad	• improvement by training
• Heating • Delay • disturbances in machine	• fix the washing technique • Enchance training
• incorrect handling of cooling	• Add more ice • Perfected equipment • Enchance training

Besides the first critical control point CCP1 have explained above, there are still some of the following points in the process flow diagrams that are considered critical are:

From the results of studies litaratur and process flow diagrams, there are some important things to note in developing HACCP frame work of the Yellow Fin Tuna in Maluku:

1. HAACP Team Composition, Product Description,Description of utility usage, Development of production process diagram /Flowchart,Confirm the location of the job. }
2. Good Manufacturing Practices(GMP) : Building and Facilities,Grounds,Plant construction and Design,General Maintenance,Pest Control,Sanitation and Food Contact Surface,Toilet facilities, handwashing, waste disposal)
3. Equipment and Utensils
4. Production and Process Control : Raw Material and Other Indigreients,Manufacturing Operations,Cold Stored,Warehousing and Container Shipping
5. Sanitation Standart Operating Procedure

Relevant institutions and laboratories were identified regarding four main responsibilities for which the commitment of government is vital (food policy, risk assessment, legislation, public authorities),recommended that industry stakeholders: review the above developments and identify key risk areas and identify opportunities to influence and so mitigate risk areas

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Reference

Ayçiçek, H., Sarimehmetoglu, B., & Çakiroglu, S. (2004). Assessment of the microbiological quality of meals sampled are the meal serving units of a military hospital in Ankara, Turkey. *Food Control*, *15,* 379-384. http://dx.doi.org/10.1016/S0956-7135(03)00101-4

Fazil, M. A. (2005). A primer on risk assessment modelling: focus on seafood products, fisheries technical paper 462, FAO, Rome.

Giampaoli, J., Sneed, J., Cluskey, M., & Koenig, H. F. (2002). School foodservice directors' attitudes and perceived challenges to implementing food safety and HACCP programs. The *Journal of Child Nutrition & Management*, *26*(1). http://docs.schoolnutrition.org/newsroom/jcnm/02spring/giampaoli1

Hwang, J. H., Almanza, B. A., & Nelson, D. C. (2001). Factors influencing Indiana school foodservice directors/managers' plans to implement a hazard analysis critical control point (HACCP) program. *The Journal of Child Nutrition & Management*, *25*(1), 24-29

Lahsen Ababouch, (2006). Assuring fish safety and quality in international fish trade, *International Journal Marine pollution Bulletin*, *53***,** 561-568. http://dx.doi.org/10.1016/j.marpolbul.2006.08.011

Lailossa,G. W., Artana, K. B., & Dinariyana, A. A. B.(2010).Cold Chain System (future research prespective), 2nd International Seminar on Applied Technology Science and Arts-APTECS ITS,pp.23 ,Surabaya,ITS. available at, http://aptecs.its.ac.id/2010/paper/Proceeding%20APTECS%202rd%202010.pdf

Melba. G. B. R., Arthur, J. R., & Subasinghe, R. P. (2008). Understanding and applying Risk Analysis in Aquaculture, Fisheries and Aquaculture Technical Paper 519, FAO,Rome

Motarjemi, Y., & Käferstein, F. (1999). Food safety, HACCP and the increase in foodborne diseases: A paradox? , *Food Control Journal, 10,* 325-333. http://dx.doi.org/10.1016/S0956-7135(99)00008-0

Murat, B., Mariye, Y., & Tufba, Ç. (2007). Dificulties and barriers for the implementing of HACCP and food safety systems in food businesses in Turkey, *Food Control Journal, 18,*124–130. http://dx.doi.org/10.1016/j.foodcont.2005.09.002

Panisello, P. J., & Quantick, P. C. (2001). Technical barriers to hazard analysis critical control point (HACCP). *Food Control Journal, 12*(3), 165-173. http://dx.doi.org/10.1016/S0956-7135(00)00035-9

Samira, S., Gilles, S., & Patrick, G. (2010). A Swot analysis of HACCP implementation in Madagascar, *Food Control Journal, 21,* 253-259. http://dx.doi.org/10.1016/j.foodcont.2009.05.015

Thomas, J. B. (2002). HACCP–a work in progress, *Food Control Journal, 13*(6-7) 359-362. http://dx.doi.org/10.1016/S0956-7135(01)00026-3

Sorghum Accessions for Use as Cover Crops and Biofuel Feedstocks

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Abstract

Phenotypes of sorghum species (*Sorghum* sp.) have characteristics making them valuable summer annual cover crops and/or biofuel feedstocks for temperate climates. In field studies conducted at Urbana, IL, USA, fourteen USDA sorghum landrace accessions and three commercial sorghum accessions were evaluated for their growth habits and regrowth potential. In Canonical Discriminant Analysis (CDA) analysis, the first two canonical variates were significant and accounted for 86% of the among-accession variability. Unmown tiller number, regrowth tiller number, and regrowth biomass best discriminated between accessions in CDA and scattergrams. The accessions clustered into three subgroups. Three multi-stemmed accessions (two commercial varieties and one USDA accession) with an ability to regrow clustered away from the bulk of the USDA sorghums. Multi-stemmed accessions are useful for breeding improved summer annual cover crops that are tall, produce copious amounts of biomass, and rapidly regrow after defoliation; although propensity to lodging and poor germination of accessions will need attention. Additionally, landrace sorghum accessions in the USDA germplasm collection are useful for breeding cover crop and biofuel feedstocks, due to their great height and biomass production, although it will be necessary to select for improved regrowth potential. Crosses between USDA landraces and

the commercially available multi-stemmed accessions could lead to a sorghum cover crop and biofuel plant with great biomass and height and ability to regrow following defoliation.

Keywords: Sorghum, accessions, Canonical Discriminant Analysis, cover crops, biofuel

1. Introduction

1.1 Background

Sudangrass (*Sorghum sudanense* [Piper] Stapf.) rapidly closes canopy, reaches heights of 3m, produces up to 8 MT ha^{-1} shoot biomass, and immobilizes nutrients, making it more competitive than weeds (Ngouajio *et al.,* 2003; Snapp *et al*., 2005). Its terminal buds and basal and axillary tillers allow sudangrass to be repeatedly mown at 15 to 20 cm (Chamblee *et al*., 1995) and to re-grow following cutting (Bicksler *et al*., 2012; Muldoon, 1985). Most research on weed suppression has used a relatively few commercially available sorghum cultivars from the United States (Czarnota *et al.,* 2003; Nimbal *et al*., 1996). Moreover, sorghum species have the potential to be used as a biofuel through cellulosic ethanol conversion or as a powerplant feedstock (Hallam *et al*., 2001; Murray *et al*., 2008; Rooney *et al*., 2007), but research has also tended to focus on commercially available cultivars (Venuto and Kindiger, 2008; Zhao *et al*., 2009). The United States Department of Agriculture (USDA) maintains a sorghum germplasm repository with over 32,000 accessions from around the world (GRIN, 2013) with traits that could prove useful for weed suppressive cover crops or as biofuel feedstock.

