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Full Length Research Paper

Studying the volatility effect of agricultural exports on agriculture share of GDP: The case of Egypt

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This article aims to examine the long and short run relationship between agricultural exports and agriculture share of GDP. Links between series considered are assessed by co-integration analysis using Johansen co-integration technique and ECM-GARCH. Results indicate a positive link in the short and long term between agricultural exports and agriculture share of GDP, as well as co-integration between the pairs of series used. Also it can be found that increases in agricultural exports were followed by increases in agriculture share of GDP. Agriculture exports and agriculture share of GDP elasticities are 0.62. The past shocks and agricultural exports increased agriculture share of GDP volatility.

Key word: Agricultural exports, agricultural economic growth, co-integration analysis, Johansen co-integration, ECM-GARCH.

INTRODUCTION

The Egyptian economy depends basically on agriculture, Suez Canal revenues, tourism, taxation, cultural and media production, natural gas exports and remittances of more than three million Egyptians abroad (mostly in the Gulf State). Agriculture plays a vital role in Egyptian economy. The agricultural sector employs about 30% of the total labor force, contributing about 14.8% of GDP, and agricultural exports contribute about 20% of total good exports, making the agricultural sector a significant national income resource (State Information System, 2012). Agriculture can salvage the prevailing economic situation under instability (Raza et al., 2012; Shirazi and Manap, 2004; Jatuporn et al., 2011; Haleem et al., 2005).

Before 2011, The Egyptian economy is evolving and this evolution only appeared on the rich and did not reach the poor, who suffer from poverty and lack of food. According to State Information System (2012), poverty increased by 50%, leading to socioeconomic and political instability. These situations led to the explosion of a popular revolution in January 25, 2011.After two revolutions in 25th of January, 2011 and 30th of June,

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2013 (Arab Spring revolutions), Egypt suffers from very bad economic situation characterized by high food and energy prices, high unemployment inflation rates, and decline in economic growth rate in most relevant sectors. These political events showed the fragility of the Egyptian economy, where the Egyptian GDP growth rate decreased from 5.1% in 2010 to 2.2% in 2014; also the inflation increased from 7.1% in 2012 to 10.1% in 2014 (World bank, 2014). Egyptian food prices increased by 17.7% from the 1st week of January 2011 till the 1st week of December 2013 (Egyptian Food Observatory, 2013). Egypt had before these two revolutions $36 billion of foreign reserves which decreased in 2016 to $16.5 billion (Africanews, 2016). It became necessary that the Egyptian government worked to increase foreign cash flow of by giving more attention to exporting goods, especially agricultural products.

Recently, Egyptian economy is suffering from a dollar shortage as a result of reduction in investment in Egypt and demise of tourism, leading to depreciation of currency inflows.

Most recent studies assessing the effects of agricultural export on economics have started to gain interest among economists. Many studies found evidence that agricultural export variable has significant effects on economic growth, where it's one of the most important sources of foreign exchange income that ease the pressure on the balance of payments and create employment opportunities. Thus agricultural export is considered as a very important one among economic growth contributors. Some economists seem to generally have agreed that exports can have high added value on economic growth, while others did not find much support to the export led economic growth hypothesis.

In this paper, the Johansen (1988) co-integration technique based on error correction model was used to investigate the relationship between agricultural exports and agriculture share of economic growth in Egypt. The bivariate models for the pairs of series are modeled by means of a GARCH (1,1) specification in order to allow for time-varying and clustering volatility.

This paper is organized as follows. In the next section, a literature review of the effect of the exports and international trade on economic growth using time-series econometric techniques is presented. In section 2, the methodological approach is described. The fourth section is devoted to the empirical implementation to assess relationship between agricultural exports and agriculture share of GDP. The last section in this article offers the concluding remarks and policy implication.

