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*Full Length Research Paper*

# Characterization of the levels of cassava commercialization among smallholder farmers in Kenya: A multinomial regression approach

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Cassava commercialization is a concept that has been used by many development practitioners because of its possible strategic role in transforming livelihoods of smallholder farmers in sub-Saharan Africa, including Siaya and Kilifi Counties in Kenya. This concept can easily be implemented when the levels of commercialization is known. However, empirical evidence reveals little information on the levels of cassava commercialization amongst smallholder farmers in these counties. Thus effective policy interventions on cassava commercialization for these farmers are difficult to implement, since there is no proper understanding of their levels of cassava commercialization. Therefore the main objective of this paper was to characterize levels of cassava commercialization among smallholder farmers. Factors influencing cassava commercialization were also evaluated. The data was collected from 381 farm households in Siaya and Kilifi Counties (Kenya). This data was used to calculate the Household Commercialization Index (HCI) and Value Addition Indices (VAI) which were then integrated to form the Commercialization Index (CI). This integrated index formed the basis for categorizing the levels of commercialization. A multinomial regression model was used to evaluate factors that affect levels of commercialization. The results obtained revealed that majority of smallholder farmers' operate at low and medium categories with very few of them at high level. Distance to the market, cassava acreage, schooling years, gender and marketing costs were the key determinants of the levels of commercialization. In order to promote high level commercialization, the study recommends developing policies that enhance formal education among farmers, optimal usage of land and minimization of transportation costs through infrastructural development.

**Key words:** Commercialization, cassava, smallholder farmers, value addition, market participation.

## INTRODUCTION

In sub-Saharan Africa, agricultural sector is one of the key sectors that have contributed to rural development. Majority of rural household dwellers, who represent 70%

of the poor, depend upon agriculture for their livelihood (Diao et al., 2010). Thus agriculture primarily contributes towards economic development of most African countries

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by reducing poverty as well as creating employment opportunities (FAO, 2012; World Bank, 2008). The contribution of agricultural sector towards poverty reduction has been realized to have a multiplier effect which is greater than the other sectors in the economy (Wiggins, 2009). One of the major features of agriculture in the developing world is that farming is mainly oriented towards small scale. This is whereby production is mainly for household consumption with extra output for small-scale commercial purpose. As summarized by (Dixon et al., 2003; Wiggins, 2009; FAO, 2015), smallholder farming is production based on small volumes, limited resources, and is predominated by family labor.

In sub-Saharan Africa, smallholder farmers are the majority of the population and they contribute enormously towards agricultural production. In addition, they account for approximately 75% of sub-Saharan Africans' land (Lowder et al., 2016). For these reasons, small holder farming has been realized to be an important activity especially in the developing nations as a stimulant to economic growth which can be done in a coordinated and smart approach. Because of agriculture's comparative advantage to other sectors much focus has been drawn towards transforming the sector through entrepreneurial activities such as commercialization. This concept has gradually gained prominence especially among smallholder farmers and to a greater extent replacing subsistence farming (Wright, 2009). It entails promoting market-oriented agriculture whereby farm households are integrated into input or output markets with an aim of boosting income (Von Braun, 1995; Barrett, 2007; Jaleta et al., 2009). Until recently, agricultural commercialization in sub-Saharan Africa had been associated with large scale farming focusing mainly on cash crops. However; this has so far changed since most of the dependable cash crops are highly rain fed and due to the climatic changes, there has been declining production hence the need for crop diversification. In line with this argument, traditional crops such as cassava and sorghum are being promoted because of their resilient to drought making them a target for food security strategy in sub-Saharan Africa (Martey et al., 2012; Obisesan, 2012). Cassava, (*Manihot esculenta* Crantz) is a species of the tuber crops which is widely produced in Africa as well as Latin America. In sub-Saharan Africa, the crop is mainly grown by small scale farmers for subsistence purposes (Nweke, 2004; Ogisi et al., 2013). Studies have revealed that there exist great entrepreneurial opportunities for cassava crop which has not been fully tapped (Ojogho and Alufohai, 2009; Agbola et al., 2010; Agwu, 2012). However, there are promising cases of smallholder farmers embracing cassava commercialization. This has been observed mainly in West African countries with very little evidence in East Africa specifically Kenya. The underlying question that the paper tries to address is whether farmers are operating at different levels of commercialization and if so, what are some of the factors

that influence their operation at the various levels.

This information is very important, more so when targeting interventions for farmers operating at the different levels. Kenya provides a good case study in understanding cassava commercialization bearing in mind that 75% of Kenyan land lies in arid and semi-arid areas and agriculture is the dominant sector. Furthermore, the overriding need for poverty reduction has presented cassava production and commercialization as a target for many interventions which also led to the development of National Policy on Cassava (MOA, 2007).

In Kenya, majority of farm households have directed their efforts on other crops such as maize and beans which are highly dependent on rainfall with minimum attention on cassava. These crops normally fail in ASAL regions due to inadequate rainfall leading to high poverty levels being experienced. Cassava may therefore provide a better alternative crop. Cassava crop has abundant opportunities such as value addition and market participation that still remains untapped.

Furthermore, the population growth and the changing demand patterns have generated high demand for various tuber crops, but farmers have not taken advantage of these opportunities. Also, diet changes amongst households have contributed towards commercialization as pointed out by Tschirley et al. (2015). Therefore it remains empirically unclear why farmers have not paid as much attention to cassava especially its commercialization as they have to commercialization of maize and beans (Muricho, 2015; Ochieng et al., 2015).

Evidences from Kenyan studies indicate that much focus on cassava has been on the promotion of production and other agronomical practices (Kamau et al., 2011; Obiero, 2013; Danda et al., 2014). Besides, farmers have been trading with raw cassava products mostly in informal markets or sometimes with low value added products (Karuri et al., 2001).

In addition, studies on commercialization have dwelt on cash crops and market participation with minimal attention on underutilized crops (Muricho, 2015; Ochieng et al., 2015). It has also been observed that a number of factories which are meant to enhance cassava commercialization are dormant.

This study was therefore motivated by the fact that value addition has not been explicitly argued in understanding commercialization and yet it is a concept that enhances commercialization. It is important to identify the different levels of cassava commercialization as well as understand some of the challenges that can be addressed so as to enable farmers operate at higher levels of commercialization which is associated with high income. In this study we contextualized commercialization as integration of value addition and market participation. This is a remarkable departure from past researches.

This study contributes to the modeling of the levels of commercialization by use of a multinomial regression model. Value Addition Index based on the different forms of value additions has been developed. This was then combined with Household Commercialization Index to form Commercialization Index. This index was later used to profile farmers based on the commercialization levels. We chose multinomial logistic model because the responses of the levels of commercialization are more than two and additionally it explicitly enumerates details for each level which are believed to be very important in understanding the barriers to cassava commercialization among smallholder farmers.

### Understanding agricultural commercialization

The concept of agricultural commercialization has been greatly applied in understanding the linkages between farm households and markets. However, understanding of the theory differ in focus and breath as evidenced by Zhou et al. (2013). Jaleta et al. (2009) and Martey et al. (2012) similarly acknowledged that there is no standard way of gauging the degree of household commercialization hence leading to varying definitions. Tipraqsa and Schreinemachers (2009) summarized agricultural commercialization as the process by which farm households increasingly integrate with both agricultural input and output markets. Von Braun and Kennedy (1994) on the other hand viewed agricultural commercialization as a combination of decision making behaviour ranging from both production and marketing activities.

Dutta et al. (2014) and Kotchikpa and Wendkouni (2016), similarly argued that agricultural commercialization occur when farm households produce marketed supply of output. Based on the household commercialization index, they identified three ways of classifying commercialization levels as non-commercial, semi-commercial and commercial farmers in which full commercialization was presented by an index of one, while non-commercialization was presented by zero. In support of this criterion, Lawal et al. (2014) and Martey et al. (2012) asserted that commercialization is based on the proportion of sales that households make relative to the total production. Considering other studies which have dwelt on other crops besides cassava, Ochieng et al. (2015) similarly echoed that commercialization is all about market orientation and participation. In their study, they measured the extent to which bananas and legumes are oriented towards market using Household Commercialization Index. Fischer and Qaim (2012) similarly studied cassava commercialization and how collective action has enabled women to participate in banana commercialization. Kabiti et al (2016) on the other hand diverted the focus on agricultural crops to livestock commercialization, while Kirui and Njiraini (2004) addressed the role of ICT as a determinant of

agricultural commercialization. Mujeyi (2009) conceptualized commercialization of *Jatropha*, is a tree species, as derivation of financial benefits from selling trees or processing them into other usable products. Further studies by Kambewa (2010), Agwu (2012), Gebreselassie et al. (2015) and Hagos and Geta (2016)) concluded that the conventional way of classifying the levels of commercialization is informed by the intensity of market participation. Based on the reviewed studies, it is evident that the concept is applicable in many ways not only in relation to crops but other agricultural sectors such as trees and livestock.

From these studies, the role of value addition has not been strongly argued yet it is a fundamental aspect of commercialization thus provoking further understanding on cassava commercialization and its determinants among smallholder farmers. There is enough evidence from past studies that agricultural commercialization is influenced by a number of factors. Jaleta et al. (2009) observed that population and demographic changes, technology, infrastructural and market factors as well as macro-economic policies majorly influence household commercialization. In relation to this, Muricho (2015) grouped the determinants of commercialization as exogenous or endogenous in which he argued that health environment is another important factor that should be considered. Gebreselassie et al.(2015), Martey et al. (2012) and Zhou et al.(2013) similarly pointed out some of the key determinants of agricultural commercialization as the amount of output, access to market information, transaction costs as well as household characteristics such as gender, age, farm size and family size. Agwu et al. (2015) identified various forms of value added cassava as well as evaluated factors such as gender, education, income, household size and value addition using a binary logistic model. Other studies on cassava commercialization include; Asogwa et al. (2013), Falola et al. (2016), Kehinde and Abaoba (2016) which revealed that diversification of cassava products into various value added forms stand out strongly as a way of increasing income as well as creating more employment opportunities, hence, making it a key component of cassava commercialization.

In summary, the reviewed studies on commercialization identified availability of processing equipment, off-farm activities, gender, age of the household head, farmer experience, market access, cassava output, farm size and transaction costs which also include marketing and transport costs, access to extension services by farmers and social networks as some of the pointers towards cassava commercialization.

### Modelling commercialization under household farm model

This study is grounded on household farm model which analyzes household farm economics and examines

household behavior based on production, the choice of technology and labor allocation (Taylor and Adelman, 2003). Commercialization can be addressed from two perspectives: first, as an increase in the marketed output, which is measured as the ratio of output sold to the production output, and secondly as the amount of inputs purchased per unit of output (Gebremedhin and Jaleta, 2010).

Cassava farm households have varying choices to make which are either aimed at maximizing profit or utility (Mottaleb et al., 2014). Utility maximization theory and profit maximization theories are premised on the household farm model and their augmentation expounds on the responsiveness of farmers towards commercialization. Even though profit maximization theory is a recessive separable process where a farm household's goal is mainly to make profits, this is not always the case with smallholder farmers. Modelling of farm households' behaviour is therefore based on interdependence between commercialization decisions as well as household consumption (Mottaleb et al., 2014). Under perfect market conditions, it is assumed that farm households maximize profits as producers and utilize the earnings generated to maximize their utility as consumers (Lofgren and Robinson, 1999).

Nevertheless, this is not realistic especially for smallholder farmers who in many cases are confronted with a set of competitive markets especially when production is both market and non-market oriented which are non-separable (Taylor and Adelman, 2003). In this context, the micro-economic theories are applicable since smallholder farmers are constrained by budget and resources hence the undertakings such as value addition and market participation must be supported by the value for the profit generated (Yan, 2007). It is therefore expected that cassava production and commercialization should contribute towards the constraints either in terms of meeting food demand or generating income from the marketed surplus.

This further suggests that there exist imperfections in the market which are caused by transactional costs, such as cost of transport, information costs amongst others which is the Kenyan case (Olwande et al., 2015). Price, which is an endogenous variable, significantly influences various transaction costs. In addition, non-existence of markets and risks involved in commercialization undertakings could be a deterrent to further engagements in commercialization. This could be attributed to some unobserved and heterogeneous factors as supported by (Gebreselassie and Sharp 2008; Nandi et al., 2011).

This study is supported by household model because the decision to commercialize is conditioned by various factors which are non-separable. Farm households are able to perform certain activities such as value addition and market participation if they have marketed surplus and this is influenced by production decisions. Therefore the variance in commercialization is explained by the

interaction between factors such as household characteristics, institutional and market factors, technical factors. For instance, household size explains the availability of family labour and influence on household consumption levels. Larger households are likely to provide labour that might be required to move cassava to the market and this would be expected to increase market participation thereby leading to a decrease in proportional transaction costs. On the contrary, large families may reduce the probability of commercialization since they reduce the marketed surplus.

Technical changes are also very important when making commercialization decisions. This explains production output by smallholder farmers in rural areas is mostly sold in either informal (in the neighborhoods) or formal local markets. Also, marketing factors such as transaction costs, market information, and distance to the market have a direct influence on the levels of cassava commercialization. In addition, access to market information increases both formal and informal market participation. Similarly institutional factors like improved credit access, group membership and extension services are hypothesized to enhance commercialization.

Contact with extension officers equips farmers with improved production methods and technology which could lead to increased production as well as value addition. Likewise, social networks are expected to reduce information costs since members within the networks are able to access information about prices and markets through interaction. Studies have found that membership of a farmer based organization or group increases access to information which is important to marketing decisions (Olwande and Mathenge, 2010). Conversely, access to reliable means of transport as well as distance to the markets influences cassava commercialization. Unreliable means of transportation and long distances increase transport cost which in turn increases transaction cost (Gebremedhin and Jaleta 2010; Ochieng' et al., 2015).

## **MATERIALS AND METHODS**

### **Study area, sampling and data collection**

The study was conducted in two different counties which lie in the Western and Coastal regions of Kenya. The two counties are the main cassava producing regions in Kenya and they are located within the arid and semi-arid land which is characterized by low rainfall and prolonged drought periods. Majority of the developing countries occupy 75% of arid and semi-arid land. Cassava crop is one of the predominant crops with high resilience to drought and has the potential to secure income as well as food security in such regions. The two regions have also experienced high rates of poverty levels of 45% and 70.8% in Siaya and Kilifi respectively. This is contributed by low productivity of rainfall-reliant crops such as maize and beans (GOK, 2011). A comparison study was necessary because of the perceived uniqueness of the regions in production and commercialization of cassava. Therefore, the study purposed to synthesize the similarities, differences and patterns of

commercialization that could guide in policy interventions for the specific regions. Data collection was based on the production year 2015 (January to December) with the respondents being smallholder farmers who had been engaged in cassava production during this period. A four stage multisampling technique was used. In the first stage, two sub-counties were purposely chosen from each county based on the intensity of cassava production. They include Alego-Usonga and Ugenya from Siaya County; Ganze and Magarini from Kilifi County. A random sampling of two locations from each sub-county was done. The third stage involved random sampling of six and five villages from Siaya and Kilifi Counties respectively. Finally, eight and ten respondents from Siaya and Kilifi Counties correspondingly were drawn through simple random sampling. The total responses were 200 and 181 farm households from Kilifi and Siaya Counties, respectively. Primary data were collected using well-structured questionnaires which were administered through oral interviews. Both descriptive and inferential statistics were used to analyze the data.

**Empirical specifications**

The study developed another index, commercialization index using both household commercialization index (HCI) and composite weighted index for value addition. HCI has been extensively used to categorize the levels of commercialization (Musah et al., 2014; Martey et al., 2012; Omiti et al., 2009; Muricho, 2015). It is an estimated single index for market participation taking into account the gross value of sales and production. The index measures the orientation of farmers towards market participation which range from 0 to 1. The interpretation of the index is that the closer it is to one, the greater the intensity of market participation. Household commercialization index was estimated as follows:

$$HCI = \frac{\text{Gross value of cassava sales}}{\text{Gross value of all cassava production}} \quad (1)$$

A composite weighted price index on value addition which is an inclusive approach was mathematically computed guided by studies such as (Grupp and Mogee, 2004; Sharpe and Andrews, 2012). The weighted index was based on the argument that value addition changes the price value of cassava products which further increases opportunities for market participation (Osmani and Hossain, 2015). The index is computed as follows:

$$\text{Composite weighted value addition index} = \frac{\sum p_i q_i}{\sum p_h q_i} \quad (2)$$

Where  $p_i$  = price of value added cassava in kg;  $q_i$  = Quantity sold and  $p_h$  = Highest price of cassava in kg

Commercialization index was therefore computed as an average of the two indices (equation 1 and 2). The index value ranged from 0 to 1. This was later used to categorize the levels of commercialization into none, low, medium and high levels.

**Modelling using multinomial logistic regression model**

Multinomial logit model is a choice model that is devised from utility maximization theories. The assumption made is that household farmer' choses areas as a result of their preferences which range from production for consumption to commercialization. The model is a very useful method in analyzing data which has more than two responses and uses the logit link (Greene, 2000; Reddington et al.,

2000). Similar to binary logistic regression model, it uses maximum likelihood estimation to evaluate the probability of the response variable (Madhu et al., 2014). Previous studies have used the model to investigate factors affecting various choices (Pryanishnikov, 2003; Kohansal and Firoozare, 2013). They found the model convenient and appropriate because it does not assume normality, linearity and homoscedasticity. In addition, the model is easily interpretable since the effect of the predictor variable is usually explained in terms of the odds ratio. In this study, the logit model was used to determine the likelihood of smallholder farmers' participation in four levels of commercialization namely none, low, medium and high levels. This model was also regarded appropriate because it supports the theoretical framework which states that smallholder farmers have a set of mutually exclusive alternatives to choose from. The decision on commercialization is informed by certain level of utilities. In the model, the variables  $u_j$  and  $u_k$  represent a household's utility for the two choices. The random utility model could then be disintegrated into two parts as shown below:

$$u_{ij} (B_j X_i + e_j) > u_{ik} (B_k X_i + e_k), k \neq \forall_i \quad (3)$$

From equation 3, perceived utilities of the levels of commercialization choices are  $j$  and  $k$ , respectively,  $X_i$  being the vector of explanatory variable that influences the perceived desirability of each choice. In case smallholder farmers decide to commercialize which is option  $j$ , it is expected that the utility derived from the choice will be greater than the utility from the other option  $k$ . The probability that a household will choose to commercialize, that is to choose method  $j$  instead of  $k$ – could then be defined as follows:

$$P(Y = 1 / X) = P(u_{ij} > u_{ik}) \quad (4)$$

$$P(B_j X_i + e_j - B_k X_i - e_k > 0 / X) \quad (5)$$

$$P(B_j X_i - B_k X_i + e_j - e_k > 0 / X) \quad (6)$$

Multinomial regression logistic model was also appropriate because commercialization responses had more than one category. One of the categories of dependent variables represented the non-commercialization which was also nominated as a reference or base category. Calculation for the other logits was done with reference to the base category and the probability for each category was estimated using the following equations:

$$\text{Log} \left( \frac{\rho_{ij}}{\rho_{il}} \right) = \beta_j \chi_i \text{ whereby } j = 1, \dots, J \text{ and } i = 1 \dots N$$

$$\text{Logit} [P(Y=1)] = \alpha + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_k x_k \quad (7)$$

The probability of  $\rho_{ij}$  can be obtained as follows:

$$\rho_{ij} = \exp \frac{(\beta_j \chi_j)}{\sum_{j=1}^j \exp (\beta_j \chi_i)} \quad (8)$$

Equation 8 can further be expanded and estimated using maximum likelihood as shown below

**Table 1.** Summary statistics of the variables used in the multinomial model (Siaya County).

Variable	None		Low		Medium		High	
	n=58		n=9		n=97		n=17	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Gender (Male)	0.172	0.381	0.262	0.445	0.278	0.451	0.235	0.437
Extension service (Yes)	0.189	0.395	0.444	0.527	0.464	0.501	0.588	0.507
Distance to market (km)	0.059	0.211	0.056	0.110	0.275	0.369	0.200	0.269
Schooling (Years)	4.81	4.253	5.444	3.087	6.526	3.992	8.176	3.627
Household size (No.)	5.431	2.61	4.889	2.522	5.866	2.714	7.059	2.304
Value addition experience (Years)	12.569	15.189	19.111	22.133	13.845	12.676	4.118	3.371
Marketing Cost (KES)	2.413	13.418	18.889	39.511	178.258	1056.112	30.588	40.693
Cassava acreage (Hectare)	0.180	0.203	0.234	0.242	0.250	0.203	0.296	0.282

Source: Household survey data (2016) Note: 1 USD = Kes 103.70.

**Table 2.** Summary statistics of the variables used in the model (Kilifi County).

Variable	None		Low		Medium		High	
	n=66		n=45		n=78		n=11	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Gender (Male)	0.272	0.448	0.333	0.477	0.269	0.446	0.455	0.522
Extension service (Yes)	0.561	0.500	0.622	0.490	0.526	0.503	0.364	0.505
Distance (km)	0.238	0.507	0.928	0.755	0.788	0.653	0.568	0.447
Schooling (Years)	3.772	4.213	3.888	3.651	4.807	4.671	6.455	4.906
Household size (No.)	7.469	3.054	7.289	3.409	6.897	3.273	8.273	5.569
Value addition experience (Years)	7.341	8.998	8.844	10.392	5.962	8.919	4.091	3.081
Marketing cost (KES)	2.413	3.630	70.222	145.293	79.167	172.200	84.545	149.623
Cassava acreage (Hectare)	0.180	0.536	0.475	0.303	0.747	0.609	0.689	0.259

Source: Household survey data (2016) Note: 1 USD = Kes 103.70.

$$p(Y = j) = \frac{\exp(\alpha + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_k x_k)}{1 + \exp(\alpha + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_k x_k)} \tag{9}$$

Where  $\beta_i$  is the estimated coefficient which explains the effect of  $x_i$  on the log odds when other variables are held constant,  $j = 1, 2$  and  $3$  since the model has four responses. Therefore the above model was used to predict the levels of commercialization as a function of explanatory variables which were empirically identified.

## RESULTS AND DISCUSSION

### Summary statistics of variables used in multinomial logistic model

The summary statistics of the variables for Siaya and Kilifi Counties respectively are reported in Tables 1 and 2. The dependent variable was considered categorical with four responses namely; none, low, medium and high levels of commercialization. It was found that 5%, 54%

and 9% of farm households from Siaya County participated in the low, medium and high level categories respectively while the rest (32%) were in the non-commercialization level. Kilifi County on the other hand had 200 respondents out of which 23%, 39% and 5% were in the low, middle and high level categories, respectively, while 33% did not commercialize (Table 2). The explanatory variables fitted in the model consisted of gender of the household head, which is a dummy variable and takes the value of one if the household head is a male and zero if she is a female. It is observed that less than 30% of the men from Siaya participated in all the levels of commercialization, while for Kilifi 45% of the men participated in high level commercialization. The study also found that 58.8% of the respondents from Siaya County who had access to extension services engaged in high level commercialization while for Kilifi County 50.5% of the respondents accessed extension services as well as commercialized. Extension contacts are important as they bridge the gap of information asymmetry, therefore farmers who receive extension services are believed to be more knowledgeable and informative than their counterparts (Rahut et al., 2015).