1.2 Weed Suppression Potential

Weed suppression from sorghum cover crops may be improved by identifying cultivars or accessions with more competitive growth habits. Traits important for weed suppression by cover crops include: rapid biomass production, tall height, large surface area index, ability to regrow following defoliation to maintain interference against weed species, allelochemical production, and adaptation to local environmental conditions (Foley, 1999; Teasdale, 1998). Among these, increased height producing much biomass has been found to increase weed suppressive ability in cereal crops (Murphy *et al*., 2008; Foley, 1999). Cover crop light reduction originating from rapid growth rates, high shade tolerance, and competitive completion for light can effectively suppress weeds (Bicksler and Masiunas, 2009; Perry and Galatowitsch, 2006). Greenhouse research found that sudangrass regrowth after defoliation is important for suppressing Canada thistle, but tillering was not as important (Bicksler *et al*., 2012). The use of sorghum or sudangrass as a weed suppressing cover crop warrants further investigation. In other cereal cultivar studies, weed suppressive ability has varied considerably across cultivars (Hoad *et al*., 2008). Understanding the traits that make sorghum accessions have high weed suppressive ability would be beneficial for breeding or selecting improved weed-suppressive cover crops.

1.3 Allelopathy Potential

Besides their competitiveness, sorghum species can be allelopathic, inhibiting the growth of weeds. Sorgoleone (2-hydroxy-5-methoxy-3-[(*Z*,*Z*)-8',11',14'-pentadecatriene]-*p*-benzoquinone) and dhurrin (p-hydroxy-(S)-mandelonitrile-β-D-glucoside) are major hydrophobic components of sorghum (Czarnota *et al*., 2003; Dayan, 2006; Weston and Duke, 2003). Allelochemical production varies according to genotypes (Czarnota *et al*., 2003;

Nimbal *et al*., 1996). Sorghum shoots, as a surface mulch or a soil-incorporated residue, release phenolic compounds and cyanogenic glucosides, such as dhurrin, that can suppress weeds (Nielsen *et al*., 2008). Traditionally, farmers in many developing countries have used sorghum as a weed suppressing mulch and leaf extracts as a natural herbicide (Cheema, 2000; Cheema *et al*., 2004; Sène *et al*., 2000). Differences in suppression of indicator plants vary between sorghum genotypes and have been correlated with phenolic concentration (Alsaadawi *et al.,* 2007; Ben-Hammouda *et al*., 1995). It may be assumed that increasing sorghum biomass is a useful trait to suppress weeds both by its physical presence and potential allelopathic potential.

1.4 Biofuel Crop Potential

Sorghum also has potential as a warm-season annual biofuel crop (Saballos, 2008; Rooney *et al.,* 2007, Murray *et al*., 2008, Stefaniak *et al*., 2012). Sorghum has high productivity, drought tolerance, and many accessions likely vary in traits useful for biofuel crops, such as high amounts of lignocellulose, sugar, and starch (Rooney *et al*., 2007). Also, many of the traits that make sorghum a useful cover crop (height, tillers, ability to undergo defoliation, and large biomass production) could also make sorghum a useful biofuel feedstock (Hallam *et al.,* 2001; Saballos, 2008; Venuto and Kindiger, 2008), if accessions could be isolated for specific traits and targeted for breeding. The ability of late-maturing sorghums to regrow after defoliation would be beneficial in a temperate biofuel usage where repeated defoliations could be made during the growing season (Venuto and Kindiger, 2008).

1.5 Using CDA to Assess Genetic Diversity

Assessing genetic diversity in sorghums (Teshome *et al*., 1997), hairy vetch (Yeater *et al*., 2004), and tall fescue (Vaylay and van Santen, 2002), has used Canonical Discriminant Analysis (CDA). CDA is an effective research tool because it can be paired with a nonhierarchical clustering procedure to group accessions into smaller subgroups that are most similar to each other (SAS Institute, 1999b; Yeater *et al.,* 2004). By joining CDA, clustering procedures, and graphical representations, accessions can be differentiated by phenotypic characteristics of importance for cover cropping and biofuel applications.

1.6 Purpose of the Study

The interest in sorghum as a temperate annual cover crop and its potential as a biofuel, coupled with the limited availability of commercial sorghum cultivars, formed the rationale for the present study. The purpose of this research was to identify *Sorghum sp.* accessions with potential for use as cover crops and/or biofuels. We hypothesized that the multi-stemmed accessions would segregate from the rest of the landraces based upon tiller number and regrowth following defoliation. We also hypothesized that several of the USDA landraces would be capable of producing large quantities of biomass and be tall.

2. Materials and Methods

2.1 Sorghum Accessions

Sorghum accessions were identified in the USDA's Genetic Resources Information Network (GRIN, 2013) by querying the Southern Regional Sorghum Germplasm Collection (Griffin, GA, USA) for accessions with large height, numerous tillers, and midrib moisture, in order to focus on accessions with potentially beneficial traits for use as a cover crop or biofuel. Representative commercial sudangrass accessions were obtained from Seeds of Change, NC+

Organics, and Welter Seed and Honey American seed companies and were sold as either animal forage or cover crops (Table 1). Characteristics useful for biofuel and cover crops include: large unmown mass, large regrowth mass and large total mass.

Table 1. Name, source, species, origin, and given trait information of various sorghum accessions used in the experiment.