LITERATURE REVIEW

During the last two decades, the role of exports in economic growth has a wide range of literature. A large extent of these empirical researches has been conducted to explore the variable of the effects of export on economic growth rate. These studies have used either cross sectional data or time series data with vary conclusions. Some of these studies have used simple correlation coefficient technique in order to analyze the relationship between economic growth and exports e.g. (Chenery and Strout, 1966); Michaely (1977); Balassa (1978); Heller and Porter (1978); Tyler (1981); and Kormendi and Mequire (1985). They found that the correlation between the growth of exports and economic growth rate was highly positive.

The second part of these studies used regression techniques to examine the relationship e.g. Voivodas (1973); Feder (1983); Balassa (1985); Ram (1987); Sprout and Weaver; 1993); and Ukpolo (1994). They found a positive and highly significant effect of the product export on GDP.

Several studies have addressed the links between exports and the national GDP by using Granger causality test which examined the causality relationship between growth of export and economic growth e.g. Jung and Marshall (1985); Chow (1987); Serletis (1992); Dodaro (1993); and Jin and Yu (1995). These bulk of studies concluded that there existed some causality relationship between exports and economic growth.

Heiko (2008) examined the links between export diversification and economic growth. He provided a robust empirical evidence of the positive effect of export diversification on per capita income growth. The study estimated a simple augmented Solow growth model and investigated the relationship between export diversification and income per capita growth. The findings of this paper was that the effect of export diversification on economic growth is potentially nonlinear with developing countries benefiting from diversifying their exports in contrast to the most advanced countries that perform better with export specialization. The evidence is strong that export concentration has been detrimental to the economic growth performance of developing countries in the past decades. Rangasamy (2009) used modern econometric techniques within a multivariate framework and attempted to ascertain whether the emphasis on export production is justified. The results showed that there is uni-directional Granger-causality running from exports to economic growth in South Africa. In addition, the gross domestic product (GDP) accounting identity underestimates the contribution of exports to economic growth.

Abou-Stait (2005) examined the export-led growth paradigm for Egypt, using historical data from 1977 to 2003. The study employed a variety of analytical tools, including cointegration analysis, Granger causality tests, and unit root tests, coupled with vector auto regression and impulse response function analyses.

The paper cited three hypotheses for testing the ELG paradigm for Egypt, (1) whether GDP, exports and imports are cointegrated, (2) whether exports Granger cause growth, (3) whether exports Granger cause investment. First two hypotheses were rejected, while the third one was accepted that exports Granger cause investment.

Most of the previous researches focused on the total exports as the only source of growth, ignoring agriculture's share to total exports. This happens during the time in which agriculture exports play substantial role in underdeveloped economies. This hypothesis has also been examined by various economists; they argued that rising agricultural exports play important role in economic growth.

Mucahit and Murat (2014) investigated the causal relationship between variable of Turkish's export and the GDP by using Augmented Dickey Fuller test and Granger causality test. The obtained results concluded that there was a unidirectional causal relationship from the GDP to the export. The results revealed that the series were not stationary.

Bulagi (2015) analyzed causality between agricultural exports and its share of gross domestic product in South Africa from 1994 to 2011. The study used Granger analyses to study the relationship between agricultural exports and agricultural GDP contribution. The results of the Granger causality test of this study showed a unidirectional causality between exports and GDP. Gilbert (2013), studying the impact of agricultural exports on economic growth in Cameroon, found that the agricultural exports have mixed effect on economic growth. Coffee export and banana export have a positive and significant relationship with economic growth while cocoa export has a negative and insignificant effect on economic growth.

Ramphul (2013) investigated the causality between agricultural exports and agriculture GDP in India by using the Granger causality test. The study has found a unidirectional causal link running from farm exports to gross domestic product of agriculture. This indicates that agricultural products export Granger caused the growth in GDP of agriculture, supporting the export led growth hypothesis.