The results shows that the mean distance for farm households in Siaya County was higher for the medium (0.28 km) and high (0.20 km) levels as compared to the low and none levels while for Kilifi the distances were high across all the levels. The mean distance for farm households in Siaya County was higher for the medium (0.28 km) and high (0.20 km) levels as compared to the low and none levels while for Kilifi the distances were high across all the levels. Distance to the market is hypothesized to influence market accessibility. Households which are located farther away from market places are less likely to engage in value addition as well as market participation (Barrett, 2007; Rios et al., 2008; Omiti, 2009).

Household size also varied across the counties in which Kilifi County had a larger mean household size (8.27 persons) as compared to the mean household size for Siaya (7.05 persons). Household size may have a two sided effect on commercialization. In the first case, large households can be a source of labor for cassava activities which are known to be labor intensive hence help in reducing cost of labor. On the other hand, the higher household size can be an impediment towards commercialization. This is because it may reduce the available cassava marketed surplus as well as increase diversification into other activities (Shapiro, 1990; Onya et al., 2016).

Farmer experience is expected to be larger for farm households that undertake high level commercialization (Agwu, 2012). This was however not the case in both regions as evidenced by the mean value addition experiences which were (4.12 years) and (4.09 years) for Siaya and Kilifi Counties, respectively. Notably, Siaya respondents had a higher mean value of value addition experience compared to Kilifi, and therefore they were expected to engage more in commercialization activities. Marketing costs can be a constraint to output market participation by smallholder farmers (Musumba and Costa, 2015). This study found that the mean marketing costs spent were very low in both counties, although the medium group had fairly larger costs (Kes 178.25) than the high level category (Kes 30.58) for Siaya County, while for Kilifi County the medium and the large categories had mean values of (Kes 79.16) and (Kes 84.54). Another important variable is cassava farm acreage which is believed to scale up production decisions consequently affecting commercialization. Farm households from Kilifi County had larger acreage of land compared to their counterparts from Siaya County. The mean acreage for Kilifi County (0.68 acres) was almost double to that of Siaya County (0.29) for the high level category.

#### **Estimation of levels of cassava commercialization for Kilifi and Siaya using multinomial logit model**

The multinomial logistic regression model was fitted and

the summary results presented in Tables 3 and 4. The diagnostic results which describe the relationship between the dependent and independent variables are also presented. It can be observed that the chi square statistic values are 135.95 and 90.25 for Siaya and Kilifi Counties, correspondingly, had  $p\text{-value} < 0.05$ . This confirms adequacy of the model and implies that at least one of the coefficients of the explanatory variables is significant. The strength of the model was also tested using Pseudo R square. The results for Siaya and Kilifi were (35.4%) and (16.5%). This implies that 35.4% and 16.5% of variation in the levels of commercialization among smallholder farmers was explained by the independent variables in the model.

Cox and Snell and Nagelkerke R squares on the other hand indicate that 50.7% and 57.4% of the variation in the model for Siaya county is explained by the explanatory variables fitted while Kilifi was explained by 38% and 40.6%. With regards to the selection of the reference group, the non-commercialization category was chosen as a base category.

Three logit models were fitted, the first logit model compared low commercialization to the reference group. The results for Siaya (Table 3) showed that only distance to market and marketing costs were statistically significant. The coefficient of distance to the market (-4.075) was negative while for marketing cost (0.801) was positive. The negative coefficient suggests that if farm households are located farther from the markets then the probability of engaging in low level category reduces.

Furthermore, as they progress to higher levels of commercialization, the coefficients become larger (medium -4.416 and high -4.486) indicating a more negative effect. It therefore implies that farmers are less likely to engage in high level commercialization than medium if they are farther from the market center and is due to increased transaction costs which results from the extra expenses incurred on transportation and time wasted in the movement of products to the market. This can be a hindrance to market participation. This finding is consistent with that of Omiti et al. (2009), Agwu (2012), Gebremedhin and Jaleta (2010), who found that distance to the market limits market access and participation of smallholder farmers. A similar finding was obtained from the interpretation of the relative risk in Table 3. The ratio implies that farmers who are farther from the market centres are less likely to engage in higher levels of commercialization. This is consistent with the above findings.

Marketing costs had a mixed effect for low and medium levels had a positive effect, thus implying that farm households are more likely to engage in low and medium levels of commercialization when the costs are increased. However, for higher levels of commercialization it is evident that farmers are less likely to engage in commercialization when marketing costs are increased. This implies that at lower levels of commercialization,

**Table 3.** Parameter estimates of the levels of commercialization (Siaya County).

Variable	Low commercialization			Medium commercialization			High commercialization		
	Coefficient	$P[ Z >z]$	RRR	Coefficient	$P[ Z >z]$	RRR	Coefficient	$P[ Z >z]$	RRR
Constant	-3.311	0.097	0.036	-4.256	0.002	0.014	-7.900	0.000	0.000
Gender ( Male)	-15.438	0.988	1.97e-07	-0.639	0.371	0.527	-1.146	0.222	0.318
Extension service ( Yes )	0.846	0.318	2.330	0.840	0.127	2.318	1.085	0.137	2.959
Distance to market (km)	-4.075**	0.017	0.017	-4.416***	0.005	0.012	-4.486***	0.006	0.011
Schooling years	0.601	0.223	1.825	0.632**	0.042	1.880	1.333**	0.016	3.793
Household size (No.)	-0.635	0.306	0.529	0.022	0.957	1.022	0.843	0.255	2.324
Value addition (Years)	0.161	0.744	1.174	0.653**	0.052	1.921	0.272	0.541	1.313
Marketing Costs (KES)	0.801***	0.005	2.229	1.154***	0.000	3.172	1.030***	0.000	2.804
Cassava acreage (Acres)	0.869	0.237	2.385	0.911*	0.059	2.487	1.328**	0.027	3.773
<b>Multinomial logistic regression</b>									
Number of observations				179					
LR $\chi^2$ (24)				135.95					
Prob> $\chi^2$				0.000					
Log likelihood				-123.995					
Pseudo R2				0.354					
Cox and Snell				0.507					
Nagelkerke				0.574					

\*\*\* p=0.01, \*\* p=0.05 and \* p=0.10

perhaps the costs incurred are less and insignificant as compared to higher levels which may demand for more costs especially on processing, storage, packaging and handling activities. This finding is in contrary to the expected results as well as other studies which have found an inverse relationship (Gebremedhin and Jaleta, 2010; Gebreselassie et al., 2015; Ocheing' et al., 2015). The studies found that various marketing costs reduce the interaction of farmers with other actors along the chain and their engagement in market participation.

The years of schooling in this study was used as a proxy to education. The coefficients were statistically significant for the medium and the high

logit models at ( $p < 0.05$ ). However; the coefficient of the high level category is larger (1.33) than the one for medium category (0.63) thus implying that as farm household heads advance in formal education, they become endowed with a number of skills such as production, processing and managerial skills. These skills are essential in making coherent farming decisions as demonstrated by Enete and Igboke 2009.

The results clearly indicate that education has a significant contribution towards cassava commercialization in Siaya County. This county is known to put high premium on education. These results are supported by the findings of Mottaleb et al. (2014), who also found a positive

relationship between education and commercialization. Contrary to the finding, Lawal et al. (2014) found that higher levels of education reduce the probability of undertaking commercialization. In fact, commercialization decision decreases as households opt for off-farm activities which are believed to have high income, Value addition experience had mixed results, which was only significant in the middle level category. This indicates that farmers who have at least some level of value addition experience are more likely to participate in advanced levels of commercialization than those who have no experience. This finding compares favorably with that of Parveen et al. (2014) which revealed that

**Table 4.** Parameter estimates of the levels of commercialization (Kilifi County).

Variable	Low commercialization			Medium commercialization			High commercialization		
	Coefficient	$P[ Z >z]$	Odds ratio	Coefficient	$P[ Z >z]$	RRR	Coefficient	$P[ Z >z]$	RRR
Constant	0.518	0.600	1.678	0.012	0.991	1.012	-0.874	0.389	0.417
Gender (Male)	-0.212	0.645	0.808	-0.955*	0.092	0.385	-1.034**	0.040	0.387
Extension service (Yes)	-1.372***	0.003	0.253	0.126	0.801	1.134	-0.913	0.839	0.913
Distance to market (km)	-1.004***	0.004	0.366	-0.533	0.162	0.586	-0.870**	0.011	0.419
Schooling years	0.479**	0.029	1.615	0.126	0.596	1.134	0.208	-0.209	1.231
Household size (No.)	-0.783*	0.055	0.457	-0.833*	0.065	1.522	-0.422	0.301	0.656
Value addition (years)	0.087	0.735	1.091	-0.097	0.724	0.908	0.288	0.237	1.335
Marketing Costs (KES)	4.804***	0.984	122.06	5.769***	0.000	144.414	4.998	0.983	148.069
Cassava acreage (Acres)	0.122	0.548	1.129	0.682**	0.027	1.251	0.298***	0.003	1.348
<b>Multinomial logistic regression</b>									
Number of observations	200								
LR $\chi^2$ (24)	90.25								
Prob>chi2	0.000								
Log likelihood	-123.995								
Pseudo R2	0.165								
Cox and Snell	0.380								
Nagelkerke	0.406								

\*\*\* p=0.01, \*\* p=0.05 and \* p=0.10.

marketing of different forms of cassava processed products requires some value addition skills and knowledge which can be sharpened through experience.

As expected, the coefficients for cassava acreage were significant and increased progressively along the levels of commercialization. This implies that an increase in farm acreage enhanced the likelihood of farmers being in the medium (0.911) and high (1.328) level categories. The RRR further showed that the effect for the high category is 1.286 times that of the medium category. This signifies that landholding is a major influencer of commercialization levels in Siaya County.

Furthermore, farm acreage determines the allocation of various crops to land holdings. Farm households with large parcels of land are more likely to produce marketed surplus that they can process into various forms and sell. Martey et al. (2012) similarly found that farmers with more acreage of land are better positioned to undertake commercialization compared to those with challenges of land acreage.

The estimated results for Kilifi County were slightly different from that of Siaya and this was however expected since the two counties have distinctive characteristics as observed from the descriptive statistics. Three logit models were fitted. In the first logit model that compared the

low level category with none category shown in Table 4 reveals that, years of schooling and marketing costs were positively significant while access to extension services, distance to the market and household size negatively influenced households' decision to engage in low commercialization. The positive and statistically significant sign of the coefficient for years of schooling showed that farm households are likely to engage in low commercialization with additional year of schooling. The variable was however not statistically significant in the medium and high levels of commercialization.

The implication is that farm household heads that are educated are less likely to engage in

higher levels of cassava commercialization. This could be argued that farmers' technical capacity can be built through experience but not necessarily education. Furthermore, an educated household head will be attracted to white collar jobs which in many cases are found in urban set ups. This lowers the possibility of engaging in farming activities. This finding gains support from the works of Mathijs (2002) who argued that a more educated household head focuses more on off-farm activities than farm activities. This was however unexpected since education, being a form of human capital, can influence the uptake of knowledge which further stimulates commercialization decisions.

The results revealed that marketing cost was significant and increased positively in both the low and the medium levels. This contradicts the apriori expectation of the study which hypothesized a negative effect of marketing cost on the levels of commercialization. This is because generally marketing costs are an impediment to active engagement in marketing activities and this result is similar situation to the one found for Siaya county, hence it concludes that other than marketing costs there are other factors which influence the choice of commercialization levels which could be that farmers are willing to spend more on marketing activities especially if the venture is profitable and the returns outweigh the costs. This requires a further in depth study.

From Table 4 it is clear that cassava acreage was positive and significant at 5% and 1% significant levels for the medium and high levels categories, although we observe a greater probability in the medium category than the high. The positive signs indicate that additional allocation of land to cassava increases the likelihood of up scaling commercialization in the medium and high categories. Further implication is that land is an incentive to enhanced production which can be partly consumed as well as marketed (Martey et al., 2012). Considering households that engaged in high levels of commercialization, land was not deemed very important. This is because the change in the coefficient was lower for the high level category than the medium level category. Unlike in Siaya, where land was highly significant especially among those who engage in high levels of commercialization, Kilifi farmers have other considerations which influence commercialization. Land was in abundance in Kilifi but a greater portion of it was on rocky ground and therefore unproductive. To a greater extent a number of farm households are rented land to supplement farm production.

Converse to Siaya results household size negatively influenced the probability of being in the low (-0.783) and medium (-0.833) categories in Kilifi County. However, the variable was statistically insignificant in the high category. The results suggest that large households are less likely to engage in commercialization since large size can exert a lot of pressure on the limited household resources including production. This would therefore mean that all

or a greater proportion of production is channeled to meet the household demand therefore limiting commercialization. The composition of the membership greatly matter. In this case majority of household members in Kilifi County were small children who in many cases cannot participate in commercialization activities either because they are attending school or they are very minor. This confirms an observation made by Gebremedhin and Jaleta (2010) those smallholder farmers can barely meet their daily requirements especially when the household size is large.

Table 4 also shows that distance to the market was significant although with a negative effect on low and high categories. However; the relative risk for high category (0.419) indicates a decrease more than that of the low category (0.366). This is similar to the findings of Ochieng' et al. (2015) who found that long distances increase transaction costs which is a deterrent to market entry. These results contradicts the findings of Lawal et al. (2014) which found that an increase in transport cost increases the likelihood of farm households' participation in commercialization. This is especially when the costs are low and insignificant.

Extension services had mixed results on the different levels of commercialization. For the low level category, it was statistically significant but negatively influenced commercialization. For the other levels, it was not significant. This implies that farm households are less likely to engage in low level commercialization despite making contacts with extension officers. As expected, contacts with extension officers act as networks for disseminating information and this is likely to heighten commercialization (Rahut et al., 2015). Probably farm households have other social networks where they can gather information related to farming and therefore they rarely interact with extension officers.

In addition, the results in Table 4 shows that gender negatively influenced the choice of being in the medium (-0.955) and high (-1.034) categories. The negative effect of the gender variable implies that male headed households are less likely to engage in advanced levels of commercialization. Studies argue that a man's social life is less interactive compared to a woman and this lowers their integration into cassava commercialization activities (Agwu et al., 2015). The implication is that men emphasize more on off farm than farming activities so as to supplement household income. Women on the other hand are motivated to engage in cassava commercialization since farming is their main economic activity as they do take charge of their homes while men are a way.

This argument contradicts the findings of Forsythe et al. (2016) in Nigeria who demonstrated that both men and women actively participate in cassava commercialization activities at different levels; men are mainly involved in marketing of cassava while women engage more in processing activities (Forsythe et al., 2016); but in overall,

they assist each other in various cassava related activities.

## CONCLUSIONS AND POLICY RECOMMENDATIONS

The primary objective of the paper was to identify and explore the different levels of cassava commercialization using cross-sectional data. This paper contributes to literature on cassava commercialization by contextualizing the concept as value addition and market participation, thus, recognizes the fact that value added cassava products provide tremendous market opportunities through diversification, further promoting commercialization. Based on this concept, different levels of commercialization were categorized using commercialization index which was developed from household commercialization index and value addition index.

To further explore factors determining every level of commercialization, a multinomial regression model was employed. The results showed that majority of cassava farm households from both counties engaged in medium level commercialization. However, a low proportion of those who commercialized were involved in high level commercialization while a good number of farmers were not involved in commercialization activities which could imply that cassava was either consumed in raw or value added form without engaging in marketing activities.

The study found that there were variations in the two counties in relation to the cause and effect of the variables influencing the different levels of commercialization. Econometric analysis found that cassava acreage and distance to the market had a significant influence on the levels of commercialization in both counties. Although land size determined the levels of commercialization, the effect was not significant for farm households from Kilifi County who highly commercialized compared to the medium level. This shows that land alone may not contribute to high levels of commercialization unless it is supported by other factors.

The study also found that farm households from Siaya had small parcels of land and this limited their engagement in high level commercialization. Also, distance to markets influenced the decision to undertake cassava commercialization or not. Farm households did not undertake higher levels of commercialization because either the roads were in poor states or markets were located farther away from the farm households, thus, reduced their participation in markets due to increased transaction costs. Considering the specific counties, Siaya County exemplifies the importance for education because it has a significant effect on the levels of commercialization. Conversely, Kilifi County had gender imbalance on cassava commercialization and very few men participated in commercialization related activities. Based on the findings, the study recommends that policy makers should strengthen market interaction by

ensuring that road networks linking farmers with the main roads are maintained and markets are well structured. In addition farmers should be sensitized on the role of cassava commercialization in the households as an effort to improve land allocation to cassava for production.

Value addition should be promoted and embraced by farmers in order to provide competitive cassava products to the market and also farmers should be given incentives such as reasonable prices which can stimulate commercialization. Gender disparity should also be addressed if farm households were to engage in higher levels of commercialization. This can be achieved by empowering and integrating men into cassava commercialization activities through trainings and capacity building so that they can support women in advancing into higher levels of commercialization. More members of the households should be encouraged to participate in cassava commercialization. Policy makers also need to support education system through programs such as free primary education.

Finally, a deeper analysis should be conducted for each County to explore other factors that could determine the different levels of commercialization.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests

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## Full Length Research Paper

## Induction of antioxidant system in niger (*Guizotia abyssinica* Cass.) under drought stress

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Drought stress is a highly pervasive and economically damaging abiotic stress that affects plant yield and productivity worldwide. Physiologically, drought stress in plants is associated with oxidative stress leading to tissue damage. Drought stress imposed over 72 h in 10 days old seedlings of *Guizotia abyssinica* Cass, niger (cv; RCR-18) under greenhouse conditions resulted in elevated levels of oxidative stress markers such as H<sub>2</sub>O<sub>2</sub>, malondialdehyde, proline, reduced glutathione and ascorbate in a time-dependent manner. Levels of antioxidant enzymes: peroxidases and glutathione reductase, and metabolic enzyme: amylase and acid phosphatase were moderately enhanced. The levels of stress markers, antioxidants, and recovery upon re-watering suggested that the antioxidant system in niger could withstand the drought stress for up to 48 h under greenhouse conditions.

**Key words:** Drought stress, antioxidants, antioxidant enzymes, malondialdehyde, abiotic stress.

### INTRODUCTION

As an important factor that determines geographical distribution of plant species, drought has major yield limiting ability (Nezhadahmadi et al., 2013). One of the earliest biochemical responses of eukaryotic cell to environmental stresses such as drought, salinity, high temperature, chilling etc., is generation of reactive oxygen species (ROS). Water deficit due to drought induces closing of stomata, limiting CO<sub>2</sub> assimilation, which in turn leads to NADPH accumulation and subsequent leakage of electrons. The leakage of electrons causes partial reduction of atmospheric O<sub>2</sub>, generating enhanced levels of ROS (Fujita and Alam, 2015). There are four general forms of cellular ROS, singlet oxygen (<sup>1</sup>O<sub>2</sub>), superoxide radical (O<sub>2</sub><sup>-</sup>), hydrogen

peroxide (H<sub>2</sub>O<sub>2</sub>) and the hydroxyl radical (HO<sup>•</sup>), each having a characteristic half-life and oxidizing potential. Plants are endowed with an array of versatile and cooperative antioxidant systems comprising enzymatic and non-enzymatic components. Enzymatic components include antioxidant enzymes; guaiacol peroxidase (GPOX), catalase (CAT), ascorbate peroxidase (APX), glutathione reductase (GR) and metabolic enzymes; amylase (AMY) and acid phosphatase (AP). While, non-enzymatic components include antioxidants like ascorbic acid (ASC) and reduced glutathione (GSH), and osmoregulants like proline to cope with ROS generated in response to stress. ROS generation due to prolonged exposure to drought stress overwhelms the antioxidant

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defense system, thereby causing extensive damage to cellular components like proteins, lipids, DNA and RNA, leading to cell death (Silva and Santos, 2015). Increasing population and growing soil aridity in future are expected to make water a scarce commodity. The profound impact of drought on agriculture and ecosystem thus makes the ability of plant to withstand stress of great economic importance (Rybka and Nita, 2015). Hence, it is important to look for alternative strategies to improve the abiotic stress tolerance of various crop plants.

*Guizotia abyssinica* (Niger) belonging to family *Asteraceae* is cultivated throughout India, West Indies and East Africa. Niger accounts for 3% of Indian oil seed production and contains 40% oil and 20% protein. Niger seed earns precious foreign exchange as it is exported as bird feed. That apart, it is mainly used for culinary purposes, manufacture of soaps, cosmetics, lighting and lubrication. Various attempts have been made to explore the potential of biodiesel production from Niger, which is cost effective, less corrosive, user and environmentally friendly green catalyst (Yerranguntla et al., 2012). Effects of polyethylene glycol 8000 and drought on *G. abyssinica* Cass cultivars (IGP 76, GA 10, No. 71 and IGP 2004) at seedling and maturity stages of the plant had been reported (Nikam and Ghane, 2011). The plant-water relationship during drought stress is an essential component for modulating the antioxidant defense mechanism. With a basic physiological and biochemical knowledge, the present study was an effort to determine the role of antioxidant defense system, in response to applied drought stress.

## MATERIALS AND METHODS

### Plant material and growth conditions

Niger seeds (RCR-18 variety) were procured from University of Agricultural Sciences, Dharward, India. All chemicals used were of analytical grade. Seeds were surface sterilized with 0.1% (w/v)  $\text{HgCl}_2$  for 30 s, rinsed immediately with large volume of distilled water. The seeds were sown in plastic trays containing vermiculite and acid-washed sand (1:1 w/w) and irrigated twice a day with distilled water. The germination was carried out under natural greenhouse conditions; day/night temperature and relative humidity were 30/25°C and 75/70%, respectively. The average photoperiod was 12 h light/12 h dark.

### Drought stress and experimental design

Drought stress was applied by withholding water for 10 days after germination (DAG) of seedlings. Leaf samples were collected at 24, 48 and 72 h and assayed for various parameters. The experimental design was carried out employing random factorial scheme, with 3 evaluation points (24, 48 and 72 h). Each experiment comprised 6 experimental units (leaf samples of control and stressed plants) and in triplicate. Seedlings watered twice a day were used as control.

### Determination of relative water content (RWC)

The relative water content was determined by following the method

of Turner and Kramer (1980), using the equation:  $\text{RWC} = (\text{FW} - \text{DW}) \times 100 / (\text{TW} - \text{DW})$ . Leaf discs of 6 mm diameter were weighed to determine the fresh weight (FW); they were soaked in distilled water at 25°C for 4 h to determine the turgid weight (TW), and then oven dried at 80°C for 24 h to determine the dry weight (DW).