Name	Source[a]	Species	Origin	Given Traits[b]		
				Height (cm)	Tillers (# $plant^{-1}$)	Midrib[c]
Akur Gok	PI 152591	*Sorghum bicolor*	Kenya	430	5	dry
Andiwo	PI 521346	*S. bicolor* (L.) Moench ssp. *drummondii*[d]	Kenya	346	-	dry
'Black African Sorghum'	Seeds of Change	*Sorghum bicolor*	Africa	275	-	-
Budy	PI 152611	*Sorghum bicolor*	Kenya	410	2-5	dry
FAO 49967	PI 562367	*Sorghum sp.*[e]	Kenya	185	1	juicy
IS22852	PI 570074	*Sorghum bicolor*	Sudan	500	2	dry
Juar 20	PI 164416	*Sorghum bicolor*	India	310	3	inter
Kamuria	PI 152955	*Sorghum bicolor*	Kenya	240	0	inter
Macro Chaeta 4	PI 563237	*Sorghum bicolor*	Kenya	167	2	dry
Muembe	PI 153877	*Sorghum bicolor*	Kenya	375	2	dry
Ndola	PI 152904	*Sorghum bicolor*	Kenya	285	1	inter
Ochuti	PI 521344	*S. bicolor* (L.) Moench ssp. *Drummondii*	Kenya	245	0	dry
Ogolo	PI 521341	*S. bicolor* (L.) Moench ssp. *Drummondii*	Kenya	275	-	dry
Orolo	PI 153830	*Sorghum bicolor*	Kenya	225	3	inter
'Special Effort'	Welter Seed	*S. bicolor* Moench x *S. sudanense* [Piper] Stapf.	USA	NA	NA	NA
Stoneville Synthetic	PI 542962	*Sorghum bicolor*	USA	NA	NA	NA
'Sweetleaf II'	NC+ Organics	*S. bicolor* Moench x *S. sudanense* [Piper] Stapf.	USA	NA	NA	NA

[a] Provenance numbers (PI) from USDA germplasm collection; Southern Regional PI Station, Griffin, GA, USA.

[b] Height, tiller number, and midrib description from USDA website information (www.ars-grin.gov/npgs/searchgrin.html) or description of seed company.

[c] Midrib traits describe moisture content of midrib of leaf: dry, juicy, or intermediate (inter).

[d] Full name is *Sorghum bicolor* (L.) Moench ssp. d*rummondii* (Nees ex Steud.) De Wet ex Davids.

[e] Unknown species.

2.2 Field Study Location

The study was conducted in 2007 and 2008 using fourteen USDA landrace accessions and three commercial cultivars (Table 1). Field experiments were conducted at the University of Illinois' Vegetable Crops Research Farm in Champaign, Ill, USA, which experiences a humid continental climate with severe winters, no dry season, and hot summers. It is classified as a Dfa Köppen-Geiger classification (Climatemps, 2015) and a USDA Plant Hardiness Zone 5a. The soil type was a Flanagan silt loam (fine montmorillonitic, mesic Aquic Agridoll), with a soil pH between 6.5 and 7.1, soil organic matter content between 4.3% and 4.7%, and cation exchange capacity (CEC) between 12 meq/100 g and 16 meq/100 g. From June to October, the mean monthly temperatures ranged from 15.5°C to 25.7°C in 2007 and from 12.7°C to 23.2°C in 2008, while the total monthly precipitation ranged from 3.8 cm to 14.4 cm in 2007 and from 1.9 cm to 20.7 cm in 2008. On March 26 and 23 in 2007 and 2008, respectively, 129 kg ha^{-1} N, 113 kg ha^{-1} P, and 135 kg ha^{-1} K was broadcast applied to the experimental site. The site was disked using a tandem disk-harrow and rototilled to remove emerged weeds and prepare for planting on June 15 and 6 in 2007 and 2008, respectively.

2.3 Experimental Design

The experiment was conducted as a randomized complete block design with four replicates and two subsamples for each treatment. Treatments were the 17 sorghum accessions. Plots were 1.44 m^2 and contained two plants of a single accession, spaced 61cm between plants.

2.4 Plot Establishment

On June 20 and June 12 in 2007 and 2008, respectively eight seeds per plot (4 seeds in each planting hole) of each sorghum accession were hand seeded at a depth of 1.3 cm into freshly prepared soil and hand watered twice weekly until established (3 weeks after planting). At 14 days after planting (DAP), emergence was recorded as a ratio of seeds emerged to seeds planted (8) in each plot. At the same time, emerged seedlings were thinned to two plants per plot with a spacing of 61cm between plants. Weeds were managed using disking and hand-pulling. One plant per plot was defoliated 2.5 months after planting to evaluate regrowth and tillering after simulated mowing, and the other plant was allowed to grow until maturity.

2.5 Dependent Variables

At 79 DAP in 2007 and 82 DAP in 2008, when many of the landrace varieties were just beginning to flower, reaching their maximum size, one plant in each plot was cut at a height of 10 cm to measure regrowth and tillering ability. At 132 DAP in 2007 and 121 DAP in 2008, the experiment was terminated. Sorghum final free-standing height and final number of shoots were measured for both plants without defoliation and the regrowth of the cut plants. Sorghum free-standing height was measured from the soil surface to the tallest naturally occurring apex of leaves. Shoot numbers (tillers) were counted at the base of each plant. Shoots were cut at the soil surface, chipped in a chipper-shredder to allow easier handling, and weighed for wet mass. Five hundred gram subsamples of chipped shoots were dried at 70 ^{o}C until constant mass, and weighed. Total shoot dry mass was extrapolated from total fresh mass and subsample dry mass.

2.6 Data Analysis

Data were analyzed using Canonical Discriminant Analysis (CDA) and a nonhierarchical clustering method on the seven continuous variables (unmown height, regrowth height, unmown dry mass, regrowth dry mass, unmown tiller number, regrowth tiller number, and emergence). These analyses were conducted using the CANDISC and FASTCLUS procedures in SAS (SAS Institute; Cary, North Carolina, USA). In CDA, a classification variable (sorghum accessions) and measured traits were analyzed to derive canonical variables (SAS Institute, 1999a; Yeater *et al*., 2004). Canonical variables were used to group the accessions into clusters with small within-cluster variation relative to between-cluster variation. Mean values of canonical variables (group centroids) were then used to calculate distances between centroid values of each group called the Mahalanobis distance (D^2) (Yeater *et al*., 2004). Then, a *k*-means approach was used in a nonhierarchical clustering procedure (FASTCLUS) to assign all accessions to similar clusters (SAS Institute, 1999b). In addition to CDA and clustering, the accessions with the best ability to produce biomass and height and to regrow after mowing were identified using Fisher's Protected LSD and three-dimensional scattergrams. Accessions were compared to an ideotype of sorghum that would best suppress weeds and act as a biofuel based upon: 1) tall height, 2) large quantity of biomass, 3) ability to regrow to tall height, and 4) ability to regrow large quantity of biomass. All continuous and ordinal data were analyzed as linear mixed models using the MIXED Procedure of SAS. Both repeats and block were random factors, while sorghum accession was a fixed factor. For all dependent variables, degrees of freedom were adjusted using the Satterthwaite correction (Littell, *et al*. 2002), and normality of the raw data and residuals was evaluated using the UNIVARIATE procedure of SAS. When factors were significant, means were separated with Fisher's Protected LSD Test at an alpha = 0.05 using the PDMIX800 macro (Saxton, 1998). The scattergrams were constructed using the G3D procedure in SAS to evaluate overall unmown and regrowth plant stature and traits with greatest potential for cover cropping and biofuel use. Overall unmown plant growth was determined from the parameters of dry mass, number of tillers, and final height of sorghums grown to experiment termination without defoliation. Plant growth after mowing was determined from the parameters of dry mass, number of tillers, and height of the defoliated plants when the experiment was terminated.