Noula et al. (2013) assessed the contribution of agricultural exports to economic growth in Cameroon. They employed an extended generalized Cobb Douglas production function model. All variables were non stationary and of an order I, and the Cointegration test was conducted for long run equilibrium. All the variables confirmed cointegration and as such the conventional vector error correction model was estimated using the Engle and Granger (1987)'s procedure. The findings of the study show that agricultural exports have mixed effect on economic growth in Cameroon.

Muhammad (2012) explored and quantified the contribution of agricultural exports to economic growth in Pakistan. He estimated the relationship between Gross domestic product GDP and agricultural and non-agricultural exports for Pakistan by using Johansen co-integration technique for the period 1972 to 2008. The finding of this study is that the agricultural exports have negative and significant effect on economic growth while agricultural exports elasticity was 0.58. Moreover there was bidirectional causality in agricultural exports and real GDP. The same results were found by Faridi (2012) who has studied the contribution of agricultural exports to economic growth in Pakistan. The results showed that the agricultural exports had negative and significant effect on economic growth while agricultural exports elasticity was 0.58; and there was bidirectional causality in agricultural exports and real GDP.

Sanjuan-Lopez and Dawson (2010) quantified the contribution of agricultural exports to economic growth in developing countries, and they estimated the relationship between GDP and exports of agricultural and non-agricultural sector for 42 countries using panel cointegration methods. The results showed that a long-run relationship existed; the agricultural export elasticity of agriculture's share on GDP was 0.07 whereas that of non-agricultural exports was 0.13. Haleem et al., (2005) estimated exports function for citrus fruit in Pakistan. The study result showed the importance of exports in the development of an economy cannot be denied. This is particularly true in case of a developing economy.

METHODOLOGY

Many empirical analyses have been introduced to assess the international trade effect on the Growth Domestic Product (GDP) in developing countries. Most of these studies rely on two main methodological approaches: they are structural analysis that can be assessed by relying on economic approaches, and econometric analysis of time series data that identify empirical regularities in the data. This paper analysis follows the second methodological approach. Analysis of the time-series data requires studying the statistical properties of these data. Most research studies evidenced the presence of a unit root in the time series data and, when related, to share a tendency to co-move in the long-run (Myers, 1994).

This analysis uses error correction model by estimating johansen cointegration techniques and generalized autoregressive conditional heteroskedasticity (GARCH) models. Cointegration and error correction models (ECM) have been introduced in the literature (Engle and Granger, 1987) to characterize nonstationary and cointegrated data and inform both on their short and long-run dynamics. Time-varying and clustering volatility, another common characteristic of time-series, is typically modeled through generalized autoregressive conditional heteroskedasticity (GARCH) models. While the use of Johansen cointegration (1988, 1991, 1995) methods is common within the financial economics literature; empirical analysis that uses Johansen (1988, 1991) cointegration to assess the link between agriculture international trade and agricultural GDP is very scarce.

The Johansen (1988) cointegration test provides a natural way to measure the relationship between two or more variables where the variables are characterized by non- stationary variables, presence of unit root, and near integrated. The Johansen test is considered as multivariate model and can be estimated by using maximum likelihood method. The Johansen's methodology based on the vector autoregression (VAR) can be expressed as:

$$y_t = \sum_{i=1}^{k} A_i y_{t-i} + \varepsilon_t \qquad (1)$$

Where y_t is an $n\times1$ vectors of integrated variables of order one for $k>1$, and ε_t are $n\times1$ error terms. Equation (1) can be re-written as:

$$\Delta y_t = \prod y_{t-1} + \sum_{i=1}^{k-1} \prod_i \Delta y_{t-i} + \varepsilon_t \qquad (2)$$

Where

$$\prod = \sum_{i=1}^{k} A_i - I \ and\ \Gamma_i = -\sum_{i=i+1}^{k} A_j. \qquad (3)$$

The coefficient matrix can be written as:

$$\prod = \alpha\beta' \qquad (4)$$

Where α are the adjustment parameters in the vector error correction model or speed of adjustment towards equilibrium and each column of β is considered as cointegrating vector.