### Determination of antioxidants and stress markers

Estimation of ascorbate (ASC) and glutathione (GSH) in control and drought stressed leaves was carried out according to Sadasivam and Manickam (1997) and Beutler et al. (1963), respectively. Further,  $\text{H}_2\text{O}_2$  levels in control and stressed samples were determined according to Velikova et al. (2000). Lipid peroxidation was determined by estimating the malondialdehyde (MDA) content in 1 g fresh tissue according to Heath and Packer (1968). The MDA content was calculated using extinction coefficient of  $155 \text{ mM}^{-1} \text{ cm}^{-1}$ . Free proline was extracted from 0.5 g of fresh tissue and estimated according to the method of Bates et al. (1973).

### Enzyme extraction

Fresh leaf plants were homogenized with pre-chilled 50 mM  $\text{Na}_2\text{PO}_4$  buffer (pH 7.0), containing 5 mM  $\beta$ -mercaptoethanol and 1 mM EDTA. Homogenate was centrifuged at 4°C for 15 min at 12,000  $\times g$ . Supernatant was used to determine the enzyme activity and protein content. Total soluble protein content was determined according to Lowry et al. (1951), using BSA as standard.

### Assay of antioxidant enzymes

Guaiacol peroxidase (POX) activity was determined according to Chance and Maehly (1955) by measuring increase in absorbance at 470 nm ( $\epsilon = 26.6 \text{ mM}^{-1} \text{ cm}^{-1}$ ) due to formation of tetraguaiacol. The reaction mixture contained 3 ml of 50 mM phosphate buffer (pH 7), 20 mM guaiacol, 10 mM  $\text{H}_2\text{O}_2$  and 100  $\mu\text{l}$  enzyme extract. One unit of enzyme activity is defined as the quantity of enzyme required to convert 1  $\mu\text{mol}$  of  $\text{H}_2\text{O}_2 \text{ min}^{-1}$  at 25°C.

Catalase activity was measured according to Aebi (1984) by following decline in absorbance at 240 nm ( $\epsilon = 39.4 \text{ M}^{-1} \text{ cm}^{-1}$ ). The reaction mixture consisted of 50 mM  $\text{Na}_2\text{PO}_4$  buffer (pH 7.0) containing 50  $\mu\text{l}$  of enzyme extract and 10 mM  $\text{H}_2\text{O}_2$ . One unit of activity is defined as the amount of enzyme that catalyzes the oxidation of 1  $\mu\text{mol}$  of  $\text{H}_2\text{O}_2 \text{ min}^{-1}$  under the assay conditions.

Ascorbate peroxidase activity assay was based on the method of Allen (1968) which measures an increase in the absorption at 290 nm ( $\epsilon = 2.8 \text{ mM}^{-1} \text{ cm}^{-1}$ ). One unit of APX is defined as the amount of enzyme required to convert  $\mu\text{mol}$  of ascorbate  $\text{min}^{-1}$  at 25°C. The reaction mixture contained 50 mM HEPES buffer (pH 7), 1 mM EDTA, 1 mM  $\text{H}_2\text{O}_2$ , 0.5 mM sodium ascorbate and 50  $\mu\text{l}$  of enzyme extract.

GR activity was measured according to Carlberg and Mannervik (1985) by measuring oxidation of NADPH at 340 nm ( $\epsilon = 6220 \text{ M}^{-1} \text{ cm}^{-1}$ ). The assay mixture contained 50 mM Tris-HCl buffer (pH 7.5), 3 mM  $\text{MgCl}_2$ , 0.2 mM NADPH and 37  $\mu\text{l}$  of enzyme extract. The reaction was initiated by the addition of 0.5 mM GSSG. One unit of activity is defined as the amount of enzyme that catalyzes the oxidation of 1  $\mu\text{mol}$  of NADPH  $\text{min}^{-1}$  under the assay conditions.

### Assay of metabolic enzymes

The activity of  $\beta$ -amylase was determined by the method of Bernfeld (1955). Reaction mixture contained 500  $\mu\text{l}$  of 2% starch solution in 50 mM phosphate buffer (pH 7.0) and 500  $\mu\text{l}$  of enzyme extract. The number of  $\mu\text{moles}$  of maltose released  $\text{min}^{-1}$  is defined

as one unit of  $\beta$ -amylase. Acid phosphatase (AP) activity was determined by measuring the release of *p*-nitrophenol at 410 nm according to the method of Hoerling and Svensmark (1976). Each unit of activity is defined as 1  $\mu$ mole of *p*-nitro phenol released  $\text{min}^{-1}$ .

### Statistical analysis

All data are expressed as a means of triplicate experiments unless mentioned otherwise and experiments were performed using randomized design. Data were subjected to analysis of variance (ANOVA) using GraphPad Prism version 6.0 and the mean differences were compared by lowest standard deviations test (LSD). Comparisons with  $P \leq 0.05$  were considered significantly different.

## RESULTS AND DISCUSSION

### Growth parameters

Water cycling through the soil-plant-atmosphere continuum can be estimated by water potential, which also suggests the energy status of plant water. Physiological consequences leading to water deficit in cell can be appropriately measured by determining RWC. Plants exhibit varied RWC values in species specific manner and extent of drought. Some drought tolerant species have been shown to possess a range of RWC from 60 to 70%, while severely desiccated and dying leaves in drought sensitive species was about 30 to 40% (Barrs and Weatherley, 1962). Niger exhibited RWC of 75 and 50%, respectively at 48 and 72 h of drought stress (Figure 2), but 72 h stressed plants failed to revive on re-watering. This suggests the detrimental effects of drought beyond 48 h. A similar relationship between RWC and survival was observed in faba bean under salinity (Tavakkoli and Rengasamy, 2010). These effects of reduced RWC were reflected in fresh weight of drought stressed seedlings (Figure 3). However, dry weight of the seedlings remained unchanged relative to control, emphasizing primacy of physiological mechanisms in water balance under drought stress.

### Stress markers

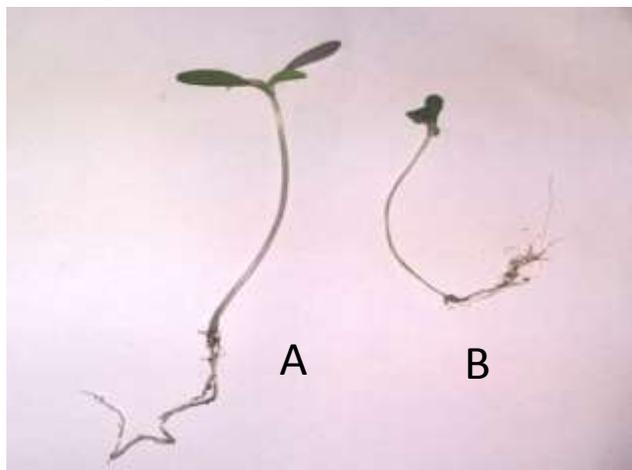
Tolerance of plants to an applied stress involves many complex and multifaceted process. Drought in plants induces oxidative stress, and ability of plants to tolerate depends upon unfolding of the genetic plasticity in order to induce specific antioxidant defense mechanism. Quantitative estimation of antioxidant components would indicate the prevalence of an adverse condition, severity of the stress and strength of antioxidant system. Oxidative stress creates imbalance in electron transport and metabolic utilization of reducing power, thereby increasing ROS levels in the cell. Progressive reduction in PS-II and  $\beta$ -oxidation of lipids during drought results in

generation of  $\text{H}_2\text{O}_2$ , most stable intermediate circumventing the other ROS species (Wang et al., 2011). A 0.74-fold increase in  $\text{H}_2\text{O}_2$  after 48 h of applied stress in niger suggested the onset of oxidative stress, as observed in *Azolla* exposed to different levels of paraquat (Sood et al., 2011). A decrease in  $\text{H}_2\text{O}_2$  level during extended drought for 72 h suggested the onset of enzymatic and non-enzymatic antioxidative defense system to control the oxidative damage.

Level of MDA is indicative of the extent of lipid peroxidation in plant under oxidative stress induced by various environmental factors. Almost exponential increase in MDA with extended duration of drought indicated the severity of stress leading to suppression of antioxidant defense systems. While similar negative correlation between lipid peroxidation and antioxidant system has been reported in wheat (Selote and Khanna-Chopra, 2010) and maize genotypes subjected to drought stress (Vishal et al., 2013), Li and Zhang (2013) had reported lower MDA content in *Zoysia japonica* pretreated with 5 and 10 mM  $\text{CaCl}_2$  under drought conditions. This suggests that pretreatment with the appropriate  $\text{CaCl}_2$  concentration reduces oxidative damage that results from drought.

A number of metabolic pathways are synchronized to alleviate induced oxidative stress. Synchronized operation of ascorbate-glutathione (ASC-GSH) pathway known to establish a balance between generation and metabolism of ROS and its reaction products is an essential plant stress tolerance mechanism (Vivancos et al., 2013). GSH, a multifunctional water soluble tripeptide contributes to cell protection against detrimental effects of free radical by recycling ascorbate in its reduced form. GSH either forms adducts directly with reactive electrophiles, or acts as a proton donor in the presence of ROS, yielding GSSG; thus, providing a mechanism to protect biological macromolecules (Shao and Kang, 2008). A 1.2- fold increase in GSH level during 48 h and further decline at 72 h of drought indicated the operation of GSH-ASC cycle during early drought stress and its inefficiency during extended drought. A similar response was reported in drought stressed Hyacinth bean (Myrene and Devaraj, 2011). ASC acts as a specific electron donor to reduce  $\text{H}_2\text{O}_2$  to water with the concomitant generation of monodehydroascorbate. As a potent reducing power, ASC maintains metalloenzyme activity and chloroplastic  $\alpha$ -tocopherol (Pang and Wang, 2010). ASC levels in stressed seedlings of niger showed a 0.48-fold increase over 72 h of exposure time. These results are in conformity with drought stressed almond (Sorkheh et al., 2011). Parallel increase in ASC and GSH levels suggested efficient operation of ASC-GSH cycle during early period of drought stress.

Accumulations of osmoregulatory molecules such as proline, glycine betaine and sugars in response to oxidative stress had been reported in many plants (Deinlein et al., 2014). In addition to being compatible



**Figure 1.** Effect of drought on niger seedlings: A: Control seedlings, B: stressed seedlings after 48 h.

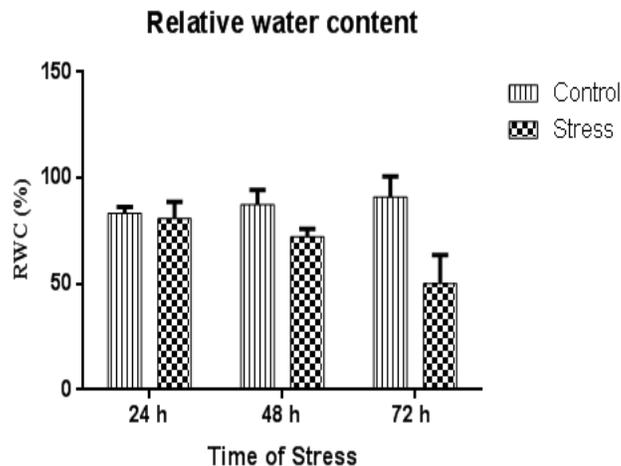
solute and enzyme protectant, proline is also known to render structural stability to macromolecules and organelles. Increase in proline levels ~20%, as compared to control during the entire period of applied stress suggested effective osmotic adjustment contributing to osmotic stress tolerance in niger. The observed proline levels in niger were in consonance with those of drought stressed sugar cane (Abbas et al., 2014) and corn cultivars (Sinay and Karuwal, 2014) (Table 1).

Seedlings of niger were drought stressed and individual seedlings were analyzed for determination of  $H_2O_2$ , ASC, GSH, PRO and MDA. Results are mean  $\pm$  SD, obtained from three replicates.

### Antioxidant enzymes

In many plant species which exhibit stress tolerance, both enzymatic and non-enzymatic antioxidant systems operate simultaneously. Guaiacol specific POXs are known to play a vital role in various biosynthetic processes like ethylene and auxin metabolism, maintain redox homeostasis in plasma membrane, lignification and suberization of cell wall and several other developmental and defense mechanisms (Lepeduš et al., 2004) thereby, making it an indispensable component of the antioxidant system. Elevated levels of GPOX up to 48 h of applied stress, and its decline beyond 48 h suggested the enzymes potential ROS quenching during 48 h of drought stress, and its insufficiency beyond 48 h of drought (Figure 1), similar to observations made in wheat species under drought stress (Sheoran et al., 2015).

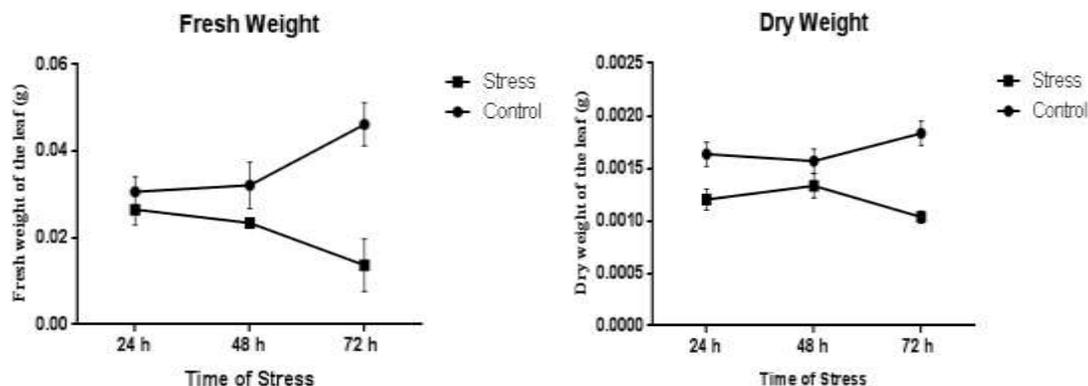
The levels of APX and GR in leaves of Niger at 48 h of drought stress showed increase in both control and stressed seedlings. Ascorbate peroxidases are class I heme-peroxidases, which utilize ASC as specific electron donor and catalyze the reduction of  $H_2O_2$  into  $H_2O$ . APX



**Figure 2.** RWC in leaf tissues of niger seedlings at 24, 48, 72 h of drought stress.

activity in response to environmental stress generally increases along with other enzymes activities, such as CAT, POX and GR (Shigeru et al., 2002). APX showed 2.5-fold enhancements after 48 h of stress (Figure 3), which coincided with relatively lower  $H_2O_2$  levels. Such changes had been reported in drought stressed *Solanum melongena* L. and *Piper longum* L. (Caverzan et al., 2012) and suggested to contribute to drought tolerance. GR evokes cell defense by detoxification of ROS and regeneration of GSH from GSSG with the accompanying oxidation of NADPH. Detoxification of ROS and maintenance of redox potential via NADP production by GR had been shown to contribute to abiotic stress tolerance. A 3.5-fold enhancement in GR levels in niger under drought indicated its role in stress tolerance (Figure 4). Similar activation in GR levels had been demonstrated in cowpea under water stress (Torres-Franklin and Zuily-Fodil, 2008) and tobacco under heat stress (Tan et al., 2011). Enhanced levels of APX and GR showed that they are essential components of ASC-GSH cycle. Contrary to the current findings, Chugh et al. (2010) reported inhibition of GR activity in maize (Paras, sensitive genotype) under drought stress, rendering it susceptible to drought.

Catalase showed a progressive decline during drought stress with 2.2-fold decline after 72 h (Figure 2). CATs are ubiquitous enzymes known to contain tetrameric-heme moiety catalyzing dismutation of two molecules of  $H_2O_2$  into oxygen and water. Although, an enzyme with high turnover number CATs lower affinity towards  $H_2O_2$  and photo-inactivation distinguishes it from other alternative  $H_2O_2$  scavenging systems. Consequently, these inhibiting conditions lower the steady state levels of the enzyme as observed in Niger. CATs are known to be efficient tools for gross removal of high  $H_2O_2$  levels, but they are less suited for fine tuning of sensitive redox balances with low  $H_2O_2$  concentrations (Nicholls and

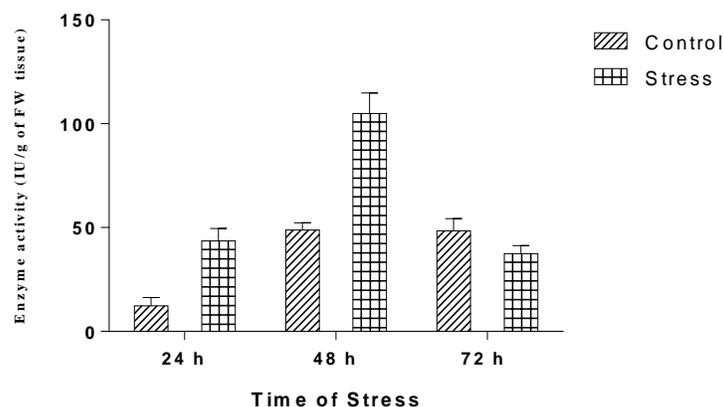


**Figure 3.** Fresh and dry weight of niger leaves at 24, 48 and 72 h of applied drought stress. Values for FW and DW are  $\pm$  SE ( $\pm 0.001$ ).

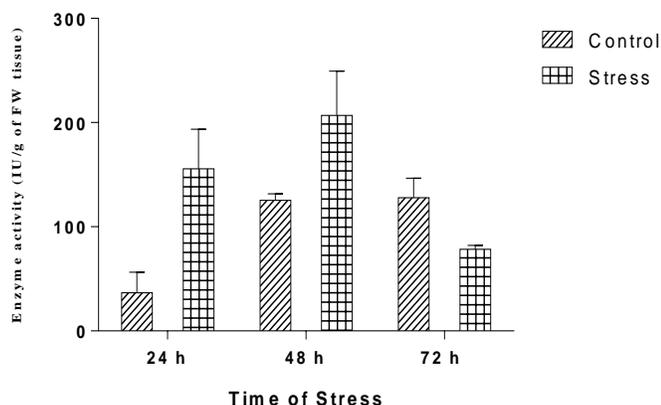
**Table 1.** Levels of stress markers in leaves of niger (*Guizotia abyssinica*) subjected to drought stress\*.

Tissue	Time	Stress marker	Control	Stress
Leaf	24 h	H <sub>2</sub> O <sub>2</sub> <sup>a</sup>	29.10664 $\pm$ 1.902405	38.78818 $\pm$ 0.748218
		Proline <sup>b</sup>	410.9 $\pm$ 6.38	505.3 $\pm$ 15.39976
		MDA <sup>c</sup>	3.460347 $\pm$ 0.37537	4.9717 $\pm$ 0.539988
		GSH <sup>a</sup>	80.605 $\pm$ 7.230614	164.15 $\pm$ 2.76101
		Ascorbate <sup>b</sup>	24.885 $\pm$ 0.518965	33.12 $\pm$ 0.476235
	48 h	H <sub>2</sub> O <sub>2</sub> <sup>a</sup>	33.91708 $\pm$ 1.301969	59.12682 $\pm$ 2.062253
		Proline <sup>b</sup>	488.2667 $\pm$ 12.76784	576.3333 $\pm$ 12.95411
		MDA <sup>c</sup>	3.347 $\pm$ 0.266551	7.6508 $\pm$ 0.447347
		GSH <sup>a</sup>	97.755 $\pm$ 3.771727	195.51 $\pm$ 6.407581
		Ascorbate <sup>b</sup>	29.7 $\pm$ 1.091192	44.01 $\pm$ 1.169134
	72 h	H <sub>2</sub> O <sub>2</sub> <sup>a</sup>	20.70311 $\pm$ 2.352013	31.29817 $\pm$ 2.50181
		Proline <sup>b</sup>	543.2667 $\pm$ 9.648201	629.0267 $\pm$ 9.16527
		MDA <sup>c</sup>	2.503267 $\pm$ 0.109233	13.6808 $\pm$ 0.673692
		GSH <sup>a</sup>	104.615 $\pm$ 3.65863	171.5 $\pm$ 6.095529
		Ascorbate <sup>b</sup>	30.555 $\pm$ 0.273724	40.85167 $\pm$ 0.837269

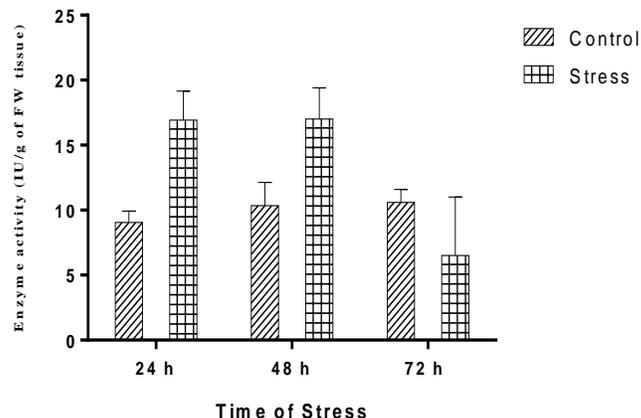
\*<sup>a</sup> $\mu$ g/g fresh weight tissue; <sup>b</sup>mg/g fresh weight tissue; <sup>c</sup>m moles/g fresh weight tissue.



**Figure 3.** Effect of drought stress on APX activity in leaves of niger. Results are mean  $\pm$  SE ( $P \leq 0.05$ ), obtained from three replicates.



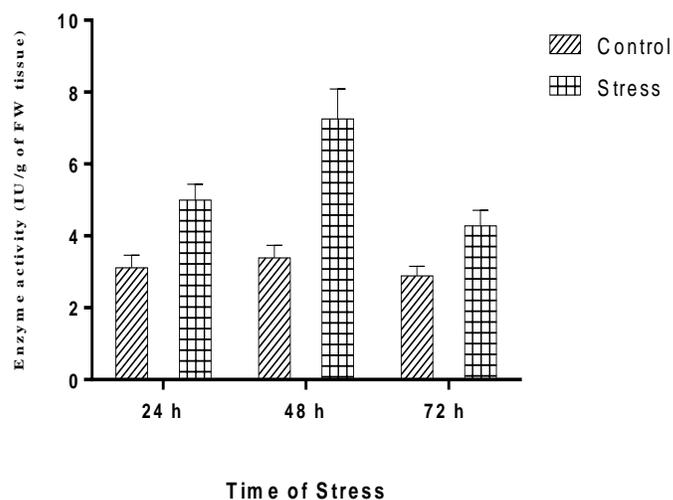
**Figure 4.** Effect of drought stress on GR activity in leaves of niger. Results are mean  $\pm$  SE ( $P \leq 0.05$ ), obtained from three replicates.