3. Results and Discussion

3.1 CDA Clustering

Canonical discriminant analysis discriminated between sorghum accessions. The first two canonical variates accounted for 86% of among-sorghum accession variance. The canonical correlation was 0.97 between accessions and the first canonical variate, and canonical correlation was 0.82 between accessions and the second canonical variate, suggesting that these canonical variates can explain much of the differences in accessions. The first canonical discriminant function was influenced by loadings from unmown tiller number, regrowth tiller number, and regrowth biomass. The second canonical discriminant function was dominated by loadings from regrowth height, unmown height, and regrowth biomass. The first canonical variate has the most discriminatory power in separating class variables. The traits that loaded for the two canonical variates suggest the sorghum accessions differ most in their tillering and regrowth after defoliation. An accession that would function well as a cover crop should regrow from tillering stems following mowing because it increases competitive ability, modifies the cover crop canopy, and allows for repeated mowing (Foley, 1999). The two canonical variates were used to cluster the accessions into three groups (Figure 1). The Mahalanobis distances were 90 between clusters I and II, 17.7 between clusters I and III and 77.1 between clusters II and III. All pairwise differences between clusters were significant (P = <0.0001). Cluster groups display smaller within-cluster phenotypic variation than among-cluster phenotypic variation (Teshome *et al*., 1997; Vaylay and van Santan, 2002). Accessions in clusters I and III contained USDA sorghum accessions and one commercial cultivar ('Black African Sorghum'). 'Black African Sorghum' was sold by Seeds of Change as a tall, early maturing, sorghum for use as a cover crop. Clusters I and III differed from each other mainly due to differences in height and regrowth biomass due to loadings of traits in canonical variate 2. Accessions in cluster II were two commercially-available hybrid sudangrass cultivars ('Special Effort' and 'Sweetleaf II') and the USDA's Stoneville Synthetic sorghum that produce many tillers; all three accessions originated in the USA. 'Special Effort' and 'Sweetleaf II' sudangrass are marketed for their ability to produce many tillers and to regrow after grazing.

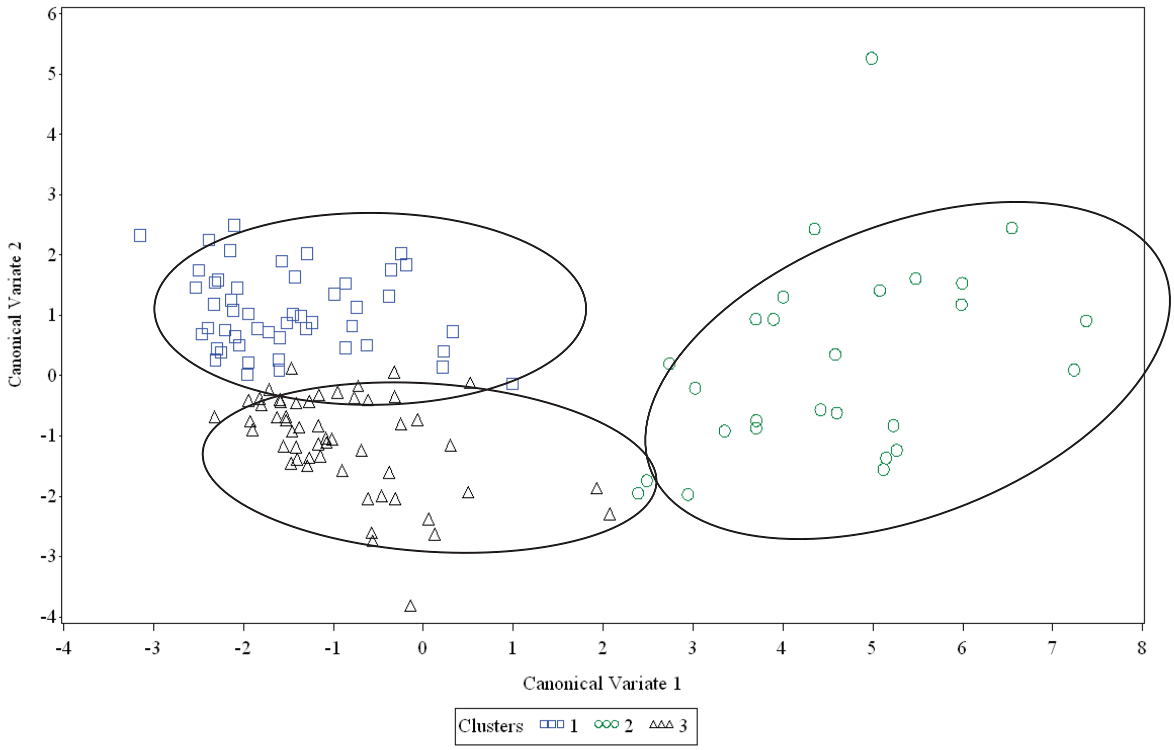

Figure 1. Scattergram of the Three Cluster Groupings on the Two Canonical Discriminant Functions for Sorghum Accessions.

Cluster groups were determined by PROC FASTCLUS in SAS using Mahalanobis Distance

(D^2) of the centroid values of two canonical variables. Seventeen accessions grown in both years were used in the cluster analysis. Cluster I includes Andiwo, FAO49967, Muembe, Ndola, Ochuti, and Ogolo. Cluster II includes ‘Special Effort,’ Stoneville Synthetic, and ‘Sweetleaf II’. Cluster III includes Akor Gok, ‘Black African Sorghum,’ Budy, IS22852, Juar 20, Kamuria, Machro Chaeta 4, and Orolo.

3.2 Emergence

Percent emergence was greatest using LSD for ‘Black African Sorghum,’ ‘Sweetleaf II,’ Muembe, Ochuti, Machro Chaeta 4, Kamuria, and Andiwo, averaging 77.6% (Table 2). Among the other commercial accessions, ‘Special Effort’ and Stoneville Synthetic averaged 50% emergence and four of the USDA sorghums averaged below 50% emergence, for unknown reasons. The seed from the USDA accessions may have been old, needing to be renewed.

Table 2. Effect of sorghum accession on emergence, averaged across 2007 and 2008 runs of the experiment.