Where $\prod$ is equal to zero that means the variables tested are not cointegrated, and the variables are to be cointegrated where the rank of $\prod \neq 0$, where r is the number of cointegrating relationships, and If the rank of $\prod$ is reduced to be $r>n$ but is not equal to zero, then its determinant is zero. To overcome this problem we can consider eigenvalues to be the estimators of the cointegrating vectors[1] (Sørensen, 2005).

Johansen tests were divided into two likelihood ratio tests to assess the null hypothesis of no cointegration against the alternative of the presence of the cointegration of the canonical correlations. These two tests are: The trace test and the maximum eigenvalue test, represented in Equations 5 and 6, respectively. First, the trace was found to maintain equilibrium parity by implementing the Johansen (1988)'s cointegration test. First, the trace test examines the null hypothesis of the rank $\prod = r$ coinegrating vectors relative to the alternative hypothesis of $r < \prod \leq n$ coinegrating vectors. Second, the maximum eigenvalue test assesses the null hypothesis of $r = 0$ relative to the alternative that $r+1=0$ (Hjalmarsson and Österholm, 2007).

$$J_{trac} = -T \sum_{i=r+1}^{n} \ln(1-\bar{\lambda}_i) \qquad (5)$$

[1]Johansen tests (1998, 1991) are based on the eigenvalues of the transformation of the variables and can assess relationships among variables which have canoncial or maximum correlation that shows the maximum likelihood estimator of the cointegrating vector leads to find higher r canonical correlation of Δyt by transforming the variable to lagged differences and deterministic variables (Johansen, 1995; Hjalmarsson and Österholm, 2007).

$$J_{\max} = -T \ln(1-\bar{\lambda}_{r+1}) \qquad (6)$$

The Augmented Dickey and Fuller (1979), Perron (1997) and KPSS (Kwiatkowski, 1992) tests used to test for unit roots are run on our data.

Results support the presence of a unit root in both agricultural export and agricultural GDP. The two variables considered are also found to maintain equilibrium parity by implementing the Johansen (1988)'s cointegration test. The bivariate models for agricultural export and agricultural GDP pairs considered (*AgExp, AgGDP*) are consequently specified as an error-correction type of model (ECM) (Equations 7 and 9). Model residuals are modeled by means of a bivariate GARCH (1,1)[2] specification in order to allow for time-varying and clustering volatility (Equations 8 and 10).

$$\Delta EXP_t = \alpha_{EXP} + \lambda_{EXp}\delta_{t-1} + \sum_{i=1}^{2} \alpha_{EXPEXPi} \Delta EXP_{t-i} + \sum_{i=1}^{2} \alpha_{EXPGDPi} \Delta GDP_{t-i} + \varepsilon_{EXP,t} \qquad (7)$$

$$\sigma^2_{EXP,t} = \omega_{EXP} + \omega_{EXP1}\varepsilon^2_{EXP,t-1} + \omega_{EXP2}\sigma^2_{EXP,t-1} \qquad (8)$$

$$\Delta GDP_t = \alpha_{GDP} + \lambda_{GDP}\delta_{t-1} + \sum_{i=1}^{2} \alpha_{GDPEXPi} \Delta EXP_{t-i} + \sum_{i=1}^{2} \alpha_{GDPGDPi} \Delta GDP_{t-i} + \varepsilon_{GDP,t} \qquad (9)$$

$$\sigma^2_{GDP,t} = \omega_{GDP} + \omega_{GDP1}\varepsilon^2_{GDP,t-1} + \omega_{GDP2}\sigma^2_{GDP,t-1} \qquad 10)$$

where *ΔGDP and ΔEXP* is the first difference of logged agricultural GDP and agricultural export, respectively. $\Delta_{GDP,EXP}$ are short-run dynamic parameters that measure the influence of past agricultural GDP and agricultural export differences on current differences. The error correction term derived from the long-run equilibrium relationship is represented δ_1, thus $\lambda_{GDP,EXP}$ measures the long-run agricultural GDP and agricultural export dynamics.$\varepsilon_{GDP,EXP}$ are normally distributed error terms. The Ljung-Box test was applied to examine that the ECM-GARCH models are well specified.