**Figure 5.** Effect of drought stress on AMY activity in leaves of Niger. Results are mean  $\pm$  SE ( $P \leq 0.05$ ), obtained from three replicates.

Ferguson, 2001). On the other hand, APX is known to have greater affinity for  $H_2O_2$  (Sofa et al., 2015), and play a pivotal role in  $H_2O_2$  detoxification. The results are in agreement with previous studies carried out in bentgrass species (Michelle and Bingru 2007) and wheat cultivars (Chakraborty and Pradhan, 2012) subjected to drought stress, exhibiting countervailing CAT activity by APX. However, the extent of stress and susceptibility of plant species may lead to significant increase in the levels of CAT activity as was reported in oats (Islam et al., 2010) and maize (Chugh et al., 2010) under drought stress.

Though antioxidant enzymes play a pivotal role in stress tolerance, there are reports of induction of metabolic enzymes like acid phosphatase and  $\beta$ -amylases (Yang et al., 2007) during abiotic stress. In response to water stress, levels of inorganic phosphate are maintained by acid phosphatase, which is accomplished by co-transporting it with  $H^+$  along the gradient of proton motive force. AP activity in niger showed 1.4-fold increase after 48 h and declined with extended exposure to stress (Figure 6). A similar observation was noted in alfalfa (*Medicago sativa* L.) explants subjected to salt and drought stress (Ehsanpour and Amini, 2003) and pigweed leaves under drought stress (Cunhua et al., 2010).  $\beta$ -Amylase plays a major role in starch degradation and in the daily turnover of transitory starch in photosynthetic organs.  $\beta$ -Amylase catalyzes the breakdown of glucans into maltose, which in cytosol is converted to glucose and ultimately leading to formation of sucrose and fructose.  $\beta$ -Amylase contributes to stress tolerance by increasing maltose and other soluble starch that can act as emergency compatible solutes (Krasensky and Jonal, 2012). Enhanced  $\beta$ -amylase levels in niger during 48 h of applied stress (Figure 5) suggested increased accumulation of sugars, which act as osmoregulant to maintain cell turgidity and maintain membrane integrity in response to the applied stress. Increase in  $\beta$ -amylase



**Figure 6.** Effect of drought stress on AP activity in leaves of Niger. Results are mean  $\pm$  SE ( $P \leq 0.05$ ), obtained from three replicates.

activity was seen in *Populus nigra* L. clones subjected to drought stress (Regier and Streb, 2009), which is interpreted as a tolerance mechanism.

## Conclusion

Effects of different abiotic stresses such as drought on plants involve overproduction of ROS leading to oxidative stress. Plants exert a positive adaptation to drought by strategizing potent antioxidant defense systems and efficiently combat by non-enzymatic components, ASC, GSH and proline and enzymatic components, GPX, APX, GR, AMY and AP. From induction of antioxidant enzymes, enhanced antioxidants and revival of plants

upon re-watering, it is concluded that Niger is tolerant to drought stress of up to 48 h. Thus, the drought response in Niger measured in terms of antioxidant and antioxidant enzymes levels suggested participation of both components in tolerance mechanism. However, the antioxidant system employed by Niger to overcome/tolerate drought appears to be sufficient to protect against short term (up to 48 h) drought stress.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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*Full Length Research Paper*

# Promoting micro, small and medium enterprises in beekeeping in Zambia's Central Province: Making a case for the adoption of business incubation strategy

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Beekeeping has been a thriving enterprise among farmers in selected parts of Zambia. However, despite its enormous potential for transforming rural communities and through income generation, the beekeeping sector has experienced stunted growth for many years (or has not experienced meaningful growth for many years). Therefore, this study investigates the nature of beekeeping in selected parts of Zambia's Central Province in order to identify the challenges being faced and the possibility of establishing a business incubation centre at Mulungushi University if the current supporting facilities are not optimal. The study reveals that there is a growing interest among the farmers to venture into beekeeping and the majority regard it as an alternative venture for income generation. Although, the production levels are not high as expected, there is great room for growth if the current setbacks are dealt with. The main challenges cited include inadequate financial support; lack of markets, charcoal burning, land conflicts, water challenges, knew knowledge and modern technology among others. The main recommendation of this study is for Mulungushi University to establish a business incubation centre to act as a conduit for support an exchange of knowledge with the beekeepers. The beekeepers also need sustained financial and material support from the government and cooperating partners. Lastly, there is need for the key stakeholders to converged and put their efforts together.

**Key words:** Capacity building, beekeeping, Central Province, Zambia, business incubation.

## INTRODUCTION

The beekeeping sector is made up of various players who include beekeepers, honey processing firms,

individual sellers, bulk buyers and individual buyers. The beekeepers can be categorized into two categories wild

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honey gatherers, and individual beekeepers (IUCN, 2015). Generally, the beekeeping industry in Zambia operates on a small-scale basis and thus most entities in this industry can be categorised as micro, small and medium enterprises (MSMEs). World over, MSMEs play a critical role in employment creation, poverty reduction and economic development. Beekeeping provides an array of opportunities for economic growth through alleviation of poverty, bringing in the much needed foreign currency in the country as well as creating a framework for forestry management (Nyatsande et al., 2014) and climate change adaptation. Beekeeping can also create vital linkages with other sectors of the economy, yet the reality on the ground is that little attention is being made to promote the viability of the sector. It can be noted that beekeeping in most parts of Zambia's Central province had remained at low level, in comparison to North-Western Province, with majority of farmers using traditional methods (Mickels-Kokwe, 2006). In general, beekeepers are lacking capacity to expand their activities. It is against this backdrop that this study sets out to investigate the factors inhibiting its growth and viability on one hand and on the other hand explore the utility of business incubation in promoting capacity building among the beekeeping MSMEs in Zambia with special focus on the selected areas in the Kabwe, Kapiri-Mposhi and Chisamba.

This study advances that matching beekeeping and business incubation will have invaluable benefits not only to the beekeeping MSMEs but also to other enterprises that use honey and its by-products for different purposes. It is envisaged that business incubation will increase the survival rate of MSMEs thereby creating employment opportunities and economic growth. Furthermore, the incubation will contribute to a sustainable environment by promoting an environmental friendly source of income among farmers and other rural dwellers. Hence, Fischer (1993) observes that a successful beekeeper accumulate wealth and establish networks through trading of honey. According to Nyatsande et al. (2014), the advantages are beekeeping is that it requires low investment, does not compete with other farming activities for resources and there are no sophisticated machinery or equipment needed.

In order to unpack the utility of business incubation as a capacity building tool for micro, small and medium enterprises, this paper explores the beekeeping activities in Kabwe, Kapiri-Mposhi and Chisamba with a view to identify the opportunities and challenges in the beekeeping sector. This entails largely examining how the beekeeping is done, the methods of marketing and the support being availed to the beekeepers. The paper also presents an analysis of the challenges facing those engaged in beekeeping activities. Understanding these overall issues about beekeeping in Kabwe, Kapiri-Mposhi and Chisamba created the foundation for making a case for the adoption of business incubation as a capacity

building for promoting MSMEs in the beekeeping and honey production industry. Among other things, the recommendation section examined how Mulungushi University can play a pivotal role in making the incubation strategy a success and the need for active stakeholder involvement in the bee sector such as the Zambian Government and Cooperating Partners.

## CONCEPTUAL FRAMEWORK

The concept of business incubation can mean different things to different people depending on the purpose it seeks to serve. According to the neurodegeneration with brain iron accumulation (NBIA, 2008), it is an economic development tool designed to accelerate growth and success of entrepreneurial company through an array of business support resources and services by nurturing the development of entrepreneurial companies, helping them survive and grow during start-up period, when they are most vulnerable. Following this definition, this study conceives of business incubation as a place where business entities are offered an organised resource rich environment and various supporting services dedicated to emerging enterprises in order to strengthen their development. In this regard, business incubators are buildings or structures that accommodate companies during their initial phases of development. Besides, it is a knowledge sharing nursery where entrepreneurs can share experiences. Accordingly, business incubators are established to help entrepreneurs to overcome business challenges associated with starting and sustaining a business enterprise. More specifically, the idea is "to help small companies to graduate or leave an incubator in a financially stable state and be able to operate on their own upon graduation" (NBIA, 2008: 16).

The support received by small companies from incubators includes both hard and soft services which ranges from physical or office spaces, equipment, shared services, business and legal and entrepreneurial advice as well as financial inputs. In fact the services that incubators can offer are many and cannot be exhausted. What is important is to structure the incubation in a flexible manner in order to be responsive to tenant companies' needs. The services offered by incubators can be regarded as remedies for set setbacks that SMEs encounter during their growth process. It is because of the challenges that the SMEs face during their formative stages that developed and some developing countries have introduced the concept of business incubation.

The concept of business incubation is being implemented in countries such as United States of America (USA), Japan, China, Nigeria, South Africa and Uganda (Bubou and Okrigwe, 2011). These countries adopted business incubation to help SMEs to ward off business tides associated with start-up period. In some instances, business incubation offers management

assistance, mentoring access to finance flexible and low-cost leases, office services and subsequently promotion of development of new and qualified SMEs (Gwiza and Hamauswa, 2015). The general benefits of business incubation include but not limited to high economic growth, creation of employment opportunities, reduction of poverty, and the promotion of innovation and entrepreneurship spirit (Bubou and Okrigwe, 2011). In light of this, adopting this strategy will go a long way to assist the existing beekeeping SMEs as well as setting a firm foundation for the development and growth of the future enterprises.

## LITERATURE REVIEW

MSMEs have been playing a major role in promoting economic growth world over and Zambia is not an exception especially considering that the economy has continued registering sustained growth in the past decade. The existence of MSMEs and their contribution to the national economy in Zambia has a strong history which dates back to the colonial period (XXX). Unfortunately during the colonial period MSMEs among the black majority were not given adequate attention and support. Following the attainment of independence in 1964, successive governments in Zambia have shown considerable efforts and commitments towards supporting the activities of MSMEs. The growth of MSMEs can largely be attributed to the liberalisation policies introduced in the early 1990's that resulted into large scale privatization of state-owned enterprises and subsequent proliferation of the informal sector, mainly attributed to considerable job losses (XXX). As such the recognition of MSMEs as engines for employment creation, economic growth and poverty reduction is unequivocal. Zambia's long term plan, the Vision 2030 also extols the importance of MSMEs towards economic growth, employment creation and poverty reduction.

### Benefits of beekeeping

It can be argued that MSMEs focusing on beekeeping can be engines that propel socio-economic development in Zambia because globally, the demand for honey and other bee products has been increasing in the recent years (ITC, 2015). This is particularly because of the increasing awareness of the significance of these products to individuals and the economy at large. The beekeeping sector provides a variety of products such as honey, wax, royal jelly, propolis, venom, among others (Hilmi et al., 2012; IUCN, 2015; Kumar, 2010). Honey provides nutrients to individual well-being in form of carbohydrates, minerals and vitamins. In Zambia, honey has also been used to brew a local beer called mbote. The wax is used to make candles, floor polish and

cosmetics (Mickels-Kokwe, 2006). While the other products like propolis and venom are used in the pharmaceutical industry to make medicines. Further, the bees play an essential role in the process of cross pollination (Hilmi et al., 2012).

Moreover, the significance of the honey sector lies in its potential to contributing towards the country's foreign exchange earnings and reducing poverty through job creation (SNV, 2010). Other than providing beneficial products to society, the sector provides self-employment and income to the people involved the value chain (Hilmi et al., 2012; Teferi et al., 2011; Singh et al., 2016; Mickels-Kokwe, 2006; Teferi et al., 2011; Moniruzzaman, 2009). The income generated keeps beekeepers out of poverty as it enables them to buy food, acquire social services, meet school fees, buy clothes, build houses, buy assets and attend to other family issue (Mwakatobe and Machumu, 2010).

Besides economic gains, the beekeeping sector significantly contributes to the protection of the environment through preservation of forests. This entails that beekeepers would not engage in environment degradation activities such as cutting trees and burning forests. This implies that if the beekeeping industry becomes viable, it would be conceivable to change the mind set of charcoal burners and convert them into beekeepers. Moreover, farmers are encouraged to plant fruit trees like mango and pawpaw trees and other beneficial trees like Moringa tree to boost the bees' potency of honey production. Despite all these advantages, the current status of beekeeping business in Zambia particularly in Kabwe, Kapiri-Mposhi and Chisamba has not been explored. There is need to unpack opportunities and challenges being faced in order to determine the actual capacity of beekeeping industry in alleviating poverty as well as contributing to the national economy. Therefore, it has been argued that beekeeping has the potential to provide sustainable livelihoods to many small-scale farmers and other rural and non-rural people (Hilmi et al., 2012).

It has been noted that in Zambia, most of the beekeeping enterprises operate in the informal sector and fall in the category of micro enterprise (employing up to 10 employees and having total investments excluding land and Buildings of K80) (MCTI, 2009; Husselman, 2008), with few in the small enterprise category (employing between 11 and 49 employees and having total investments excluding land and buildings of between K80 and K200) enterprises. Businesses in this category face a lot of challenges which contribute to their high death rates. The challenges they face include access to capital, access to markets, business management skills, deforestation, and access to soft and hard infrastructure among others (Husselman, 2008; Simukoko, 2008).

In order to enhance their growth and enable them effectively contribute to employment, poverty reduction, foreign exchange earnings and support industrial growth

and sustainable development, key strategies and interventions have to be put in place to address the impediments. One key intervention to address the technical and management skills deficiencies would be to offer the beekeepers training in management and marketing skills to encourage use of sustainable methods of beekeeping and improve the knowledge and capacity of small-scale farmers (Hilmi et al., 2012). It is envisaged that this would enhance the success and growth of the beekeeping enterprise. According to Ramesh et al. (2012), beekeeping training imparts knowledge which has a positive impact on the development of the beekeeping enterprise and the generation of employment opportunities to the unemployed youth and rural people. In addition, business incubators should be established to help address the other impediments and ensure success of these enterprises.

Furthermore, Zambia has a conducive environment for beekeeping and has the potential to be one of the leading exporters of honey and honey related products (Husselman, 2008). This is evidenced by the increased production and export of the honey and comb honey. Food and Agriculture Organisation (FAO) estimates indicate that honey production in Zambia has increased from 520 tonnes (valued at \$1 304 000) in 2007 to 750 tonnes (valued at \$1 882 000) in 2013 while beeswax has increased marginally from 25 tonnes (valued at \$234 000) in 2005 to 36 tonnes (valued at \$335 000) in 2014 (FAOSTAT Data, 2017). The North-Western province of Zambia is the major producer of the bulk of the Zambian honey and beeswax production. This is the most profitable province for honey production. The province is conducive for beekeeping because it is located in the region with high rainfall precipitation and is rich in the natural vegetation and the miombo woodlands, which are favourable for beekeeping. Beekeeping also takes place in other provinces, but at a lower scale relative to North Western province. These include Copperbelt rural, parts of Western, Luapula, Northern, Eastern and Central provinces. The beekeepers are categorized into group beekeepers wild honey gatherers, individual beekeepers (IUCN, 2015).

### **Regulatory and policy environment**

Currently, the beekeeping sector is regulated by the Forestry Department under the 2015 Forest Act. The Act allows for forest resource co-management between communities and government through JFM. Under this formal approach, communities, including beekeepers, may gain formally recognised user rights to forest areas and increase incomes from forest products through controlled harvesting (Mickels-Kokwe, 2006). The regulatory framework provides an opportunity for strengthening the viability of the beekeeping industry because it encourages community participation. This is

cardinal in sustainable development because it creates a sense of ownership and responsibility among the grassroots with regards to management and preservation of natural resources such as forests.

## **METHODOLOGY**

### **Study setting and design**

This study was conducted in Central Province of Zambia in the districts of Kabwe, Chisamba and Kapiri Mposhi. In carrying out this study, the research employed exploratory and descriptive research designs where both qualitative and quantitative approaches were used to collect and analyse data.

### **Study population and sampling design**

The primary target population were men and women engaged in beekeeping in Central province and who were members of the beekeeping groups. Both the beekeeping groups and respondent for the survey were selected through a convenient sampling method (Figure 1).

### **Data collection**

#### **Key informant interviews**

Key informant interviews were conducted to collect information from respondents who had special information about the nature and dynamics of beekeeping in the Central province. In this regard five key informant interviews were conducted with representatives from the Forestry Department, Agricultural Extension Services and academic experts in the area.

#### **Focus group discussions (FGDs)**

FGDs were conducted with the purpose of understanding the perspectives of the communities with regard to the status of beekeeping enterprises in the studied areas. In this regard, a focus group discussion guide was utilised as a data collection tool. In total of four FGDs were conducted. These groups included Tilitonse beekeepers in Luanshimba-in Kapiri-Mposhi, Mubila Youth Multi-purpose Beekeepers in Kapiri rural, Chikonkomene Beekeepers in Chisamba, and Kabule Women beekeepers in Kapiri-Mposhi. Throughout the FGDs the participants explained how they started beekeeping as well as the challenges they have been facing. Field notes and electronic devices were used to capture the information during the discussions. Focus group discussions were conducted in local languages with the four beekeeping groups.

#### **Documentary search**

Documentary search involved the collection of relevant data from already published materials. These included books, book chapters, journal articles, newspapers, reports from government departments and other Non-Governmental Organisations (NGOs). The information from published materials was important in understanding the historical developments as well as contemporary developments with regard to beekeeping in the Central province and Zambia in general. Through documentary search it was also possible to identify lessons that beekeepers in Zambia can learn

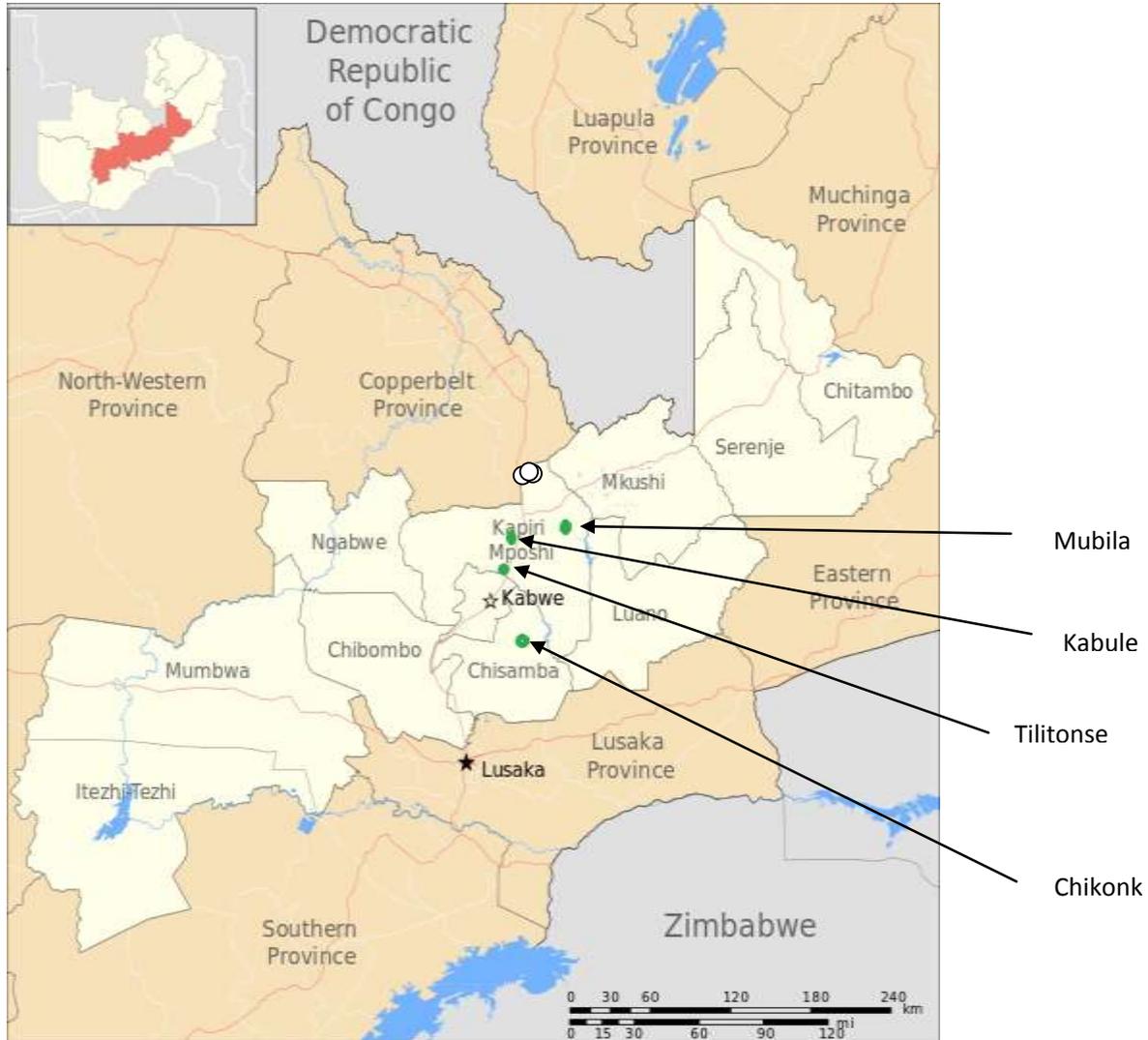


Figure 1. Map of the Central Province of Zambia with the surveyed areas (green dots) (chalochatu.org).

from other countries such as Tanzania and Kenya.

**Personal observations**

Personal observations were also used to collect important information for the understanding of beekeeping activities in the Central Province of Zambia. During the field visits, it was observed that beekeepers are now conscious of protecting the forests. Through observations, it was possible to identify the types and quantities of beehives being utilised by the farmers. Cameras were used to capture important information and photographs that were vital for the study.

**Survey**

Quantitative data were collected through semi-structured questionnaires with the help of research assistants and focal persons. Questionnaires were distributed to ninety bee-keepers and only eighty-eight were collected. The survey was meant to

complement information collected through the aforementioned qualitative methods.

**Data analysis procedure**

Quantitative data were entered, coded, and analysed using SPSS for windows version 21.0. Descriptive statistics were analysed to describe the proportions in the characteristics of the beekeepers. The qualitative data were analysed through the use of thematic approach. The thematic approach of data analysis helped determine the common factors that affect the beekeeping sub-sector.

**Presentation, analysis and discussion of findings**

Here entails the presentation and analysis of the major findings from the data that were collected in parts of Kabwe, Chisamba and Kapiri Mposhi districts. The

collected quantitative data were analysed using percentages, while the qualitative data were analysed and organised into emerging themes depicting the status, challenges and opportunities of beekeeping enterprises in the aforementioned districts.