Name	Emergence (%)
Akur Gok	43
Andiwo	75
‘Black African Sorghum’	85
Budy	52
FAO49967	36
IS22852	48
Juar 20	51
Kamuria	75
Macro Chaeta 4	76
Muembe	78
Ndola	51
Ochuti	77
Ogolo	59
Orolo	22
‘Special Effort’	46
Stoneville Synthetic	54
‘Sweetleaf II’	77
LSD within column	22.7***[a]

[a] P-value of ANOVA, where *P<0.05, **P<0.01, and ***P<0.001.

3.3 Biomass, Height, and Tillers

The greatest unmown dry mass plant^{-1} and unmown height was in several of the USDA landrace accessions (Muembe, Ochuti, Ogolo, Ndola, and Andiwo, averaging 1700 g plant^{-1} and 275 cm), as well as commercially available ‘Sweetleaf II’ (Table 3, Figure 2). Several USDA landrace accessions (Andiwo, Ogolo, and Ndola) were close to the ideotype for an unmown sorghum cover or biofuel crop, offering potential for breeding on the basis of unmown dry biomass and height, two parameters useful for a cover and biofuel crop (Figure 2). Three multi-stemmed accessions (‘Sweetleaf II,’ ‘Special Effort,’ and Stoneville Synthetic, averaging 117 g plant^{-1}) that clustered together using CDA and scattergrams had the greatest regrowth dry mass plant^{-1} (Table 3, Figure 3). 'Sweetleaf II' and 'Special Effort' had the greatest combined regrowth height, regrowth biomass, and regrowth tillers of the 17 accessions (Figure 3), suggesting they were good starting places for regrowth breeding, but are hybrids. Additionally, 'Special Effort,' and 'Sweetleaf II,' cultivars grouped together near the ideotype for an ideal cover crop (Figure 4), yet both could be improved by increasing unmown height and biomass, to make them equally useful for biofuel purposes.

Table 3. Effect of sorghum accession on unmown and regrowth height, unmown and regrowth biomass, and unmown and regrowth tillers, averaged across 2007 and 2008 runs of the experiment.

Name	Height[a] (cm)		Biomass[b] (g plant^{-1})		Tillers (# plant^{-1})	
	Unmown	Regrowth	Unmown	Regrowth	Unmown	Regrowth
Akur Gok	238	38	1372	4	7.5	2.7
Andiwo	314	94	1517	73	5.6	8.9
'Black African Sorghum'	231	76	880	37	7.5	8.3
Budy	201	52	1337	13	7.1	3.7
FAO49967	255	69	1456	39	7.5	8.4
IS22852	228	34	1201	6	9.3	2.7
Juar 20	216	105	480	41	9.0	9.9
Kamuria	215	59	898	16	5.0	3.1
Macro Chaeta 4	199	92	625	129	6.1	12.4
Muembe	260	38	1820	23	13.8	12.4
Ndola	282	64	1683	27	9.8	8.9
Ochuti	248	80	1780	51	5.9	6.6
Ogolo	271	80	1703	79	13.8	16.5
Orolo	210	75	1212	44	14.4	23.3
'Special Effort'	220	126	1039	182	30.8	41.9
Stoneville Synthetic	169	96	786	103	30.8	42.5
'Sweetleaf II'	247	130	1763	231	34.1	47.4
LSD within column	41.1***[d]	32.4***	457.1***	77.0***	5.3***	10.7***

[a] Height measured from ground to tallest free-standing leaf.

[b] Biomass measured on a plant-clump basis.

[c] Variances between years were not statistically significant for any dependent variable, so years were combined for analysis.

[d] P-value of ANOVA, where *P<0.05, **P<0.01, and ***P<0.001.

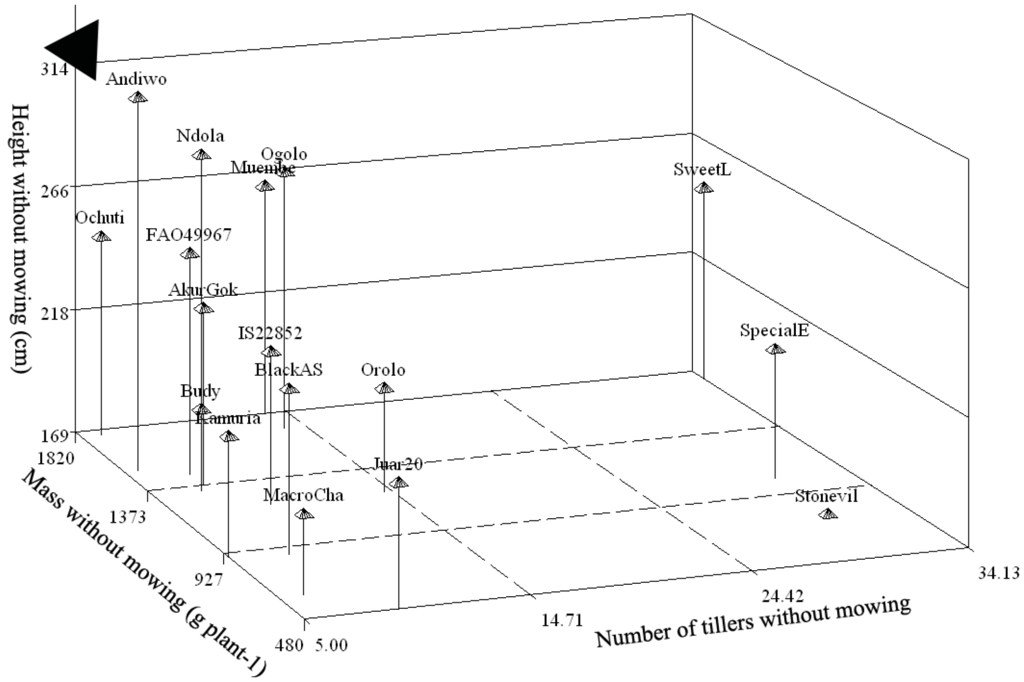

Figure 2. Scattergram of 17 Sorghum Accessions Clustered by Unmown Parameters (Unmown Tiller number, Unmown Dry Biomass, and Unmown Height), Averaged Across 2007 and 2008 Runs of the Experiment.

Black triangle represents sorghum ideotype for use as a cover crop or biofuel feedstock. Unmown data were collected 126 DAP.