RESULTS AND DISCUSSION

Empirical analysis

The analysis based on the dataset includes annual Egyptian agriculture's share on GDP and agriculture exports for the period 1970 to 2013, yielding 44 observations. Agriculture's share of GDP and agriculture exports expressed in constant 2005 dollars (Figures 1 and 2) data were obtained from the United Nations statistical database (UN database, 2016). Logarithmic transformations of agriculture GDP and agriculture

[2] The number of lags used in ECM-GARCH models was determined based on statistical significance and parsimony.

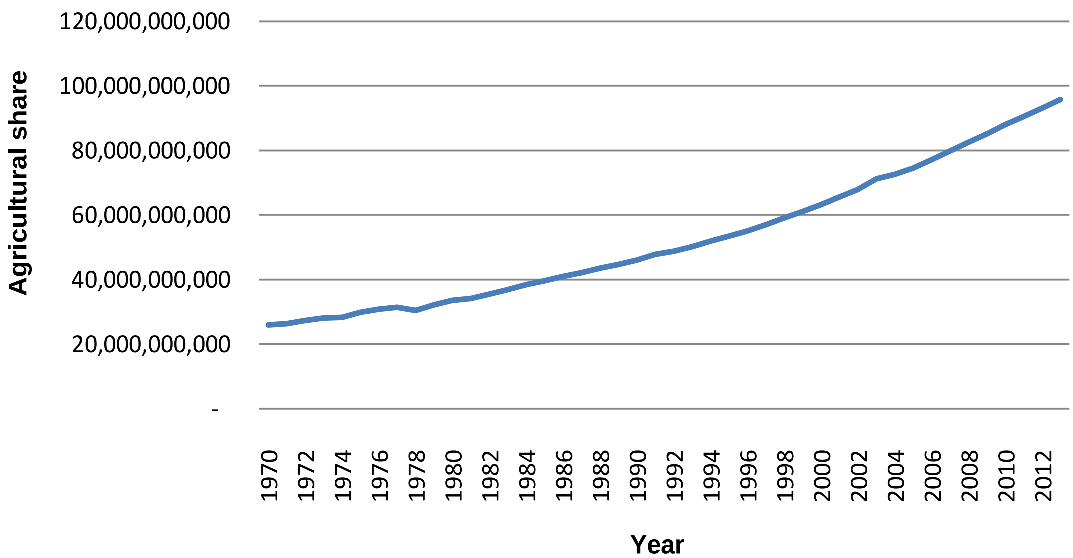

Figure 1. Annual agriculture's share on GDP expressed in dollars and expressed in constant 2005$.