### **Beekeeping in Zambia's Central Province: A synopsis**

In order to understand the nature of beekeeping enterprises in the Central province, the study examined the current situation, the motivational factors for engaging in beekeeping, the nature of support, if any, from either government or other development partners and the challenges being faced. As explained earlier, this study also examined the general production output, processing, and marketing strategies being employed. The findings from our study indicated that men dominate the beekeeping sector in Zambia's Central Province. As illustrated Figure 2, 71.3% of the beekeepers interviewed were men while 28.7% were women. Although men continue to dominate the sector 28.7% show that beekeeping is no longer a preserve for men. Thus, there is an indication that women are increasingly becoming involved in the beekeeping business. This is a positive development because in most societies women have been excluded from economic activities. The women who were interviewed indicated that beekeeping has changed their lives and one woman from Kabule highlighted that she managed to buy a cow using the proceeds from selling honey. This also shows that there could be factors that inhibit women to participate in this industry at the comparable level with men hence need to identify those factors and incorporate strategies that will encourage more participation from the women.

This study reveals that the elderly people have dominated the beekeeping sector in the Central Province of Zambia. As shown in Figure 3, the majority of the beekeepers are over 40 years of age (62.5%), while only 21.3% are between 15 and 30 years old. Although the elderly dominate the sector and it is interesting to note that the youthful ones are also involved as well. The involvement of the youth provides a strong case for provision of training and other supporting facilities for the beekeepers. There is also need to assess the perception of youths with regards to the beekeeping industry. This is cardinal because the sustainability of the industry depends on the youths driving it.

As illustrated in Table 1, the main occupation of most beekeepers interviewed was crop farming (96.3%). Thus, the majority of farmers are taking beekeeping as an alternative source of income alongside crop farming. Although almost all farmers mentioned crop farming as their main farming activity, a significant number indicated that they would want to make beekeeping the main farming activity. These findings agree to those noted by other researchers (Fisher, 1993) who noted that beekeepers allocate more time to other farm activities at

the expense of beekeeping. From the responses shown in Table 1, it can be noted that about 78% indicated their desire to expand their beekeeping enterprises. In pursuit of this aspiration, some beekeepers have gone to the extent of consulting the respective government departments on how their products such as honey can be certified and approved even for exportation. This is because most of them felt that honey and other related products can bring more income as compared to other crops such as maize. In addition, the beekeepers acknowledged that beekeeping was a less costly venture compared to crop farming which requires many inputs. The desire by farmers to expand the beekeeping industry provides an opportunity for growth and contribution to sustainable development support can be provided by stakeholders like relevant government institutions and NGOs.

### **Categories of beekeepers**

In general, there are two categories of beekeepers in the areas under consideration, namely, individual beekeepers and loosely coordinated groups. However, even though groupings do exist there is a general inclination towards individual beekeeping. Out of the four beekeeping groups, it was established that only three beekeeping groups seemed to be doing well in terms of working together and registering growth of beekeeping enterprises. Those groups that are doing well have shown signs of strong leadership skills with the leaders playing critical roles in encouraging other people to venture into beekeeping. This provides an opportunity for the Department of Cooperatives to mobilise farmers and develop the beekeeping industry to viable levels and enhance sustainable socio-economic development.

### **Motivation for beekeeping**

There is growing interest among the farmers in the visited areas which include Chikonkomene, Luansimba, Kabule and Mubila. The majority of members heard from friends about the potential in beekeeping while some generally developed the interest and saw the potential. Other farmers were attracted to beekeeping because it proved to be a lucrative enterprise. Hence, the majority of the respondents, about 90% stated that they are into the beekeeping business to generate income for their livelihoods. This is against 7.5 and 2.5% who started beekeeping for leisure and that it has been a family practice. The chairperson of Tilitonse beekeeping cooperative started as a bee hunter, then was offered help by Heifer International with a modern beehive. From the focus group discussion, it emerged that the same chairperson was instrumental in influencing others to join beekeeping enterprise. In other areas such as Kabule some farmers learnt about beekeeping through the some

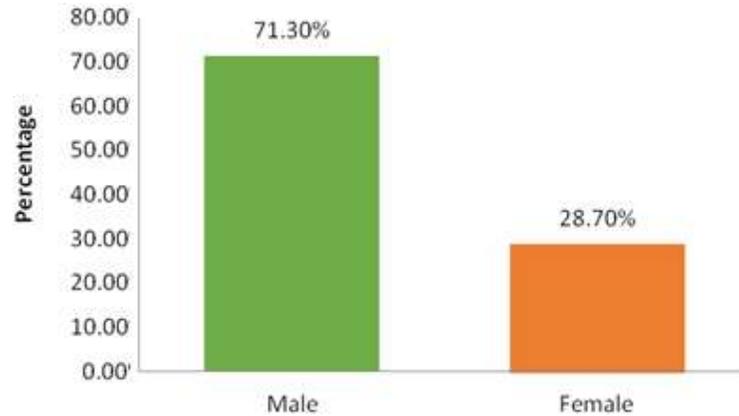


Figure 2. Gender distribution of the beekeepers surveyed.

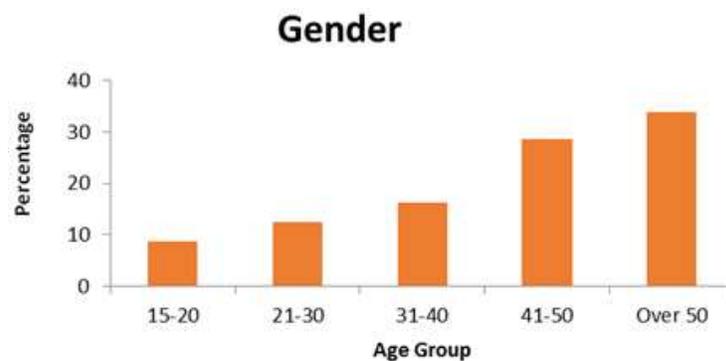


Figure 3. Age distribution of the beekeepers interviewed.

Table 1. Occupation of the respondents.

Item	Percentage
<b>Occupation</b>	
Farming	96.3
Government employee	1.3
Farm employee	1.3
Not employed	1.3
<b>Growth aspiration</b>	
Yes	73.8
No	26.3

radio programmes, while others grew up in families that were engaged in beekeeping.

**Nature and levels of production**

The current honey production levels are not as high as

expected but they are impressive in that they indicate great potential. As indicated in Table 2, most of the beekeepers (47.5%) have been producing above 50 L of honey per year. Those producing 20 L and below constituted about 26.3% of the respondents. The production levels are in line with the type and number amount of beehives being used. On the number of

**Table 2.** Nature and level of production.

<b>Number of hives</b>	<b>Percentage</b>
1-5 Hives	53.8
6-10 Hives	26.3
11-15 Hives	15
Above 15 Hives	5
<b>Beekeeping training</b>	
Yes	41.3
No	58.8
<b>Honey output</b>	
0 to 20 L	26.3
21 to 30 L	7.5
31 to 40 L	18.8
Above 50	47.5

beehives, 53.8% has between 1 and five beehives and only 5% had more than 15 beehives while those with 6-10 beehives constitute 26.3%. It is worth noting that there are two harvesting season with the first one beginning in May while the second spans between November and December. The honey production fluctuates and to a large extent unpredictable. However, the highest yield of honey is between May to July.

Due to financial challenges, farmers are more inclined to traditional methods especially on processing. Traditional beehives are still in use. For example at Tilitonse, Chikonkomene and Kabule beekeeping cooperatives farmers still use traditional beehives made from tree barks. However, there is a strong desire to shift from the traditional to the modern methods of doing beekeeping. It is worth noting that traditional beehives are an impediment to the growth of the business since they lead to the destruction of the trees which are necessary for beekeeping. Further, the traditional beehives give very low yields compared to the modern hives. In addition, traditional beehives are very susceptible to attack by ants.

### **Beekeeping support in the area**

Beekeeping in Kabwe district has been receiving considerable support from the government in partnership with the donor community. The Zambian Forestry Department is one of the departments that represented the government in supporting beekeeping in the country. The government's support for beekeeping is based on the need to reduce pressure on the country's forestry by reducing deforestation. The beekeeping initiatives are meant to enable live side by side with the forestry without being a threat to their continued existence.

### **Materials and infrastructure support**

Much of the support given to the beekeepers was in form of materials and infrastructure. This support was in form of modern beehives, honey processors and bulk processing centres. For example beekeepers at Chikonkomene farming community beekeepers indicated that they received support from ZAMSIF. They were given 150 beehives as well assistance on building a bulk centre. While farmers in Kabule and Mubila pointed out that they were helped by SNV with 60 and 150 beehives, respectively. The beekeepers also said that SNV also helped with the construction of bulk processing centres and honey pressers or processing machines in both groups. Besides, key informants indicated that SNV was engaged by the Government of the Republic of Zambia to provide this support after they received funding from the World Trade Organisation (WTO). Respondents said that Heifer International also supported the Tilitonse group with modern beehives. This study has noted some weaknesses in this support. While these farmers received this support, the supporting organisation did not put in place monitoring and evaluation mechanisms to track whether the businesses were growing or not and see whether the objective of the support was being achieved. Moreover, the Kabule reported that they were not taught how to use the bee processing machine donated to them. They have not since used the machine and have continued to use traditional methods of processing, that is crushing and sieving. The beekeepers expressed desire to embrace new technology in beekeeping.

Unfortunately, moreover, beekeepers indicated that the assistance from ZAMSIF was a once off support and the organisation never came back to make follow ups or evaluate the impact of their support. They also reported that SNV has been supporting beekeepers in various

**Table 3.** Challenges and the needs of beekeepers.

<b>Operational challenges</b>	<b>Percentage</b>
Market	12.5
Financial	22.5
Training	23.8
Processing and packaging	41.3
<b>Support needed</b>	
Training	25
Processing and packaging	36.3
Connections	13.8
Quality assurance	25
<b>Sales outlets</b>	
Highway market	67.5
Nearby towns	20
Local markets	11.3
Own shop	1.3

number of areas through training and provision of modern beehives. However, it was reported that the NGOs were no longer supporting beekeeping projects, for their support was based on a specific project whose life span has ended.

### ***Training support***

Beekeepers interviewed indicated that they have received some training on beekeeping. In all 41.3% of the beekeepers have received some form of training in beekeeping. However, the training has not been continuous and uniform as it differed from one group to the other. For instance, members of Tilitonse beekeeping cooperative received support from Heifer International. They were trained on how to live side-by-side with the environment; although, there has been no follow up to review the success of the training. Besides, beekeepers received some training from agriculture extension officers from time to time. They also reported that Mulungushi University also supported the members through a workshop on beekeeping which was meant for knowledge exchange and sharing. In addition, the Zambian Government Forestry Department also offered training to other beekeepers.

### ***Financial support***

The study discovered that all the beekeeping groups have received some form support from various organisations. Beekeeping was part of the promotion of the Forestry Action Programme which was funded by the Government of Zambia and the Government of Finland.

The funding had a beekeeping component which was used as a pilot study. Various groups of people were given the financial support to start up the beekeeping business. However, beekeepers reported they were not asked to write any reports regarding the utilisation of the funds. The Forestry Department's support also came under the auspices of the government of Zambia's Poverty Reduction Strategy (PRS). Through this funding, beekeepers were given some start-up funds to work in groups. The idea was to create satellite beekeeping zones. The beneficiaries reported that they worked well until the funding was withdrawn. However, there is little or budgetary allocation towards the beekeeping sector in the 2017 national budget. However, the Kabwe Forestry Department no longer include beekeeping in their financial budgets.

## **CHALLENGES AND NEEDS OF BEEKEEPERS**

Beekeepers face various challenges which negatively affect the growth of the business and the sector at large. These challenges cover the beekeeping production, processing, marketing and access to finance affect issues of business sustainability. Table 3 contains the percentage distribution of the challenges facing beekeepers in the Zambia's Central Province and their needs.

During an interview, one of the key informants noted that the project aimed at supporting beekeepers was void of sustainability because most of beneficiaries disappeared (after receiving support or were not traceable after receiving support from the Government). Out of the beneficiaries (how many/kindly indicate the number) of the project, about two individuals seem to

have continued with the beekeeping business. In this regard, sustainability of beekeeping project was found to be the major challenge.

Moreover, land conflicts are threatening beekeeping in Zambia and Kabwe and particularly in Kapiri Mposhi in particular. The Kabwe District Forestry Department respondents observed that there is a fierce contestation for the control and utilisation of land among various government departments. For example some reserved forests are now being targeted for occupation by the traditional leaders and for the expansion of Kabwe town. Such developments are threatening the existence of forests which will in turn threaten beekeeping projects.

Further, due to economic challenges compounded by dwindling employment opportunities in Kabwe and Kapiri-Mposhi, squatter settlements on reserved forests are on the increase. The reserved forests are also the major catchment areas for the rivers in Kabwe or Kapiri-Mposhi. The town expansion is negatively affecting water bodies through tree cutting and land clearance for infrastructure development and farming activities. Consequently, this adversely affects the hydrological cycle. Since bees thrive where there is water, if there is little or no water, the beekeeping business gets negatively affected. Additionally, charcoal burning and wild bee hunters who tend to cut trees or put the beekeeping business at risk thereby causing a serious challenge to the beekeeping industry. This was also observed by Jumbe et al. (2008).

### Marketing problems

All the beekeepers have indicated that they have problems with the markets. The marketing challenges are actually multifaceted. Firstly, the prices for the produced honey are not attractive and the beekeepers feel they are being short-changed when selling their products to wholesalers. Ultimately, the beekeepers are not realising the anticipated profits from their products which would help move the business forward. For instance, one of the agricultural extension officers noted that unattractive prices could be one of the many reasons why the number of active beekeepers has declined in Luashimba area in Kapiri-Mposhi. These results are consistent with those of Hilmi et al. (2012) who noted that poor road infrastructure, lack of transport, and lack of access to credit for example can all hinder access to markets.

Secondly, the erratic availability of reliable buyers is another problem. In this regard, some producers who are close to the Great North Road sell their products on the roadsides commonly known as highway markets while those far away from the highway sell their products to marketers and the local community. This study revealed that about 67.5% sold their honey by the road sides of along the highway (Figure 4). This shows that the beekeepers do not have viable and reliable markets. In Luanshimba, Kapiri-Mposhi, organised buyers would

come from Kabwe and Lusaka. Also Chikonkomene on the other hand take their honey to Kabwe and Lusaka or sell within their local community. Farmers from all the visited farming communities indicated that, the prices being offered by the buyers are not attractive as the wholesalers were deemed to be exploitative. For example, the 2016 prices ranged from 60 to 120 Kwacha per 2.5 L of honey. By and large the common problem is that there were no reliable markets offering attractive prices for bee products.

Thirdly, the beekeepers in Zambia are relying more on the informal local market which is unreliable and does not offer lucrative prices. This is mainly because their products have not been certified by the Zambia Bureau of Standards (ZABS) to enable them penetrate the formal local and international market. Even though some of the beekeepers would want to have their honey approved by ZABS, the prices being charged certification charges are too exorbitant for the small scale farmers. Therefore, the fees being charged are either affordable nor being discriminatory and not supportive to the farmers. As a result the farmers are unable to access lucrative markets within as well as outside the country.

Furthermore, the packaging materials being used are not making the honey from small scale farmers attractive. The majority are using standard 2.5 L plastic containers of the packaging companies. However, there are no branded labels on their products. The containers are just plain white. For the smaller quantities below 2.5 L, the farmers and marketers are using empty drink bottles. These containers make the honey unattractive to buyers and raises quality concerns. This is because the consumers are now conscious of the hygiene issues related to packaging of foodstuffs. Therefore, in terms of challenges, processing and packaging (41.3%) were the most dominant challenges identified by the beekeepers, while 12.5% mentioned access to the market for the products. As such 36.3% needed support in the area of processing and packaging, 25% felt that they needed support in form of beekeeping training and quality insurance.

The other issue is that the road side marketers supplement the supplies from the local people with honey from outside Central province for example, from the North Western province. The respondents noted that the other problem is that the honey from the other areas is of lower quality when compared with the one produced in Luashimba in Kapiri-Mposhi and other surrounding areas. In other instances, these sellers buy rejected honey from North western province and its rumoured that they add water and sugar syrup to it before selling it. As a result, the image of the honey produced in Central province is being tarnished. More so the highway marketers on the roadside buy comb honey or unprocessed honey because it is cheaper and process it themselves thereby benefitting from both the honey and other by-products at the expense of the beekeepers.



**Figure 4.** Roadside honey seller at Luanshimba with Mr Hamauswa (Picture by authors).

### **Lack of sustained support**

Beekeepers expressed concerns over the lack of sustained support from the government and other development partners. In terms of extension services, the agricultural extension officers who were interviewed noted that they do not have specialised skills in beekeeping. As a result they are limited in offering relevant advice to the beekeepers within their jurisdiction. Instead, farmers have been receiving training arrangements from the Forestry Department and at times from Mulungushi University though on an ad hoc arrangement due to lack of proximity. The agricultural extension officers also lack adequate resources to reach out to the beekeeping farmers. The other missing link is that where the agricultural extension officers operate from, the land is small such that they are not able to set up demonstration facilities for the purposes offering practical lessons to the farmers.

### **Inadequate to non-existent financial support**

Beekeepers lack financial support services. In the case of beekeepers from Luashimba, farmers and their representatives such as the Zambia Honey Council (ZHC) have tried to lobby for financial support to no avail. The issue is not necessarily the unavailability of organisations which can give the financial support, but also that the farmers are lack proper organisational structures. It was also apparent from the interviews that the beekeepers have not explored other avenues such as the Citizenship Economic Empowerment Commission (CEEC), Youth Development Fund (for youth

beekeepers) and Women Empowerment Programmes (for female beekeepers).

### **Inadequate modern beehives or lack of new technology**

Another problem related to the financial challenges is lack of new technology in general and inadequate modern beehives in particular. The beekeepers explained that the modern beehives are expensive because as of 2016 one beehive was pegged at K400.00 which translates to about US\$40.00 at the spot exchange rate prevailing at that time. As a result most beekeepers were using a mixture of modern and traditional beehives while others utilise mostly on traditional beehives made out of tree barks. The disadvantage of traditional beehives is that they give poor yields when compared to modern hives. Their life span is also short because they are exposed to adverse weather conditions. In addition, traditional beehives are susceptible to various wild animals and insects that attack bees. A study by Tesfaye et al. (2017) also identified lack of modern beehives and insect infestation as some of the major challenges faced by beekeepers. Moreover, this method encourages deforestation as trees have to be cut to remove the bark. Figure 5 shows an example of a traditional beehive.

### **Charcoal burning and bee hunters**

In all the areas covered by the study, beekeepers expressed concern over charcoal burning. It was identified as a major threat to the survival of the



**Figure 5.** Traditional beehive in Chikonkomene (Picture by authors).

beekeeping sub-sector, our personal observation concurred with these sentiments. It was observed that charcoal burning is a thriving business in the areas. Rampant tree cutting for charcoal burning causes deforestation which later forces the bees to migrate to other areas. Deforestation also negatively impacts the catchment area of the nearby water sources.

#### **The unpredictable nature of bees and beehive invaders**

Another problem common to all was the fact that beehives tend to be invaded by the ants, mice and bee-killers. Further, water is a necessity for bees to produce honey. Most water bodies dry up around September and October. These factors may cause bees to migrate causing production to go down. Various researchers (Lijalem et al., 2017; Tesfaye et al., 2017; Chala et al., 2012) have highlighted that bee absconding poses as one of the challenges of beekeepers in Gomma district of Ethiopia.

#### **OPPORTUNITIES FOR GROWTH AND IMPORTANCE OF BEEKEEPING**

The study revealed several opportunities associated with the beekeeping industry as the following.

##### **Tree planting projects**

The Kabwe municipal council is working on a project to

be funded by the World Bank aimed at reforestation. The primary purpose is to reduce the adverse effects of the lead polluted soil around the former mining area. The tree planting project offers an opportunity for the beekeeping industry. However, as the Forestry Department representative suggested, there is need to make the tree planting project attractive to the local people. One way of doing this, is to combine tree planting with other projects such as beekeeping. Another tree planting project is being planned in the Chisamba district in the Chikonkomene farming area under the auspices of Green Living. One of the farmers noted that for the project to be successful, the farmers should be involved in identifying the type of trees to be planted in their areas. They said they would prefer those trees which would benefit them beyond the idea of preserving the forests. In this regard, fruit trees would get much support and their sustainability is assured because normally, the farmers would not cut them for other purposes. These trees would in turn provide nectar, a necessity for bees to produce honey.

##### **Level of knowledge among beekeepers**

The other opportunity for the growth and expansion of beekeeping in Zambia is based on the calibre of the farmers who have the zeal and interest in beekeeping. This was revealed by one of the key informants during an interview. He stated that the farmers in Luanshimba area for instance, are cognisant of the potential of beekeeping for improving their livelihoods. He also added that the Luanshimba area has not suffered much destruction to the environment especially the forests. Our own observations during the field research confirmed these

observations.

The majority of the beekeepers interviewed have some general knowledge on the essential factors necessary for beekeeping enterprise to thrive. The Tilitonse members noted that for beekeeping to thrive, there is need for availability of water. They also highlighted that type of trees such as Miombo tree and the Musamba tree, Mupundu, Mubanga are important for good quality honey. In addition, exotic trees such as sweet apple tree, Moringa can be planted to enhance honey production.

Despite understanding the essential conditions for beekeeping, the majority of the farmers interviewed indicated full awareness of the importance of bees in the ecosystem. They help with cross pollination and can help improve yields for various crops such as maize and sunflower.

### **Cost effectiveness**

Beekeeping is a cost effective venture because it does not require much farming and it is not labour intensive. This entails that the potential of yielding huge profits is high if production is done on a large scale.

### **Sustainable livelihoods and wealth creation**

The majority of beekeepers interviewed have a traceable record of how beekeeping enterprises have been instrumental as form of livelihood and helps in wealth creation. There is a realisation among beekeepers that the business is important for poverty reduction, employment creation, wealth creation among others. The study established that beekeeping is a very important business both to the individual beekeepers, the community and the country at large. Beekeeping provides employment and income to the dwellers hence sustaining their livelihoods. From the income generated, beekeepers are able to pay school fees for their children, buy food and can enhance wealth creation as people are able to buy assets like bicycles and even build houses. Further it supports, by providing inputs, to businesses involved in beekeeping products like honey producers, candle industry, wax polish and medicine among others. The results are in line with those of Hilmi et al. (2012) who noted that beekeeping is a source of income, improved nutrition as well as having curative properties.

In some cases they have used the money from beekeeping projects to purchase household goods, build houses, and buy assets like bicycles as well as paying school fees for their children. During a focus group discussion with the Kabule beekeepers, a female beekeeper noted that she bought a cow after selling honey.

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employment creation, wealth creation among others. The study established that beekeeping is a very important business both to the individual beekeepers, the community and the country at large. Beekeeping provides employment and income to the dwellers hence sustaining their livelihoods. From the income generated, beekeepers are able to pay school fees for their children, buy food and can enhance wealth creation as people are able to buy assets like bicycles and even build houses.