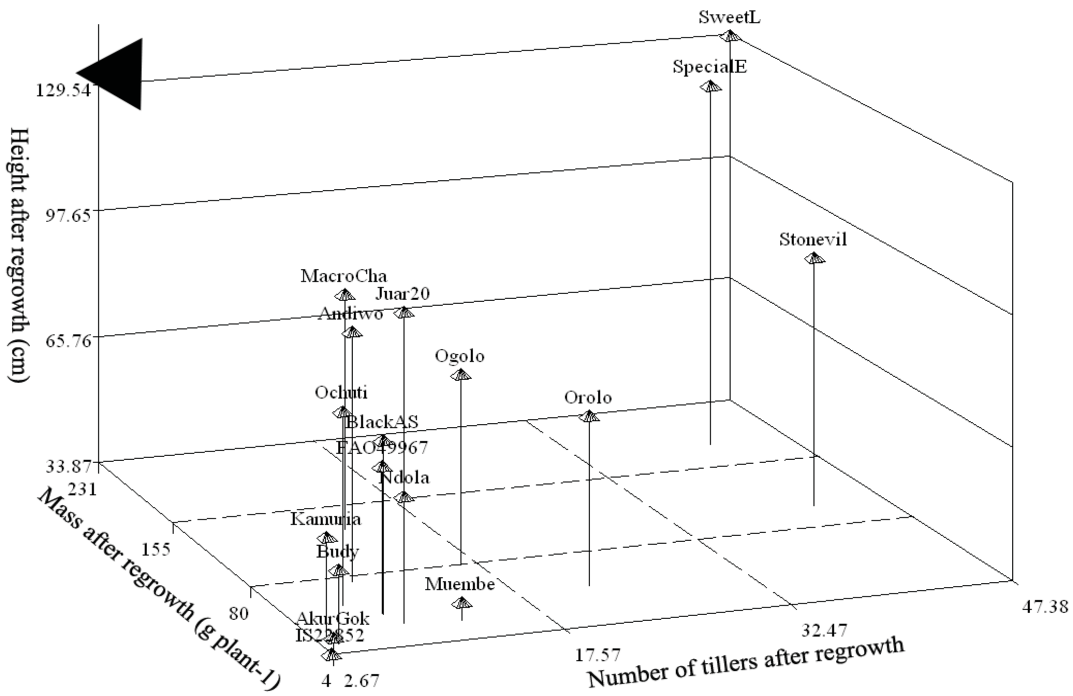

Figure 3. Scattergram of 17 Sorghum Accessions Clustered by Regrowth Parameters (Regrowth Tiller Number, Regrowth Dry Biomass, and Regrowth Height), Averaged Across

2007 and 2008 Runs of the Experiment.

Black triangle represents sorghum ideotype for use as a cover crop or biofuel feedstock. Regrowth data were collected 46 days after mowing.

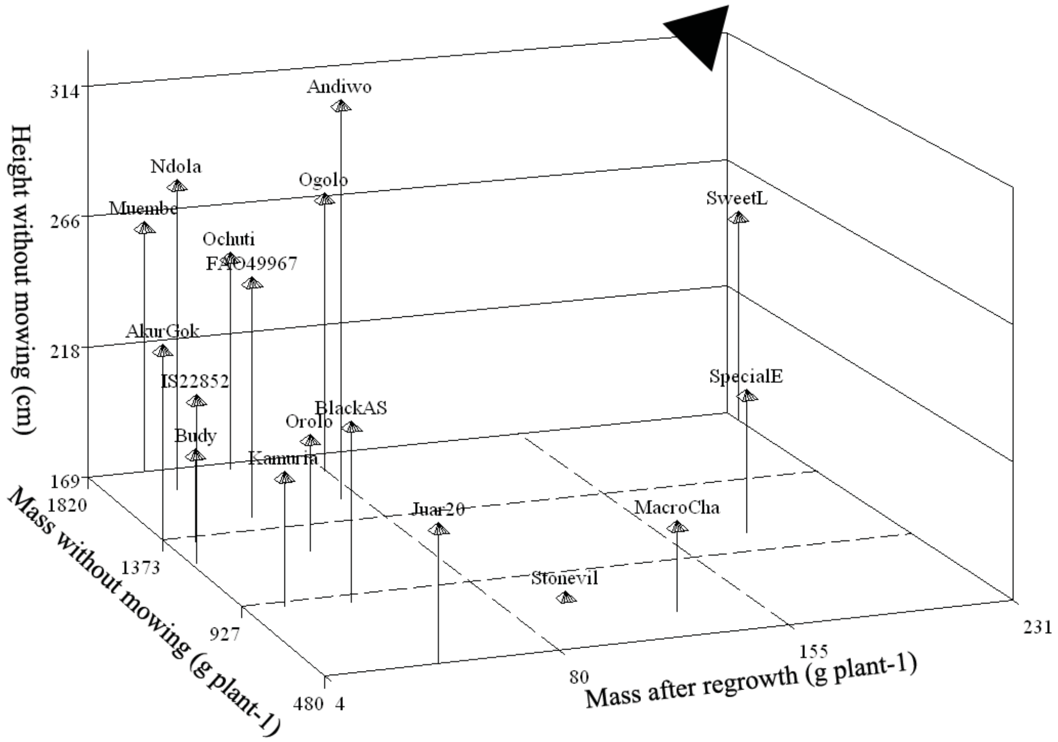

Figure 4. Scattergram of 17 Sorghum Accessions Clustered by Ideal Cover Crop Parameters (Unmown Height, Unmown Dry Biomass, and Regrowth Dry Biomass) Averaged Across 2007 and 2008 Runs of the Experiment.

Black triangle represents sorghum ideotype for use as a cover crop. Unmown data were collected 126 DAP and regrowth data were collected 46 days after mowing.

4. Conclusions

4.1 Sorghum's Potential as a Cover Crop

Regrowth mass and height is an important trait for summer annual cover crops to increase competitive ability, canopy diversity, and tolerance to mowing (Foley, 1999; Teasdale, 1998). Ability to regrow after mowing allows for increased mulch production, which can smother weeds. Of the three multi-stemmed accessions, 'Sweetleaf II' had greater number of unmown and regrowth tillers, unmown and regrowth mass, and regrowth height than 'Special Effort' or Stoneville Synthetic. Yet, regrowth ability alone does not maximize competitive ability. Initial unmown height and biomass (within first 2.5 months after planting) are also important for increased weed control (Murphy *et al.,* 2008), and were best exhibited by several of the USDA landrace sorghums such as Andiwo and Ogolo, consistent with Stefaniak *et al*. (2012), who found that biomass yields of biomass sorghums and sweet sorghums were greater than sorghum-sudangrass hybrids. The inbred parents of 'Sweetleaf II' and several of the USDA landrace sorghums might be a good starting point for breeding programs to increase both unmown and regrowth height and biomass of sudangrass cover crops. A combination of Andiwo's and Ogolo's unmown height and unmown biomass with 'Sweetleaf II's' regrowth biomass could produce a cover crop with excellent overall competitive ability and regrowth potential following defoliation. Improvements to these accessions for use as cover crops should target: increasing emergence, reducing lodging, increasing unmown biomass and height, and increasing secondary traits, such as allelopathy.