### **Potential for value addition**

There is great potential for the beekeeping business to create sustained linkages with other related enterprises such as candle making, soap making, and pharmaceuticals. This is because after processing the honey, the by-products can be used to make wax which will be used for making candles, polish and other things. In Chikonkomene, two farmers managed to bring their wax to the focus group discussion. While they can sell the wax to other buyer in nearby towns, the farmers noted that they are willing to use their wax to manufacture various products provided they are trained and given adequate support. Jumbe et al. (2008) made similar observations that production and processing technologies for honey and beeswax are still very basic in Zambia and there is a huge potential for improving production levels and value addition. Figure 6 shows a bucket with the wax by-products from the processed honey and a sample of semi processed wax produced from the wastes. It is worth noting that not all beekeepers are utilising the waste materials to form wax. Some throw away the by-products while others sell comb-honey or raw honey.

Apart from supplying raw materials for the manufacturing of other products, beekeeping is also in the Central Province is also important in supplying honey for the highway markers. The interviews with the marketers revealed that selling honey is a lucrative business because they can sell up to five 2.5 L bottles of honey per day. The only challenge the roadside traders are going to face is that their honey is widely condemned for not being pure and improperly processed.

### **Conclusions**

From the findings obtained in this study, it can be concluded that there is great potential for the growth of beekeeping business in the Central province. The potential stems from the zeal and insatiable desire for growth displayed by the majority of farmers. More so the farmers are conscious of the need to protect the forests. In fact, the forests in some of the areas are well protected and conserved. The availability of trees such as miombo also makes the area more conducive for beekeeping. The



**Figure 6.** Unprocessed and semi processed wax (Picture by authors).

study also concludes that beekeeping support in the area, either from the government or the development partners has been erratic leading to the high failure rate of various enterprises at the infant stages. As a result, no single enterprise has managed to grow from a small scale to medium scale enterprises. The majority of farmers are still operating mainly for subsistence purposes, hence the need to explore the growth of the beekeeping industry through the establishment of a business incubator. Consequently, beekeeping has remained a complementary activity to crop farming.

Therefore, with all the hitherto benefits realised by most farmers, and clear signs of potential for growth, beekeeping in the Central remains constrained and poorly supported. It is from this basis, the high potential for the growth of beekeeping and limited support, that the following recommendations are made.

## RECOMMENDATIONS

### **Establishment of business incubation centre at Mulungushi University**

This study recommends the establishment of a business incubation centre at Mulungushi University with special focus on promoting the local communities engaged in beekeeping. The success of business incubation in beekeeping will have ripple effects into other sectors such as biomedical studies, agricultural processes and marketing among others. Philips (2002) correctly observes that incubators are important for universities because they help setting up linkages with the commercial world making it possible for commercialisation of research and transfer of technology.

For the business incubation at Mulungushi to be successful, there is need for an effective administrator who organises support services well. The administrator will perform a number of duties including the identification

and selection of beneficiaries linking them with other key stakeholders such as donors and the relevant government departments.

The established incubator should also offer business services and assistance to the beekeepers. Such services can include marketing strategies, training on packaging and preservation of honey, customer care services and general business management skills. While the School of Agriculture will be running the incubation centre, there is need to work in collaboration with experts from other faculties and departments especially on marketing, and business management. It is argued that availability of management consulting services may be the most critical contribution the incubator can make to put the emerging SMEs on successful tracks.

### **Need for a strong beekeeping association and cooperatives**

For the beekeepers to succeed there is need for a strong beekeeping association. In this regard the ZHC needs to be reorganized in order to strengthen it. A stronger association will be able to push the agenda of its members in such a way that their concerns will no longer be ignored by various key stakeholders. A well organised association is also vital for setting up uniform standards to be followed by all the beekeepers in the country. Cooperation with other development partners and financial supporters can be much easier if there is a properly organised association.

The beekeepers can also organise themselves into working cooperatives that can be vital for improved productivity through shared responsibilities. The Kabule Women Beekeepers Cooperative was cited by the agricultural extension officers at Luashimba as a success story of that can be replicated in other areas. Our visit to Kabule reviewed that the cooperative is making some successes and they have traceable records of their

production and sales. However, their production levels as a cooperative are not impressive when compared to other beekeepers who are operating on individual basis.

### Sustained financial support backed by training

Almost all beekeepers interviewed are indicated that they were in need of support in the area of training. Therefore, there is need to for sustainable financial support anchored by training not only on beekeeping or production but on business management and entrepreneurship skills as well. These supporting services can be sustainable if there is strong working relationship between the beekeepers, Mulungushi University and other stakeholders in beekeeping industry.

### Support in material and infrastructure

Beekeepers pointed out the need for infrastructure development such as apiaries or bee processing houses to enable them standardise the processing of honey. Moreover, most of them lamented over the limitations of traditional beehives and showed quest for modern beehives. Therefore, there is need for various key holders to take keen interest in the beekeeping industry and revamp support activities in material and infrastructure provision to aid in making the beekeeping sector a robust industry.

### Stakeholder convergence

One of the major missing links in the beekeeping industry in Zambia is a well-coordinated approach which can bring all the stakeholders in the industry together. With the convergence of stakeholders, the support given to the beekeepers can be sustainable and possibly uniform without duplication of activities. In addition, the coming together of stakeholders is vital in ensuring that the farmers and technical institutions are consulted and given enough space to make their own contribution. In view of bringing all the stakeholders together, Mulungushi University can play a central role by creating avenues for potential linkages among the key partners and farmers. Some of the key partners that need to be brought on Board are is the Zambian Government particularly the Ministry of Forest, Agriculture, Commerce, Department of Cooperatives, the Citizens Economic Empowerment Commission (CEEC), the Zambia Development Agency and Zambia Bureau of Standards, NGOs, Donor Community and Mulungushi University to mention but a few.

### Processing and branding

Once a strong partnership has been established, it would

be possible to negotiate with the Zambia Bureau of Standards to offer beekeepers lower rates for standardising their products to enable them sell to well establish markets both locally and internationally. The partnerships would also assist beekeepers to find competitive markets both home and abroad.

### CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

# The influence of organic manure formulated from goat manure on growth and yield of tomato (*Lycopersicum esculentum*)

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The influence of organic hydroponic nutrient solution on tomato growth and yield was studied using a randomized complete block design (RCBD) with three treatments (organic nutrient solution, conventional hydroponic fertiliser (as positive control) and plain tap water (as negative control)) replicated three times. Determinate tomato seeds were germinated and transplanted into the 3 treatments. Twenty days after transplanting, vegetative response variables were recorded at fifteen days intervals from each treatment. Vegetative response variables included plant height, number of leaves and stem diameter. The reproductive parameters included number of flowers per plant, number of fruits per plant, average fruit weight (g), yield (kg) per plant and yield (kg) per treatment. Furthermore, the organic nutrient solution formulated from goat manure positively improved plant growth and yield performance of a tomato crop, and provided a technique feasible and alternative to conventional hydroponics. These results open further possibilities for other crops currently grown in hydroponics using conventional fertilisers.

**Key words:** Organic nutrient solution, growth, yield, goat manure, tomato.

## INTRODUCTION

The use of inorganic fertilisers for agriculture is relatively expensive worldwide (Dopler, 1980; Osman et al., 2009) and in particular Africa (Sanchez, 2002). This cost has

been particularly pronounced in hydroponic systems which rely on use of the same expensive inorganic fertilisers. Though hydroponics can be an important crop

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production solution in water limited countries like Namibia, not all communities can afford to practice horticulture using conventional hydroponics. This has been the drawback for many even around Henties Bay where this technology has been demonstrated for years to the local community by Sam Nujoma Marine and Coastal Resources Research Centre (SANUMARC). This situation can partly be addressed by development of cheaper, alternative fertilizers such as using manure for hydroponics.

Generally, organic nutrient solution for hydroponics is a fairly new practice despite the similarities in plant growth when either conventional or organic fertilizer is applied on soil (Liang et al., 2014). It was not until the early 1990s when liquid manures for hydroponics were introduced. Challenges emerged such as organic fertilizer being unsuitable to plant growth (Garland et al., 1997; Liedl et al., 2004), because nitrogen in manure is predominantly organic, hence unusable by plants. The forms of nitrogen absorbed by plants are nitrate and ammonium (Strayer et al., 1997). Therefore, the nitrogen in manure requires to be mineralised prior to use by plants hydroponically. Several studies including Garland et al. (1997) and Shinohara et al. (2011) have demonstrated that using microorganisms to degrade organic nitrogen in organic sources such as manure results in nitrates and ammonium production which in turn are used for plant production.

Therefore, the current study investigated the efficacy of an organic hydroponic nutrient solution on plants' performance. The organic nutrient solution was processed from goat manure using a specialized culture of microbes from natural compost.

## MATERIALS AND METHODS

### Experimental setup

To determine the effect of the organic hydroponic nutrient solution on growth and yield of tomato, hydroponic tables (22.8 × 250 × 150 cm<sup>3</sup>) constructed from planks and black sheeting were used in a greenhouse at the Sam Nujoma Marine and Coastal Research Centre (SANUMARC), Henties Bay. Styrofoam that completely covers the hydroponic tables yet float on water in the table was added. Each hydroponic table covered an area of 3.75 m<sup>2</sup>. A randomized complete block design (RCBD) with three treatments (organic nutrient solution, conventional hydroponic fertiliser (as positive control) and plain tap water (as negative control)) replicated three times in this experiment. Each replicate was a hydroponic table of 6 plants and served as an experimental unit. Organic nutrient solution was formulated in 2016 at SANUMARC, Henties Bay using natural compost containing ammonia and nitrite oxidising bacteria to convert organic nitrogen into nitrates from goat manure. The control treatment was a nutrient solution made from the conventional hydroponic fertilisers; Calcium Nitrate and Hygrotech. The final nutrient solution made from the 2 fertilisers consisted of: Calcium (Ca) 217 mg/L, Nitrate (N) 225 mg/L, Phosphate (P) 46.5 mg/L, Potassium (K) 372 mg/L, Magnesium (Mg) 58 mg/L, and Sulphur (S) 141 mg/L. Organic nutrient solution had Nitrate (N) 198 mg/L, Phosphate (P) 42.1 mg/L, Potassium (K) 360 mg/L, Magnesium (Mg) 67 mg/L, Sulphur (S) 198 mg/L, and Calcium (Ca)

250.

The formulated organic hydroponic nutrient solution was therefore compared with the conventional nutrient solution according to the method by Shinohara et al. (2011) and the negative control. Determinate tomato seeds were germinated on coconut husks in polystyrene trays on 23 February 2017 and transplanted into 3 treatments (conventional fertiliser and organic nutrient solution and plain water) on 24 March, 2017.

Twenty days after transplanting, vegetative response variables were recorded at fifteen days intervals from each treatment (Liu et al., 2014).

### Vegetative growth

Response variables included plant height (cm) measured from the ground to the main apex, number of leaves and stem diameter measured 10 cm above the root level.

### Reproductive growth

The reproductive parameters included number of flowers per plant, number of fruits per plant, average fruit weight (g), yield (kg) per plant and yield (kg) per treatment. In order to determine yield, tomato fruits were picked and weighed when they had reached full maturity at harvest time (Mehdizadeh et al., 2013).

### Statistical analysis

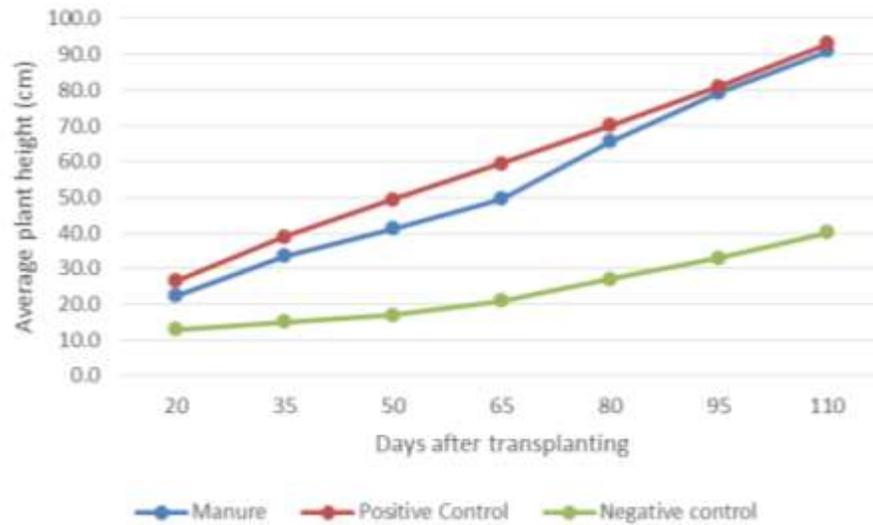
Means comparisons analysis were applied whereby a One-way Analysis of Variance (ANOVA), followed by mean separation by Least Significant Difference (LSD) was used when ANOVA determined that the effects of the treatments were significant ( $p < 0.05$  for F-test).

## RESULTS

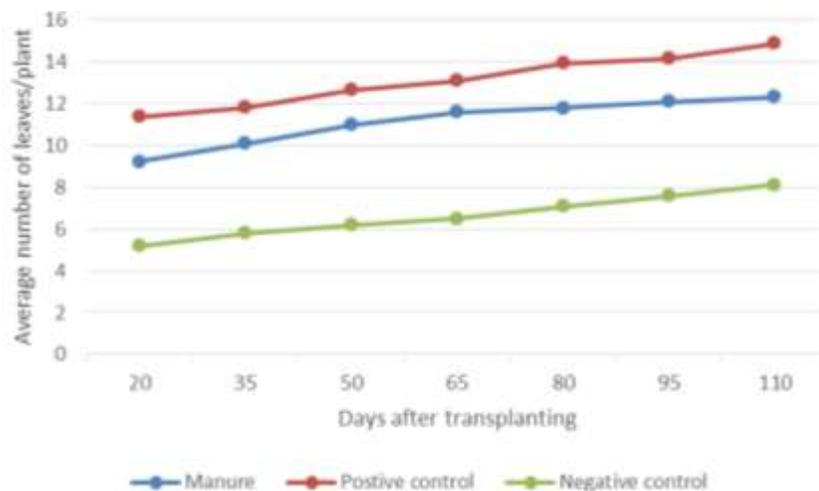
### Vegetative growth

Vegetative plant growth was measured as plant height, number of leaves, and stem diameter. Figure 1 shows that tomato plant height increased over time and was high in plants growing under manure nutrient solution and under the conventional hydroponic fertilisers compared to plants grown under the negative control. ANOVA results indicate that at  $P < 0.05$ , there were significant differences in tomato plant height between the three treatments. The LSD further shows that the significant difference ( $P = 0.000$ ) was between the negative control and the other 2 treatments, whereas there was no significant difference ( $P = 0.249$ ) in plant height between manure nutrient solution and the conventional hydroponic nutrient solution.

Figure 2 shows that vegetative growth in terms of the number of leaves followed the trend: conventional fertiliser nutrient solution, manure nutrient solution, and lastly tap water. Therefore, tomato plants produced more leaves when grown under the conventional hydroponic solution ( $P = 0.009$ ) than under manure nutrient solution which in turn produced more leaves than plants grown



**Figure 1.** Effect of different nutrient solution on growth of tomato plant height.



**Figure 2.** Effect of different nutrient solutions on the number of leaves produced by tomato plants.

under plain tap water ( $P=0.000$ ).

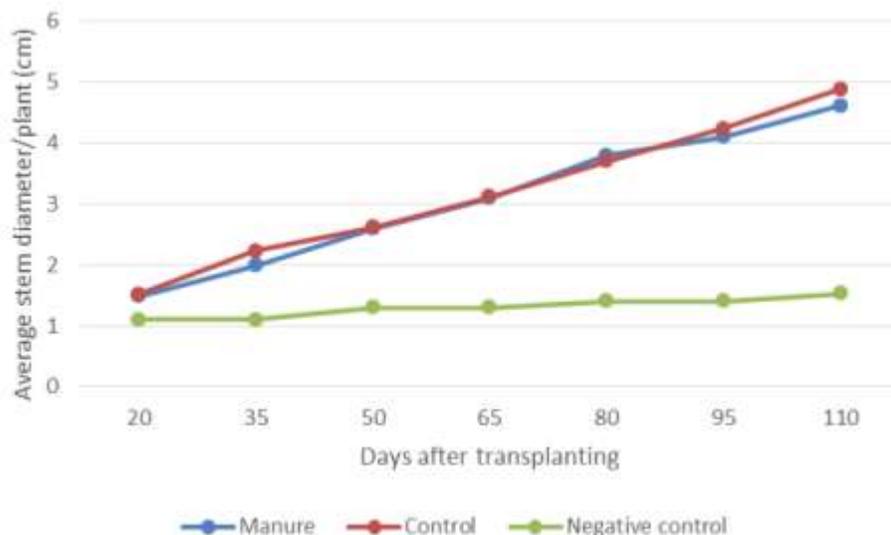
Figure 3 displays that growing tomato plants under manure nutrient solution and conventional nutrient solution increased the plant stem diameter more than when grown under tap water. ANOVA indicates that this difference between the negative control and the other treatments is significant, whereas there is no difference in stem diameter between plants grown under manure nutrient solution and the conventional nutrient solution.

### Reproductive growth

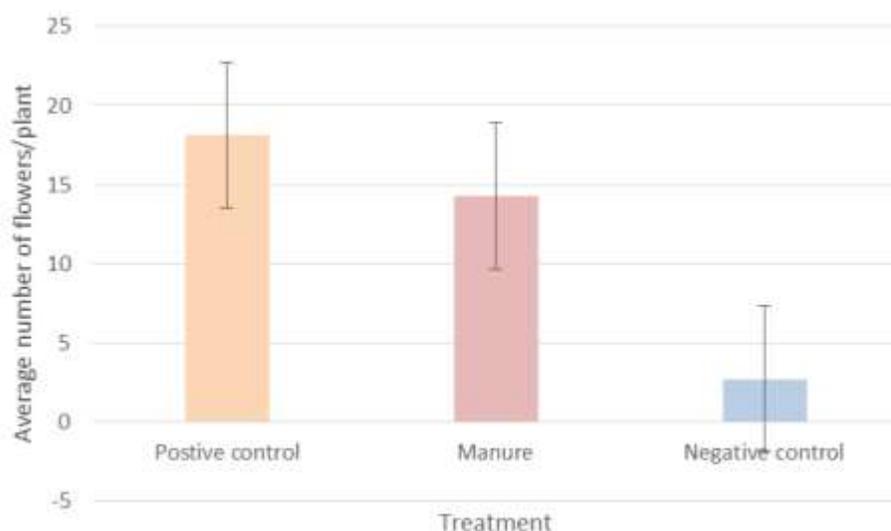
Reproductive plant growth was measured as the number

of flowers, number of fruits, and yield (fruit weight). Figure 4 indicates that tomato plants grown under conventional hydroponic nutrient solution and under manure nutrient solution produced more flowers compared to those grown under tap water. ANOVA shows that this was a significant difference ( $P=0.000$ ) and that there is no significant difference in the number of flowers produced by tomato plants grown under manure and conventional nutrient solution ( $P=0.018$ ).

Figure 5 indicates that there were more fruits produced by tomato plants grown under conventional hydroponic nutrient solution than those grown under manure nutrient solution and tap water. ANOVA results uphold the observed trend in Figure 5, by indicating that these



**Figure 3.** Effect of different nutrient solutions on stem diameter of tomato plants.



**Figure 4.** Average number of flowers produced by tomato plants according to different treatments.

differences are significant ( $P=0.000$ ).

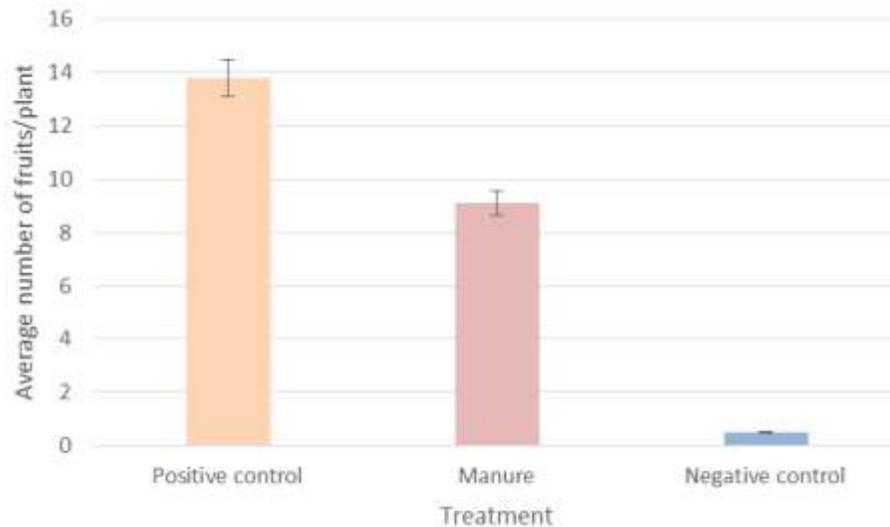
Figure 6 shows that in terms of yield, tomato plants grown under the conventional hydroponic nutrient solution produced more than those grown under manure nutrient solution which in turn, produced more than the plants grown under plain tap water. These are significant differences as provided by ANOVA ( $P=0.000$ )

As shown in Figure 7, the average weight of a single tomato fruit was more from tomato plants grown under conventional nutrient solution and manure nutrient solution compared to fruits from plants grown under plain water. The addition of either manure nutrient solution or

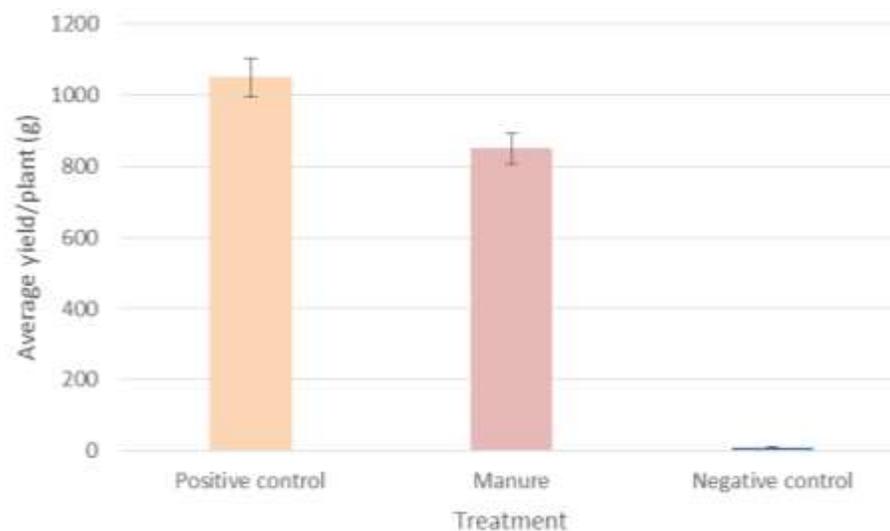
conventional nutrient solution significantly increased the weight of each single tomato fruit compared to when only plain water was used to grow tomato plants hydroponically.

## DISCUSSION

The performance of tomato plants grown in manure nutrient solution was similar to those grown in the conventional nutrient solution and was more than those in the negative control. Similar results have been reported



**Figure 5.** Average number of fruits produced by each tomato plant according to different treatments.



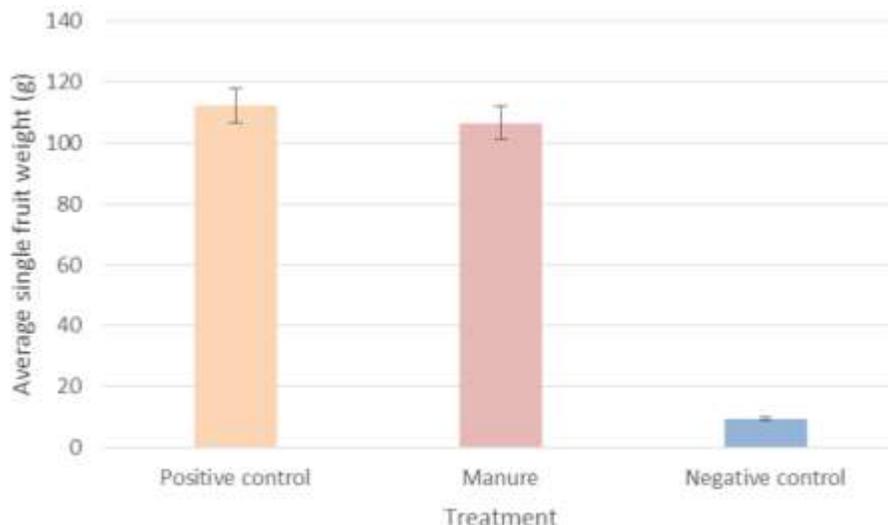
**Figure 6.** Average yield per tomato plant as influenced by different nutrient solution.

for other organic sources of nutrients. Shinohara et al. (2011) reported that tomato vegetative growth in fish-based organic fertiliser mineralised by microorganisms was similar to those in the conventional fertiliser. Kawamura-Aoyama et al. (2014) maintain that vegetative growth can be increased even in other crops such as lettuce when grown in organic nutrient solution degraded by microorganisms. This is because there are sufficient levels of nitrate in nutrient solutions formulated from organic sources such as animal manure, since most vegetable crops prefer nitrate (N) over ammonium (N) (Cruz et al., 2006). As is evident from the current study's levels of nitrate in the organic nutrient solution, it was

sufficient to produce vegetative growth in tomato plants similar to when they were grown under conventional nutrient solution, and significantly more improved more than when plants were grown without the addition of either manure or fertilizer.

These results further suggest that the minimum amounts of other nutrients required for tomato plant growth were sufficient in the organic nutrient solution to result in similar growth patterns as those from the conventional fertilizer.

Reproductive growth was significantly high in tomato plants grown in manure nutrient solution compared to the negative control, though lower than those grown in the



**Figure 7.** Average weight of a single fruit produced by tomato plants as influenced by nutrient solution.

conventional nutrient solution. Differences in fruit yield in tomato plants grown under manure nutrient solution compared to those grown under conventional nutrient solution are most likely due to differences in nitrate and other nutrient levels between the conventional nutrient solution and manure nutrient solution. These results support those of Muñoz et al. (2008) who indicate that nitrate levels in the nutrient solution influence tomato yield, with higher nitrate levels yielding more. Gore and Sreenivasa (2011) uphold that the levels of nitrogen in liquid manure influence the yield of tomato plants, with higher nitrogen levels yielding more. For the current study, conventional nutrient solution had Nitrate (N) 225 mg/L, Phosphate (P) 46.5, Potassium (K) 372 mg/L; in contrast manure nutrient solution had Nitrate (N) 198 mg/L, Phosphate (P) 42.1 mg/L, and Potassium (K) 360 mg/L. This may also be attributed to the result that tomato yield was significantly high in tomato plants grown under manure nutrient solution compared to the negative control where no nitrates and other nutrients were added other than the content in tap water.

These results are also supportive of earlier findings indicating that manures and other organic sources of plant required nutrients indeed provide sufficient nutrients to promote plant growth and yield (Atiyeh et al., 2002; Ojeniyi, 2008; Mehdizadeh et al., 2013; Wilkinson, 1979).

## Conclusion

The organic nutrient solution formulated from goat manure positively improved plant growth and yield performance of a tomato crop, and provided a technique feasible and alternative to conventional hydroponics. This is particularly significant to communities living in

Namibian areas where fertilizer access, water or fertile soil are limiting factors to horticultural production in that locally available waste resources can be added value to and used as the main input for horticultural production.

These results open further possibilities for other crops currently grown in hydroponics using conventional fertilisers and being baseline for Africa in terms of organic hydroponics and provided a foundation for further research in this regard.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

## ACKNOWLEDGEMENTS

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Full Length Research Paper

## Multi-locational evaluation of cooking banana cultivars ‘NARITA 4’ hybrid and ‘Mpologoma’ in Rwanda

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This study assessed the growth and yield of two introduced cooking banana cultivars ‘Mpologoma’ and ‘NARITA 4’ relative to seven local highland cooking cultivars, across three sites in Rwanda, namely Karongi (1496 m a.s.l.), Gatore (1523 m a.s.l.) and Rwinzuki (1671 m a.s.l.). Data were obtained during two cropping cycles (plant crop cycle and the 1st ratoon). Data on pseudostem girth (cm) at 100 cm above the ground was collected at flowering, while number of hands per bunch, number of fingers of the second lowest hand and bunch weight (kg) were obtained at bunch harvest. Significant differences for all assessed growth and yield parameters were observed between cultivars ( $p < 0.001$ ). Generally, the two exotic cultivars ranked high with respect to number of fingers on the second lowest hand and number of hands per bunch. ‘Mpologoma’ had the largest bunch with a mean bunch weight of 23 kg, whereas ‘NARITA 4’ had a bunch weight of 17 kg which was comparable to the local cultivars. Thus, these 2 cultivars could potentially be adopted by farmers.

**Key words:** Banana germplasm, local cultivars, plant crop, ratoon crop.

### INTRODUCTION

*Musa* spp. (banana and plantain) is a major staple food crop, source of income and employment for millions of people, and it is cultivated in up to 130 countries, mainly in the tropical and sub-tropical regions (FAOSTAT, 2017).

Banana and plantain are grown under various types of cropping systems over a harvested area of approximately 10 million hectares worldwide, with an annual production of 144.8 million tons (Mt) (FAOSTAT, 2017). The vast

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majority of producers are small-scale farmers who grow the crop either for home consumption or for sale in local markets. The banana fruit is eaten cooked as a vegetable or ripe as a fruit, and it is also used to produce beer and wine (Rishirumuhirwa, 2010). Besides being a cheap and easily produced source of energy, it is also a good source of vitamins A, C, B6 and minerals, such as potassium (Davey et al., 2007; Ekesa et al., 2013). Rwanda with an annual per capita consumption of 258 kg (Jagwe et al., 2008) and production of 1.8 Mt (FAOSTAT, 2017), ranks among the top banana producers in the world.

Like the entire African Great lakes region, the most common and economically important cultivars in Rwanda belong to the East African highland banana group (*Musa* AAA-East Africa [-EA] genome) and are mainly used for cooking and beer/wine production (Karamura et al., 1998; Ocimati et al., 2013, 2016). East African highland banana plants grow and perform well at altitudes ranging from 1000 to 2000 m above sea level (m a.s.l.) (Karamura et al., 1998). Nevertheless, Rwanda has experienced declines in banana diversity and production in the past decades due to several factors including social unrest/insecurity, land/population pressure, pests and diseases (such as *Fusarium* wilt and *Xanthomonas* wilt of banana), and declining soil fertility (Okech et al., 2002; Nsabimana and van Staden, 2005; Ocimati et al., 2014). Increasing the diversity of banana germplasm through the introduction of high-yielding conventionally bred hybrids and other commercial cultivars/landraces forms an integral part of technology packages for improving banana diversity and production in the central African region.

In this study, the performance of two exotic cooking banana cultivars, namely 'Mpologoma' and 'NARITA 4' hybrid were evaluated against seven local cooking cultivars. Assessment of the *Musa* cultivars was carried out across three sites/agro-ecosystems in Rwanda. 'Mpologoma' is a high yielding AAA-EA cooking cultivar with a high market value/demand in neighboring Uganda, while 'NARITA 4' is a promising highland cooking banana hybrid bred by the International Institute of Tropical Agriculture (IITA) and the National Agricultural Research Organization (NARO) of Uganda for resistance to black leaf streak and high yield. Depending on the growth and yield performance under Rwandese agro-ecological conditions, these cultivars could potentially provide an additional source of high quality germplasm/seed for higher farm productivity and household income.

## MATERIALS AND METHODS

Banana germplasm evaluations were carried out between April, 2007 and March, 2011 at three different sites in Rwanda, namely Karongi (S 2° 5' 29"; E 29° 23' 3"; 1496 m a.s.l.), Gatore (S 2° 16' 44"; E 30° 34' 37"; 1523 m a.s.l.) and Rwinzuki (S 2° 39' 2"; E 28° 55' 36"; 1671 m a.s.l.), with varying altitude, soil fertility and rainfall (Table 1).

Karongi is located in the Lake Kivu border agricultural zone of

Rwanda, with good to excellent soil and climate conditions for agricultural production, while Gatore and Rwinzuki are located in the Eastern plateau and Impara agro-ecological zones, respectively. All three sites possess conducive conditions for banana production. A detailed description of the site's agro-ecological characteristics is provided in Table 1. The geographical coordinates of each experimental site were recorded using a GARMIN Geographical Positioning System (GPS).

Seven East African highland cooking banana (*Musa* AAA-EA) landraces from Rwanda, one AAA-EA landrace from Uganda (but grown on a limited scale in Rwanda at the time of the trial) and an East African AAA-EA secondary triploid hybrid (Table 2) were planted and evaluated at each of the three sites. The IITA/NARO hybrid ('NARITA 4') was multiplied at the Phytolabu tissue culture (TC) laboratory in Bujumbura, Burundi, while sword suckers (lateral shoots with lanceolate type leaves and a pseudostem length of 80 to 120 cm) sourced from well-managed and disease-free fields were used for the 8 landraces. It was assumed that the differences in the planting material types would not significantly affect subsequent plant growth and yield. The TC-derived plantlets were hardened (acclimatized) over three months (until they were on average, 30 cm high and had at least 3 to 4 functional green leaves) before planting. In contrast, the sword suckers with the remaining 30 cm long pseudostem section were pared (all cord roots and outer corm tissue were removed using a machete) and treated with hot water to eliminate all pests. The treated suckers were planted with a small portion (15 cm) of the pseudostem sticking above the ground.

Fifteen plants of each cultivar (in 3 reps of 5 plants) were planted at each experimental site. Plants were spaced at 3 × 2 m (in a rectangular design), giving a total of 1,667 plants/ha. A randomized complete block design comprising 3 blocks with one replicate (of 5 plants) for each cultivar was used. The overall experimental field at each of the 3 sites was 810 m<sup>2</sup> large. The size of the planting hole was 60 × 60 × 60 cm and 10 kg of decomposed cow manure was applied in each planting hole at planting. No additional manure was applied during the growth period of the plants. Weeding was carried out at 3-month intervals, while de-suckering (the removal of all excess lateral shoots) and de-trashing of dead/dried leaves was practiced on a case-by-case basis. Three plants were kept per mat (parent, first ratoon (or daughter sucker) and second ratoon (or granddaughter sucker)). A mat comprises of physically interconnected/attached shoots. Mulching was carried out at the beginning of each dry season (in December and June). Where necessary, forked wooden poles were used to support mature plants with heavy bunches to prevent plant toppling (a plant getting uprooted due to the weight of the bunch, leading to loss of a bunch) and doubling (the pseudostem of a plant breaking due to weight of the bunch).

Banana growth and yield data were obtained during two cropping cycles (that is, plant crop cycle and 1<sup>st</sup> ratoon crop). Data on pseudostem girth (cm) at 100 cm above the ground were collected at flowering stage (bunch emergence) of each cropping cycle, while number of hands per bunch, fingers of the second lowest hand and bunch weight (kg) were obtained at bunch harvest during each cropping cycle. Mature bunches were harvested when the fingers of the second lowest hand had attained a round shape.

Data are presented as means across the two cropping cycles, in order to eliminate seasonal effects. Statistical analysis was carried out using GenStat 11<sup>th</sup> Edition (VSN International Ltd, 2008). Means were separated using the least significant difference at 5%.

## RESULTS AND DISCUSSION

Significant differences ( $p < 0.001$ ) in pseudostem girth (cm) at 100 cm height, measured at plant flowering,

**Table 1.** Altitude, rainfall, soil characteristics and agricultural value of the agricultural zones where the *Musa* germplasm field evaluations were carried out.

Trial site	Agro-ecological zone	Altitude (m a.s.l.)			Rainfall (mm)			Soil characteristics	Agricultural value
		Min	Average	Max	Min	Average	Max		
Rwinzuki	Impara	1,400	1,700	1,900	1,300	1,400	2,000	Very fine, red, basalt	Good
Karongi	Lake Kivu border	1,460	1,600	1,900	1,150	1,200	1,300	Shallow, clay loam	Good-excellent
Gatore	Eastern plateau	1,400	1,500	1,800	900	950	1,000	Laterite soil	Moderate-good

Source: Verdoodt and Van Ranst (2003).

**Table 2.** Cultivar name, clone set, genome or sub-group and use.

Cultivar name	Cultivar/hybrid	Clone set	Subgroup (Genome group)	Use
Ingagara	Landrace	Nakitembe	AAA-EA	Cooking
Ingaju	Landrace	Nfuuka	AAA-EA	Cooking
Ingarama	Landrace	Mutika/Lujugira	AAA-EA	Cooking
Injagi	Landrace	Musakala	AAA-EA	Cooking
Intariho	Landrace	Nfuuka	AAA-EA	Cooking
Kisansa	Landrace	Musakala	AAA-EA	Cooking
Mbwazirume	Landrace	Nakitembe	AAA-EA	Cooking
Mpologoma	Landrace (introduced from Uganda)	Musakala	AAA-EA	Cooking
NARITA 4	Secondary triploid hybrid	Cross from Enzirabahima, Nfuuka clone set	AAA-EA	Cooking

**Table 3.** Mean plant pseudostem girth (cm), number of fingers on the second lowest hand on the bunch, number of hands per bunch and bunch weight (kg) for 9 cooking banana cultivars assessed at 3 trial sites and over two growth cycles in Rwanda between 2007 and 2011.

Cultivar	Mean pseudostem girth at 100 cm height (cm)	Mean number of fingers on the second lowest hand of the bunch	Mean number of hands per bunch	Bunch weight (kg)
Ingagara	53.6±1.0	7.9±0.1	7.5±0.2	15.9±0.7
Ingaju	58.0±0.8	8.3±0.1	7.8±0.1	17.6±0.7
Ingarama	53.1±1.2	7.8±0.2	7.6±0.2	14.6±0.9
Injagi	58.0±0.9	8.0±0.1	7.8±0.1	19.2±0.7
Intariho	50.5±1.0	7.6±0.2	7.1±0.2	14.6±0.8
Kisansa	52.7±1.1	7.7±0.1	7.4±0.2	15.4±0.8
Mbwazirume	50.3±0.9	7.7±0.1	7.0±0.1	15.1±0.7
Mpologoma	58.1±0.9	8.5±0.1	8.1±0.1	22.8±0.7
NARITA 4	50.7±1	8.7±0.1	8.6±0.2	16.7±0.8
Lsd (5%)	2.3	0.3	0.4	1.8
Cv%	12.1	11.3	13.2	27.6
P value	<0.001	<0.001	<0.001	<0.001

mean number of fingers on the second lowest hand of the bunch, number of hands per bunch and bunch weight (kg) were observed between the cultivars. 'Mpologoma' had pseudostem sizes comparable to the best performing local landraces. In contrast, 'NARITA 4' had a small-sized pseudostem compared to the other cultivars (Table 3). The introduced cultivars 'NARITA 4' (with 8.7 fingers and

8.6 hands) and 'Mpologoma' (with 8.5 fingers and 8.1 hands) were significantly superior to the local landraces evaluated in this study in terms of the mean number of fingers on the second lowest hand and hands on the bunch (Table 3). 'Mpologoma' with an average bunch weight of 23 kg was the best performer among the 9 banana cultivars.

In contrast, the average bunch weight for 'NARITA4' was 17 kg, though comparable with most local cultivars (Table 3). Therefore, both exotic cooking cultivars produced acceptable bunches. As bunch size and market demand are important criteria in the selection of cooking cultivars for cultivation in Rwanda by farmers (Ocimati et al., 2014), 'Mpologoma' and even 'NARITA4' have a high chance to be adopted by farming communities.

## Conclusion

'Mpologoma' performed as good as or better than the best local cooking cultivars, while 'NARITA4' performed better than half of the local cultivars. Considering the important shift from beer to cooking and dessert types in Rwanda, these 2 exotic cooking cultivars have the potential for wide-spread adoption. Additional organoleptic/taste panel assessments should however be carried out with various farming communities before embarking on large-scale multiplication and distribution efforts.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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## Full Length Research Paper

# Slaughter performance and meat quality of intact and castrated Washera sheep kept under feedlot condition

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A study was conducted to evaluate the feedlot performance in carcass traits and meat quality of intact and castrated Washera sheep under low (300 g/day) and high (450 g/day) dry matter (DM) levels of concentrate mix supplementation. The concentrate mix contained 68% wheat bran and 32% noug seed cake. 24 sheep (12 intact and 12 castrated) with age range of 9 to 10 months and initial weight of  $24.1 \pm 1.8$  kg (mean  $\pm$  SD) were used. A randomized complete block design in a 2x2 factorial treatment arrangement (2 sex category and 2 concentrate levels) was employed. Basal hay was fed *ad libitum* at a rate of 20% refusal. After 90 days of fattening, all sheep were slaughtered and meat sample from *longissimus dorsi* muscle of each animal was taken for color and pH measures, and chemical composition analysis. High level supplementation promoted significantly ( $p < 0.001$ ) higher carcass weights, dressing percentage in slaughter body weight (SBW) basis, rib eye-muscle (REM) area, fat thickness (FT), carcass compositions and higher ( $p < 0.05$ ) total edible offal component than low supplementation level. Intact sheep attained higher ( $p < 0.05$ ) SBW (29.4 vs 28.2 kg); empty body weight (23.7 vs 22.9 kg), and produced relatively more carcass yield with higher ( $p < 0.001$ ) muscle, but lower fat composition than castrates. Castrated sheep produced significantly ( $p < 0.01$ ) higher total non carcass fat (0.65 vs 0.46 kg) than intact sheep. Meat from intact sheep comprised of higher ( $p < 0.01$ ) moisture (73.63 vs 72.43%) with lower fat composition (2.06 vs 3.16%) and was less ( $p < 0.05$ ) luminous ( $L^*$ ) in color (34.56 vs 36.63) than castrated sheep. It is concluded that fattening of intact Washera sheep with high level of concentrate supplementation is a better option for production of more carcasses yield with higher proportion of muscle and less fat.

**Key words:** Carcass composition, dressing percentage, meat color, proximate compositions.

## INTRODUCTION

Meat production is the most important function of sheep in Ethiopia. As a result the demands for meat from sheep in the country particularly during religious festivals are very high (Amha, 2008). Farmers usually try to manipulate growth of small ruminants through several

means such as breeding, nutrition, and castration to increase meat production and maximize income.

Castration is an important on-farm management practice performed by sheep producers in Ethiopia. The prominent reasons for castration include reducing

aggression and sexual activity, easier and safer handling, management flexibility to finish lambs to meet market specifications under variable seasonal conditions, and more importantly for the production of improved meat quality related to carcass composition and weight development (Alemu, 2008; Sheep Standards and Guidelines Writing Group (SSGWG), 2013).

However, the appropriate age of castrating sheep for fattening in Ethiopia appears not to be clearly defined (Getachew and Wamatu, 2014). Ideally, castration should be done at the youngest age possible, usually less than 3 weeks of age (Alemu, 2008); if it is late, before 12 weeks old (SSGWG, 2013) as the stress of castration can adversely affect growth in older animals. But, under Ethiopian conditions this is not usually the case and many farmers prefer to castrate male sheep at a later age; in most cases after sexual maturity is attained, mainly from yearling to 2 years old (Alemu, 2008). Similarly, Washera sheep producing farmers in Northwestern Ethiopia believe that rams mature, finish their growth and fetch good price when they are castrated at the late age (Mengistie et al., 2010).

Apart from the big variations among different meat animal species in the production of carcass yield or dressing percentage and quality of meat, there is also gender effect (male, female and castrate) which is mainly related to the quantity of fat deposited, deposition site, growth rate and carcass yield (Guerrero et al., 2013).

Many studies have been published in relation to carcass characteristics of various indigenous sheep breeds in Ethiopia mainly for growing male sheep. Despite the very long traditional activity of sheep producing society in castrating sheep and fattening for economic and social values in Amhara region (Mengistie et al., 2010; Yenesew et al., 2013), no comparative performance evaluation study between intact and castrated Washera sheep is available. Therefore, the present study was designed to fill this gap with the objectives of evaluating the difference in carcass and non-carcass characteristics, and meat quality of intact and castrated Washera sheep kept under feedlot condition.

## MATERIALS AND METHODS

### The study area

The study was conducted at Burie, Debre Markos University campus, which is situated at latitude 10°42' North and longitude 37°4' East and at an altitude of 2091 meters above sea level. The area features a semi-humid climate with relatively cool temperatures. The average minimum and maximum annual

temperature of the area are 14 and 24°C, respectively. It has unimodal rainfall pattern with annual precipitation of 1000 to 1500 mm, the bulk of which occurs from May to September (IPMS, 2007).

### Experimental animals and managements

A total of 24 male Washera sheep of about 8 to 10 months of age were purchased from the local market and used for the experiment. The age of the animals was estimated by the pattern of eruption of the incisor teeth (Solomon and Kassahun, 2009), and the information obtained from the owners.

In the experimental site, the sheep were quarantined for 21 days in order to observe their health condition, and vaccinated for sheep pox and injected with 20% oxy-tetracycline for treatment of Pasteurellosis. Ivermectin was injected as a broad spectrum treatment against internal and external parasites. They were also de-warmed with Albendazole mainly against the adult stages of internal parasites. During the third week of the quarantine period, twelve of the twenty four rams were castrated using Burdizzo clamp method. Then all animals were left grazing for about 45 days to help the castrated animals recover from the stress of castration.