4.2 Sorghum's Potential as a Biofuel Crop

Assuming the feasibility of converting lingo-cellulose to usable fuels or using dried biomass directly in power plants, biofuel feedstock breeding on the basis of unmown mass (Saballos, 2008) could target these African USDA accessions. If multiple defoliations were desired for the biomass crop production, regrowth biomass production found in the multi-stemmed accessions would be the best for future research and crosses with the USDA landraces (Saballos, 2008).

4.3 Future Directions

Overall, CDA and nonhierarchical clustering, LSD, and scattergrams consistently discriminated sorghum accessions on the basis of phenotypic traits and commercial breeding. 'Sweetleaf II,' 'Special Effort,' and Stoneville Synthetic were in one cluster, while USDA sorghum accessions were in two different clusters that were similar in tillering to each other, yet differed in regrowth height, unmown height, and regrowth biomass. These three accessions of multi-stemmed commercial sorghums originating in the USA with excellent regrowth potential are a good starting point for farmers to use in cover cropping applications and for breeders to improve upon as summer annual cover crops. Increased cover crop growth, biomass production, and canopy production has been shown to be directly related to weed suppression (Foley, 1999). Our research has built upon the work of Rooney *et al.* (2007), Saballos (2008), and Venuto and Kindiger (2008) to distinguish USDA landrace accessions such as Muembe, Ochuti, Ogolo, Ndola, Andiwo, and Orolo, which would be excellent candidates for biofuel breeding and/or could be improved upon for regrowth potential as summer annual cover crops because of their height and biomass potential. But, their limited regrowth would not be favorable for multiple harvests. Crosses between USDA landraces and the multi-stemmed accessions could lead to a sorghum cover crop with great unmown biomass and height and ability to regrow following mowing, and would approximate a sorghum cover crop ideotype. Previous research on several sorghum accessions confirmed that sorghum had the lowest cost per ton of biomass produced compared to switchgrass, big bluestem, alfalfa, and reed canary grass (Hallam *et al.,* 2001). This research has confirmed that several of the USDA's accessions of landrace sorghums would be useful for biomass breeding (Stefaniak *et al*., 2012) and the effectiveness of CDA for rapid clustering of accessions for targeted traits (Teshome *et al.,* 1997). Future research should examine optimal plant spacing, seeding density, and plant populations in field scale experiments for biofuel production (Goff *et al*., 2010).

References

Alsaadawi, I. S., Al-Ekelle, M. H. S., & Al-Hamzawi, M. K. (2007). Differential Allelopathic Potential of Grain Sorghum Genotypes to Weeds. *Allelopathy Journal*, *19*, 87-95.

Ben-Hammouda, M., Kremer, R. J., Minor, H. C., & Sarwar, M. (1995). A Chemical Basis for Differential Allelopathic Potential of Sorghum Hybrids on Wheat. *Journal of Chemical Ecology*, *21*, 775-786. http://dx.doi.org/10.1007/BF02033460

Bicksler, A. J., Masiunas, J. B., & Davis, A. (2012). Canada Thistle (*Cirsium arvense*) Suppression by Sudangrass Interference and Defoliation. *Weed Science*, *60*, 260-266. http://dx.doi.org/10.1614/WS-D-11-00145.1

Bicksler, A. J., & Masiunas, J. B. (2009). Canada Thistle (*Cirsium arvense*) Suppression with Buckwheat or Sudangrass Cover Crops and Mowing. *Weed Technology, 23(4),* 556-563. http://dx.doi.org/10.1614/WT-09-050.1

Chamblee, D. S., Green, J. T., Burns, J. C. (1995). Principle forages of North Carolina: adaptation, characteristics, management, and utilization. In D. S. Chamblee, & J. T. Green (Eds.), *Production and utilization of pastures and forages in North Carolina*. Technical Bulletin No. 305. Raleigh, North Carolina: North Carolina Agricultural Research Service.

Cheema, Z. A. (2000). Use of Sorghum Allelopathic Properties to Control Weeds in Irrigated Wheat in a Semi Arid Region of Punjab. *Agriculture, Ecosystems and Environment, 79,* 105-112.

Cheema, Z. A., Khaliq, A., & Saeed, S. (2004). Weed Control in Maize (*Zea mays* L.) Through Sorghum Allelopathy. *Journal of Sustainable Agriculture, 23*(4), 73-85. http://dx.doi.org/10.1016/S0167-8809(99)00140-1

Climatemps.com. (2015). Urbana, IL, Climate and Temperature. [Online]. Available: http://www.urbana-il.climatemps.com/ (August 24, 2015).

Czarnota, M. A., Rimando, A. M., & Weston, L. A. (2003). Evaluation of Root Exudates of Seven Sorghum Accessions. *Journal of Chemical Ecology, 29,* 2073-2083. http://dx.doi.org/10.1023/A:1025634402071

Dayan, F. E. (2006). Factors Modulating the Levels of the Allelochemical Sorgoleone in *Sorghum bicolor*. *Planta, 224*(2), 339-346. http://dx.doi.org/10.1007/s00425-005-0217-5

Foley, M. (1999). Genetic Approach to the Development of Cover Crops for Weed Management. *Crop Production, 2*(1), 77-93. http://dx.doi.org/10.1300/J144v02n01_05

[GRIN] Germplasm Resources Information Network. (2013). National Plant Germplasm System. [Online] Available: www.ars-grin.gov/npgs/searchgrin.html (Dec. 6, 2013).

Goff, B. M., Moore, K. J., Fales, S. L., & Heaton, E. A. (2010). Double-Cropping Sorghum for Biomass. *Agronomy Journal*, *102*(6), 1586-1592.

http://dx.doi.org/10.2134/agronj2010.0209

Hallam, A., Anderson, I. C., & Buxton, D. R. (2001). Comparative Economic Analysis of Perennial, Annual, and Intercrops for Biomass Production. *Biomass and Bioenergy*, *21,* 404-424. http://dx.doi.org/10.1016/S0961-9534(01)00051-4

Hoad, S., Topp, C., & Davies, K. (2008). Selection of Cereals for Weed Suppression in Organic Agriculture: A Method Based on Cultivar Sensitivity to Weed Growth. *Euphytica, 163,* 355-366. http://dx.doi.org/10.1007/s10681-008-9710-9

Littell, R. C., Stroup, W., & Freund, R. J. (2002). *SAS for Linear Models.* (4th ed.). Cary North Carolina: SAS Institute.

Muldoon, D. K. (1985). Summer Forages Under Irrigation: 1: Growth and Development. *Australian Journal of Experimental Agriculture*, *25,* 392-401. http://dx.doi.org/10.1071/EA9850392

Murphy, K. M., Dawson, J. C., & Jones, S. S. (2008). Relationship Among Phenotypic Growth Traits, Yield and Weed Suppression in Spring Wheat Landraces and Modern Cultivars. *Field Crops Research, 105,* 107-115. http://dx.doi.org/10.1016/j.fcr.2007.08.004

Murray, S. C., Rooney, W. L., Mitchell, S. E., Sharma, A. P., Klein, E. J., Mullet, E., & Kresovich, S. (2008). Genetic Improvement of Sorghum as a Biofuel Feedstock: II. QTL for Stem and Leaf Structural Carbohydrates. *Crop Science, 48,* 2180-2193. http://dx.doi.org/10.2135/cropsci2008.01.0068

Ngouajio, M., McGiffen, M., & Hutchinson, C. M. (2003). Effect of Cover Crop and Management System on Weed Populations in Lettuce. *Crop Protection, 22,* 57-64. http://dx.doi.org/10.1016/S0261-2194(02)00111-4

Nielsen, K. A., Tattersall, D. B., Jones, P. R., & Møller, B. L. (2008). Metabolon Formation in Dhurrin Biosynthesis. *Phytochemistry*, *69,* 88-98. http://dx.doi.org/10.1016/j.phytochem.2007.06.033

Nimbal, C. I., Pedersen, J. F., Yerkes, C. N., Weston, L. A., & Weller, S. C. (1996). Phytotoxicity and Distribution of Sorgoleone in Grain Sorghum Germplasm. *Journal of Agricultural and Food Chemistry*, *44,* 1343-1347. http://dx.doi.org/10.1021/jf950561n

Perry, L. G., & Galatowitsch, S. M. (2006). Light Competition for Invasive Species control: A Model of Cover Crop-Weed Competition and Implications for *Phalaris arundinacea* Control in Sedge Meadow Wetlands. *Euphytica*, *148,* 121-134. http://dx.doi.org/10.1007/s10681-006-5946-4

Rooney, W. L., Blumenthal, J., Bean, B., & Mullet, J. E. (2007). Designing Sorghum as a Dedicated Bioenergy Feedstock. *Biofuels, Bioproducts and Biorefining*, *1,* 147-157. http://dx.doi.org/10.1002/bbb.15

SAS Institute, Inc. (1999a). *SAS/STAT User's Guide: Chapter 21: The CANDISC Procedure, version 8*. Cary North Carolina: SAS Institute, Inc.

SAS Institute, Inc. (1999b). *SAS/STAT User's Guide: Chapter 27: The FASTCLUS Procedure, version 8.* Cary North Carolina: SAS Institute, Inc.

Saballos, A. (2008). Development and utilization of sorghum as a bioenergy crop. In Vermerris, W. (Ed.), *Genetic Improvement of Bioenergy Crops*, 211-248. New York: Springer. http://dx.doi.org/10.1007/978-0-387-70805-8_8

Saxton, A. M. (1998). A macro for converting mean separation output to letter in Proc Mixed, In *Proc. 23rd SAS Users Group Intl., SAS Institute, Cary NC*,1243-1246.

Sène, M., Doré, T., Pellissier, F. (2000). Effect of Phenolic Acids in Soil Under and Between Rows of a Prior Sorghum (*Sorghum bicolor*) Crop on Germination, Emergence, and Seedling Growth of Peanut (*Arachis hypogea*). *Journal of Chemical Ecology*, *26*(3), 625-637. http://dx.doi.org/10.1023/A:1005420020135

Snapp, S. S., Swinton, S., Labarta, M. R., Mutch, D. J., Black, R., Leep, R., Niyiraneza, J., & O'Neil, K. (2005). Evaluating Cover Crops for Benefits, Costs, and Performance Within Cropping System Niches. *Agronomy Journal*, 97, 322-332.

Stefaniak, T. R., Dahlberg, J. A., Bean, B. W., Dighe, N., Wolfrum, E. J., & Rooney, W. L. (2012). Variation in Biomass Composition Components Among Forage, Biomass, Sorghum-Sudangrass, and Sweet Sorghum Types. *Crop Science*, *52,* 1949-1954. http://dx.doi.org/10.2135/cropsci2011.10.0534

Teasdale, J. (1998). Cover crops, smother plants, and weed management In: Hatfield, J. L., Buhler, D. D., & Stewart, B. A. (Eds.), *Integrated Weed and Soil Management*, 247-270.

Teshome, A., Baum, B. R., Fahrig, L., Torrance, J. K., Arnason, T. J., & Lambert, J. D. (1997). Sorghum [*Sorghum bicolor* (L.) Moench] Landrace Variation and Classification in North Shewa and South Welo, Ethiopia. *Euphytica, 97,* 255-263. http://dx.doi.org/10.1023/A:1003074008785

Vaylay, R., & van Santen, E. (2002). Application of Canonical Discriminant Analysis for the Sssessment of Genetic Variation in Tall Fescue. *Crop Science*, *35,* 1222. http://dx.doi.org/10.2135/cropsci2002.0534

Venuto, B., & Kindiger, B. (2008). Forage and Biomass Feedstock Production from Hybrid Forage Sorghum and Sorghum-Sudangrass Hybrids. *Grassland Science, 54,* 189-196. http://dx.doi.org/10.1111/j.1744-697X.2008.00123.x

Weston, L. A., & Duke, S. O. (2003). Weed and Crop Allelopathy. *Critical Reviews in Plant Sciences, 22*(3), 367-389. http://dx.doi.org/10.1080/713610861

Yeater, K. M., Bollero, G. A., Bullock, D. G., Rayburn, A. L., & Rodriguez-Zas, S. (2004). Assessment of Genetic Variation in Hairy Vetch Using Canonical Discriminant Analysis. *Crop Science*, 44, 185-189. http://dx.doi.org/10.2135/cropsci2004.0185

Zhao, Y. L., Dolat, A., Steinberger, Y., Wang, X., Osman, A., & Xie, G. H. (2009). Biomass Yield and Changes in Chemical Composition of Sweet Sorghum Cultivars Grown for Biofuel.

Field Crops Research, 111, 55-64. http://dx.doi.org/10.1016/j.fcr.2008.10.006

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