After the recovery period, sheep within the same sex were blocked into six groups of two sheep each based on their initial weights and randomly assigned to treatments (six animals per treatment) and well-ventilated individual pens equipped with watering and feeding troughs. The sheep were acclimated to the pen environment and experimental condition for about two weeks, which was followed by 90 days of fattening/feeding trial.

### Experimental design and treatments

The experiment was arranged in a randomized complete block design with 2x2 factorial arrangements (two sex categories (castrated and intact sheep) and two concentrate levels). The experiment feeds consisted of mixed sward natural pasture hay as a basal diet and concentrate mix as a supplement. The hay was manually chopped to about 2.5 cm sizes and fed *ad lib* ensuring a refusal of 20%, and the amount of offer was adjusted once every third day. Animals were supplemented with either low (300 g DM/day/head) or high (450 g DM/day/head) level of concentrate mix. The concentrate diet was introduced gradually over the two weeks of acclimation period until the total daily offer reached the end of the acclimation period.

The levels of concentrate were designed on the basis of recommended levels used in earlier works to evaluate fattening potential of Washera sheep (Tesfaye et al., 2011). The concentrate mix composed of 68% wheat bran (WB) and 32% noug seed cake (NSC) and was formulated to have about 22% crude protein (CP) (Table 1) to fulfill the nutrient requirements of growing lambs based on the recommendations by Kearn (1982). The concentrate was offered twice a day in two equal portions at 0800 and 1600 h. Clean water and salt lick were available all the time throughout the experimental period.

### Slaughter of animals and carcass measurements

At the end of the 90 days fattening period, all animals were

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**Table 1.** Chemical composition (% for DM and % of DM for others) of experimental feeds.

Experimental feed	DM	OM	Ash	CP	NDF	ADF	ADL
Hay	92.1	90.0	10	7.9	72.2	46.5	10.1
Wheat bran (WB)	90.8	89.7	10.3	18	44.1	14.4	8.1
Noug cake (NSC)	92.2	91.9	8.1	31.8	34.9	28.2	10.9
Concentrate mix	90.9	91.7	8.3	21.6	41	15.5	8.7

Note: DM = Dry matter; OM = Organic matter; CP = Crude protein; NDF = Neutral detergent fiber; ADF = Acid detergent fiber; ADL = Acid detergent lignin; Concentrate Mix = 32% NSC + 68% WB.

withdrawn from feed overnight with free access to water, and slaughtered after recording slaughter body weight (SBW). The blood was drained into a bucket and weighed. After the removal of digestive tract and non-carcass components, hot carcass weight (HCW) was recorded including tail fat.

Edible and non-edible offal components and all non-carcass fat depots (kidney, omental and mesenteric fats) were weighed and recorded. The weight of the digestive tract was recorded while full and empty thus, weight of gut-content was computed as the difference between digestive tract weights while full and empty. Empty body weight (EBW) was determined as SBW less gut contents. Dressing percentage (DP) was calculated as  $(HCW/SBW) \times 100$  and  $(HCW/EBW) \times 100$ . Rib eye-muscle area (REM) and fat thickness (FT) were measured at the 12/13<sup>th</sup> rib position using transparent paper and plastic ruler, respectively.

The left and right REM area were traced onto a square paper which was placed on the transparency, and the area of the squares (0.25 cm<sup>2</sup> each) that fell within the traced area was measured and those partially outside was estimated; thus the average of the two sides was taken as the REM area. After the tail of each carcass was removed and recorded, the whole carcass was split into two halves (left and right) along the dorsal mid-line with a band saw, and the left half of each carcass was kept in a cold (4 to 5°C) room for 24 h. The cold carcass weight (CCW) was recorded for each and dissected into muscle, bone and fat (subcutaneous and intermuscular) to determine carcass composition. Water loss of the carcass was determined as shrink loss.

#### Chemical analysis of feed

Representative samples of feeds and hay refusals were dried at 60°C for 72 h. The dried samples were ground using laboratory mill to pass through 1 mm screen, and stored for subsequent analyses of dry matter (DM), crude protein (CP), ash (AOAC, 1990), acid detergent fiber (ADF), neutral detergent fiber (NDF) and acid detergent lignin (ADL) (Van Soest and Robertson, 1985). The CP was calculated as  $N \times 6.25$ .

#### Proximate chemical analysis of meat

Meat samples were taken from longissimus dorsi muscle (LDM) at 10 to 13<sup>th</sup> rib positions, chopped and thoroughly mixed and frozen at -20°C until partially dried. The frozen fresh samples were partially dried at 55°C for 72 h, packed in polyethylene bags and stored in a refrigerator at 4°C pending proximate chemical analysis. About 2 g of partially dried samples were weighed into a pre-weighed crucible dish, and dried in an oven at 102°C overnight to determine percentage of DM. Ashing was carried out at 600°C for 6 h. Total fat was extracted using Soxhlet apparatus for 6 h with diethyl ether (boiling point of 34.5°C), and the dried residue was weighed for fat content. Crude protein was determined by Kjeldahl procedure

(AOAC, 1990).

#### Meat pH and color measurements

Trimmed meat samples taken from areas of LDM for proximate composition analysis were used for pH and color measurements. The pH measurements were made 1 and 24 (ultimate) h after slaughter using portable pH-meter (Meat PH meter-HI99163, HANAN instruments) having sharp penetrating electrode. The probe was cleaned with distilled water and calibrated with pH 4.1 and 7.1 standard buffer solutions between sample measurements. For met color measurements, the cut surface of frozen samples at 4°C were freshly exposed on flat surface of white background in the measuring room, and allowed to bloom for about 30 to 45 min at ambient temperature. Then, meat color parameters that is, CIE L\*a\*b\* values (L\*=lightness, a\*=redness and b\*=yellowness) were obtained using the digital colorimeter (HunterLab MiniScan EZ, Serial No. MsEZ1547, 45/0° illumination/viewing system, D65 light source, and 10° observer angle) calibrated with black and white standardized calibration plates between sample measurements (AMSA, 2012). Three random readings at different locations per sample were taken and averaged.

#### Statistical analysis

Data was analyzed using the general linear model GLM procedure of SAS (SAS, 2003). Adjusted Tukey test was used to locate the significant differences between means when F-test declare significance at  $p < 0.05$ . The statistical model used was:

$$Y_{ijkl} = \mu + B_i + S_j + C_k + (S \times C)_{jk} + \epsilon_l$$

Where:  $Y_{ijkl}$  = the response variable;  $\mu$  = overall mean;  $B_i$  = effect of block;  $S_j$  = effect of sex;  $C_k$  = effect of concentrate level;  $(S \times C)_{jk}$  = interaction between sex of sheep and concentrate level, and  $\epsilon_l$  = random error.

Since interaction between sex and concentrate level for all attributes evaluated were not statistically significant ( $p > 0.05$ ), only means for main effects were presented and discussed.

## RESULTS

### Carcass yield and carcass characteristics

Intact sheep had about 4% higher ( $p < 0.05$ ) SBW and EBW than castrates, but there was no difference ( $p > 0.05$ ) in HCW and CCW weights, DP and other carcass attributes between the two sex (Table 2). Unlike sex effect, almost all carcass characteristics were significantly

**Table 2.** Carcass yield and carcass characteristics of intact and castrated Washera sheep fed grass hay basal diet supplemented with two levels of concentrate mix.

Parameter	Sex category (S)			Concentrate level (C)			SEM
	Intact	Castrate	p-value	Low	High	p-value	
Number of sheep	6	6	-	6	6	-	-
SBW (kg)	29.4 <sup>a</sup>	28.2 <sup>b</sup>	0.008	28.1 <sup>b</sup>	29.5 <sup>a</sup>	<.001	0.27
EBW (kg)	23.7 <sup>a</sup>	22.9 <sup>b</sup>	0.028	22.5 <sup>b</sup>	24.1 <sup>a</sup>	<.001	0.24
HCW (kg)	12.7	12.3	0.257	12.0 <sup>b</sup>	13.1 <sup>a</sup>	0.001	0.19
CCW (kg)	12.2	11.8	0.271	11.5 <sup>b</sup>	12.5 <sup>a</sup>	0.001	0.18
Shrink (kg)	0.53	0.51	0.10	0.49 <sup>b</sup>	0.55 <sup>a</sup>	<.001	0.01
Dressing percentage							
EBW basis	53.3	53.9	0.463	53.2	54.0	0.266	0.54
SBW basis	43.1	43.8	0.288	42.7 <sup>b</sup>	44.2 <sup>a</sup>	0.019	0.44
REM area (cm <sup>2</sup> )	9.9	8.6	0.051	8.4 <sup>b</sup>	10.3 <sup>a</sup>	0.002	0.40
FT (mm)	5.2	5.3	0.710	4.9 <sup>b</sup>	5.5 <sup>a</sup>	0.003	0.12

<sup>a,b</sup>Means with different superscript letter within sex category and diet in the same row differ significantly ( $p < 0.05$ ); Low = 300 g/d concentrate mix; High = 450 g/d concentrate mix; SEM = Standard error of mean; SBW = Slaughter body weight; EBW = Empty body weight; HCW = Hot carcass weight; DP = Dressing percentage; FT = Fat thickness; REM = Rib eye muscle.

**Table 3.** Carcass composition of intact and castrated Washera sheep fed grass hay basal diet supplemented with two levels of concentrate mix.

Parameter	Sex category (S)			Concentrate level (C)			SEM
	Intact	Castrate	p-value	Low	High	p-value	
Carcass composition (kg)							
Muscle	6.85 <sup>a</sup>	6.12 <sup>b</sup>	0.002	6.41	6.56	0.499	0.15
Fat	1.45 <sup>b</sup>	1.66 <sup>a</sup>	0.002	1.44 <sup>b</sup>	1.67 <sup>a</sup>	0.001	0.04
Bone	2.89 <sup>b</sup>	3.08 <sup>a</sup>	0.001	2.73 <sup>b</sup>	3.13 <sup>a</sup>	<.001	0.05
Tail fat	1.0	0.99	0.943	0.89 <sup>b</sup>	1.11 <sup>a</sup>	0.022	0.06
Carcass composition (%)							
Muscle	56.7 <sup>a</sup>	51.7 <sup>b</sup>	<.001	52.6 <sup>b</sup>	55.8 <sup>a</sup>	<.001	0.41
Fat	11.6 <sup>b</sup>	13.9 <sup>a</sup>	<.001	12.5 <sup>b</sup>	13.4 <sup>a</sup>	0.003	0.17
Bone	23.3 <sup>b</sup>	25.9 <sup>a</sup>	<.001	23.8 <sup>b</sup>	25.1 <sup>a</sup>	<.001	0.21
Tail fat	8.3	8.5	0.840	7.9 <sup>b</sup>	8.9 <sup>a</sup>	0.015	0.49

<sup>a,b</sup>Means with different superscript letter within sex category and diet in the same row differ significantly ( $p < 0.05$ ); Low = 300 g/d concentrate mix; High = 450 g/d concentrate mix; SEM = Standard error of mean.

( $p < 0.01$ ) affected by supplement levels. Sheep that consumed high level of concentrate supplement had heavier carcass (HCW and CCW) weights, were better in DP on basis of SBW, and had higher REM and FT than those supplemented in the low level.

### Carcass composition

The effects of sex and concentrate level were significant for majority of the carcass composition parameters (Table 3). Carcasses obtained from sheep that consumed high level of concentrate had higher ( $p < 0.01$ ) fat, bone and tail

fat weight. When computed on percentage basis, all carcass compositions were higher ( $p < 0.001$ ) for high concentrate level. On the other hand, intact sheep had significantly ( $p < 0.01$ ) higher muscle, but lower fat and bone compositions.

### Edible and non-edible offal components

Among edible offal components, blood and intestine were higher in intact than castrates, while fats from omental and mesenteric areas, and total non-carcass fat (TNCF) were higher ( $p < 0.01$ ) for castrates (Table 4). Heart,

**Table 4.** Edible offal components of intact and castrated Washera sheep fed grass hay basal diet supplemented with two levels of concentrate mix.

Edible offal (kg)	Sex category (S)			Concentrate level (C)			SEM
	Intact	Castrate	p-value	Low	High	p-value	
Blood	1.15 <sup>a</sup>	1.02 <sup>b</sup>	0.049	1.05	1.12	0.256	0.04
Heart	0.11	0.12	0.254	0.10 <sup>b</sup>	0.12 <sup>a</sup>	0.002	0.01
Kidney	0.07	0.08	0.215	0.06 <sup>b</sup>	0.08 <sup>a</sup>	0.027	0.01
Liver	0.41	0.38	0.380	0.33 <sup>b</sup>	0.46 <sup>a</sup>	0.002	0.03
Empty Stomach	0.74	0.73	0.660	0.71 <sup>b</sup>	0.76 <sup>a</sup>	0.019	0.01
Intestine	0.74 <sup>a</sup>	0.68 <sup>b</sup>	0.018	0.68 <sup>b</sup>	0.74 <sup>a</sup>	0.033	0.02
Head & tongue	1.59	1.48	0.208	1.55	1.53	0.812	0.07
Heart fat	0.04	0.05	0.359	0.04	0.05	0.124	0.01
Kidney fat	0.07	0.09	0.367	0.08	0.07	0.518	0.01
Omenetal fat	0.12 <sup>b</sup>	0.21 <sup>a</sup>	0.001	0.15	0.16	0.770	0.01
Mesenteric fat	0.17 <sup>b</sup>	0.24 <sup>a</sup>	0.007	0.20	0.21	0.696	0.02
TNCF	0.46 <sup>b</sup>	0.65 <sup>a</sup>	0.002	0.54	0.57	0.625	0.04
TEO	5.21	5.04	0.252	4.97 <sup>b</sup>	5.28 <sup>a</sup>	0.046	0.10

<sup>a,b</sup>Means with different superscript letter within sex category and diet in the same row differ significantly ( $p < 0.05$ ); Low = 300 g/d concentrate mix; High = 450 g/d concentrate mix; SEM = Standard error of mean; TNCF = Total non carcass fat; TEO = Total edible offal.

**Table 5.** Non-edible offal components of intact and castrated Washera sheep fed grass hay basal diet supplemented with two levels of concentrate mix.

Non-edible offal (kg)	Sex category (S)			Concentrate level (C)			SEM
	Intact	Castrate	p-value	Low	High	p-value	
Lung	0.25	0.24	0.557	0.23 <sup>b</sup>	0.26 <sup>a</sup>	0.007	0.01
Trachea	0.08	0.10	0.065	0.08	0.10	0.051	0.01
Esophagus	0.04	0.05	0.374	0.04	0.05	0.142	0.003
Spleen	0.07 <sup>a</sup>	0.05 <sup>b</sup>	0.003	0.05 <sup>b</sup>	0.07 <sup>a</sup>	0.003	0.003
Testicle	0.36 <sup>a</sup>	0.15 <sup>b</sup>	<.001	0.23 <sup>b</sup>	0.27 <sup>a</sup>	0.027	0.012
Penis	0.06 <sup>a</sup>	0.04 <sup>b</sup>	<.001	0.05	0.05	0.936	0.004
Skin and legs	3.77 <sup>a</sup>	3.43 <sup>b</sup>	0.019	3.58	3.62	0.751	0.089
Gut content	5.61	5.26	0.200	5.53	5.34	0.496	0.186
TNEO	10.26 <sup>a</sup>	9.35 <sup>b</sup>	0.005	9.82	9.79	0.904	0.188

<sup>a,b</sup>Means with different superscript letter within sex category and diet in the same row differ significantly ( $p < 0.05$ ); Low = 300 g/d concentrate mix; High = 450 g/d concentrate mix; SEM = Standard error of mean; TNEO = Total non-edible offal.

kidney, liver, empty stomach and intestine produced from sheep consumed high level concentrate were heavier than sheep fed low level ( $p < 0.05$ ). Although the effects of concentrate levels on the weight of individual edible offal components were inconsistent, total edible offal (TEO) was higher for sheep that consumed high level of concentrate. As depicted in Table 5, the effect of sex was found to be significant for some of non-edible offals (spleen, testicle, penis and skin and legs) and TNEO ( $p < 0.01$ ), where intact sheep had higher values than castrates. On the other hand, level of supplement affected ( $p < 0.01$ ) the weights of lung, spleen and testicle with higher values for the high level of supplement. The

weight of trachea tended to be higher for castrate ( $p = 0.065$ ) with high supplement level ( $p = 0.051$ ).

#### Proximate chemical composition of meat

There were significant ( $p < 0.01$ ) variations between meat from castrate and intact sheep in its moisture and fat contents (Table 6). Meat from intact sheep had 1.2% higher proportion of moisture, but 1.1% lower fat concentrations than castrates. Concentrate level did not have a significant effect ( $p > 0.05$ ) on the proximate composition of meat. But, the ash content of meat from



availability and the degree of fat deposition and muscle development. A REM area of 7.3 cm<sup>2</sup> (Berhanu et al., 2014), 12.2 cm<sup>2</sup> (Tesfaye et al., 2011) and a FT of 6.9 mm (Tesfaye et al., 2011) were also reported for the same breed of sheep under different amount of supplement and feeding regimes.

Regardless of the variations between supplement levels, the average DP value on SBW basis fall within the range of 40 to 50% recorded for many tropical sheep breeds (Payne and Wilson, 1999). However, the DP values calculated on SBW and EBW basis were higher than the values (32.7 and 48.2%) reported for the same breed in another study (Berhanu, 2014).

The variations in DP of the same breed at different supplements clearly showed plain of nutrition to have a positive effect on carcass yield as described by Payne and Wilson (1999). The lack of significant difference in DP regardless of the variation in SBW and EBW between sex groups is because of the higher amount of total non-carcass components in intact sheep. Earlier studies also noted increased non-carcass component for intact Afar sheep consuming high level of concentrate (Awet and Solomon, 2009).

### Carcass composition

The ideal carcass of meat animals can be described as the one that has a minimum amount of bone, a maximum amount of muscle and an optimum amount of fat (Amha, 2008). The higher proportions of muscle, fat and bone recorded in sheep consumed high level concentrate was presumably a consequence of higher nutrient intakes (Mudalal et al., 2014). The higher proportion of muscle in carcass of intact sheep could be related to testosterone hormones production, which is responsible for favouring nutrient utilization for better growth and masculine body development than deposition of body fat (Ismail, 2006). In agreement with the present finding, Mahgoub et al. (1998) reported that intact male lambs produced highest proportion of lean, lowest proportion of non-carcass and carcass fat than other sex groups. Conversely, the higher proportion of carcass fat in castrated sheep could be attributed to the fact that castrated animals tend to disburse proportionally much energy in fat deposition than muscle development (Alemu, 2008).

### Edible and non-edible offals

In different areas of the world, various offal components of meat animals including blood are edible and saleable, and fetch extra money that could add value to the carcass. Ewnetu et al. (1998) noted that in almost all parts of Ethiopia, yield of offal components are important, and it is common to find dishes exclusively made from these items. The increased weight of functional organs

and TEO at high level of supplementation in the present study indicated that improving the nutritional status of the animal has a positive impact on the development of such organs and edible offal components proportional to the increased body weight (Archimede et al., 2008). However, the lack of significant differences in most of the individual and TNEO components between supplement levels of the present study agrees with the results of Hirut et al. (2011) who reported that the supplementation has no impact on majority of individual and TNEO components. Similarly, the increased weights of testicle, penis and TNEO of intact sheep might be attributed to the positive impact of male sex hormones on the development of such tissues. This agrees with the results of Awet and Solomon (2009) who reported lower genital organ weight in castrates than intact Afar sheep.

### Chemical composition of meat

According to Moran and Wood (1986), meat composition is an important aspect of meat quality and is normally assessed by the amount of physical dissected tissues or chemical analyzed constituents. The lower intramuscular fat concentration of meat produced from intact sheep is associated with an increased moisture concentration. This is in line with the fact that there is an inverse relationship between fat and moisture concentrations of carcass (Stankov et al., 2002). The average moisture, CP, fat and ash contents of the sheep meat in the present study is in line with the 75% water, 19% protein, 2.5% lipid and 0.65% ash contents of sheep meat (Amha, 2008). Mohammad et al. (2013) reported 76.2% moisture, 17.79% protein, 3.02% fat and 1.22% ash contents for sheep aged greater than 6 months and 75.12% moisture, 18.31% protein, 3.91% fat and 1.33% ash content for yearling sheep. The differences in chemical constituents of meat between studies are related to feed type and feeding regime (Guerrero et al., 2013), animals age, breed and sex differences (Shija et al., 2013).

### Color and pH of meat

Meat color is an important appearance quality trait as it is the first factor seen by the consumer, and is used as an indication of freshness and wholesomeness (Joo et al., 2013). The higher L\* value recorded as a measure of lightness in meat of castrates than intact sheep in the present study could be an attribute of the more intramuscular fat content that makes the meat luminous (Amha, 2008). The present finding agreed with the results obtained by Vnucet et al. (2014) who reported the effect of sex of sheep on L\*, but not on pH values and a\* and b\* measures.

The average L\* value (35.6) of sheep meat, regardless

of sex category, in the present study is comparable with the value of 36.4 reported for fat-tail Arsi-Bale sheep, but lower than the 37.2 reported for Black head Ogaden sheep of Ethiopia (Girma et al., 2010). Amha (2008) noted that meat color can be affected by several factors such as species/breed, age, sex, cut of meat, surface drying of the meat and surface spoilage, muscle pH and diet of the animal.

Comparing the meat color measures reported for exotic breeds of sheep, the  $L^*$  value in the present study is lower than the results reported by different researchers (Craigie et al., 2012; Vnucec et al., 2014). In terms of meat quality, the present color value show that the meat produced is fitted into the values with lightness  $L^* \geq 34$  and redness  $a^* \geq 9.5$  considered as acceptable appearance by average consumers (Khliji et al., 2010).

The average ultimate pH value in the present study was in the range of 5.4 to 5.7 considered as good quality meat (Amha, 2008; Chulayo and Muchenje, 2013). The result is also within the ultimate pH range of 5.49 to 5.86, which is considered as normal (Arguello et al., 2005). Thus, the present finding indicated that the animals were in good physical condition with sufficient glycogen reserve at slaughter for the normal glycolysis process and the associated increase in lactic acid production (Chulayo and Muchenje, 2013). In terms of meat quality, the present pH measure show that the meat produced is fitted into the ultimate pH value ranged from 5.3 to 5.7 considered as meat with good visual appeal and potentially good eating quality (MSA, 2011).

## Conclusion

The present study highlighted that intact Washera sheep produced more carcasses, and less carcass and non-carcass fat than castrates. Intact sheep produced meat that tended to be redder than meat from castrates, which was lighter in color. On the other hand, fattening of Washera sheep with high level of supplementation is recommended for production of more carcasses, and carcass from both sexes had a similar pH value in the normal range.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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