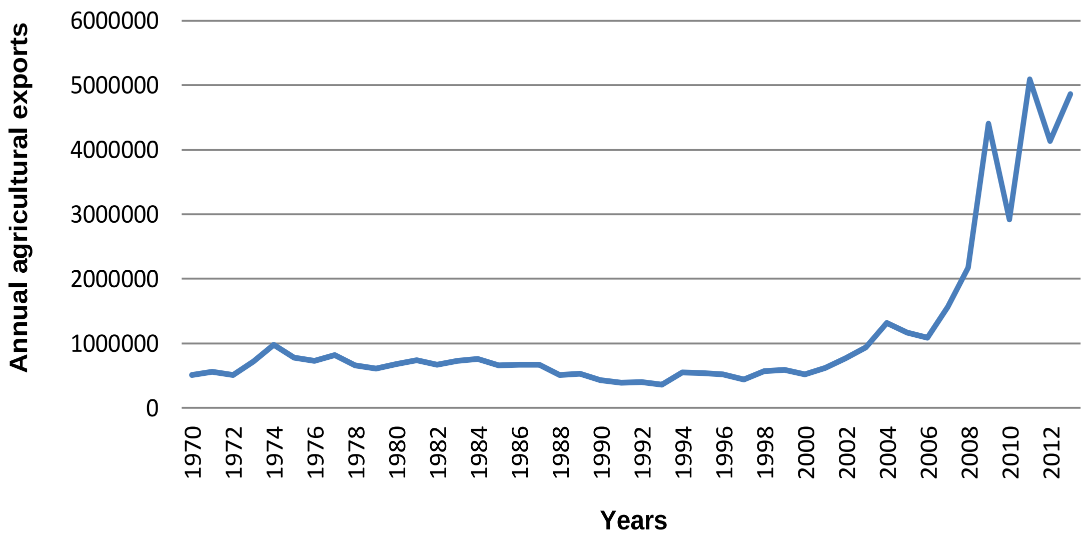

Figure 2. Annual agricultural exports expressed in dollars and expressed in constant 2005$.

exports series are used in the empirical analysis. Since ECM- GARCH modeling can only be applied to stationary data, the Augmented Dickey and Fuller (1979), Perron (1997) and KPSS (Kwiatkowski, 1992) unit root tests have been conducted and shown that none of the series is stationary and there is the unit root (Table 1). Thus we take the logged agriculture's share of the Egyptian GDP and agriculture exports series in first differences. Table 1 presents summary statistics for first differenced logged series used in the analysis.

We applied the Johansen's (1988) cointegration to assess the existence of an equilibrium relationship between the pairs of series studied and to drive the error correction term in order to estimate ECM-GARCH bivariate model and evaluate the short run relationship between the agricultural exports and agriculture's share of the GDP.

Our findings suggest that there is a long-run relationship between agriculture exports and agriculture's share of the Egyptian GDP (Table 2). Existence of co-integration suggests the existence of trade flows from agriculture exports to agriculture's share of GDP. Since series used in the analysis are expressed in logarithms, co-integration parameters can be interpreted as agricultural exports and agriculture's share of GDP

Table 1. Summary statistic for first log-differences series.

Unit root testing on logged agriculture GDP and agriculture exports series		
Test	**Agriculture GDP**	**Agriculture Exports**
Perron	1.326	0.718
Critical values	-3.584 (1%)	-2.928 (5%)
Augmented Dickey-Fuller	2.902	3.179
Critical values	7.06 (1%)	4.86 (5%)
KPSS	1.201**	0.586*
Critical values	0.739 (1%)	0.463 (5%)

Summary statistic for first log-differences agriculture GDP and agriculture exports series		
Test	**Agriculture GDP**	**Agriculture exports**
Mean	0.001	0.054
Standard deviation	0.002	0.035
T-statistic	14.687	1.479
Skewness	-2.086	0.669
Kutosis (excess)	8.731**	0.461
Jarque-Bera statistic	167.803**	3.598
ARCH LM statistic	14.085**	11.632**
Number of observations		43

Table 2. Johansenλ_{trace} test for cointegration and cointegration relationship.

Agriculture GDP - Agriculture Export			
H_0	Ha	$\lambda trace$	P-value
$r = 0$	$r > 0$	35.276	0.000
$r \leq 1$	$r > 1$	2.865	0.614
	Agriculture GDP	**Agriculture Exports**	
Chi-Square(r) (P-values)	29.416 (0.000)	0.688 (0.407)	
	Cointegration: Agriculture GDP -Agriculture Export		

$$GDP_{Agr} \underset{(-1.569)}{-0.627^{**}} Exp_{Agr} \underset{(-3.954)}{-7.376^{**}} = \nu_{GDP_{Agr}Exp_{Agr},t}$$

elasticity. Agriculture exports and agriculture's share of GDP elasticities are 0.62. It is not surprising to find high correlation between agriculture exports and its share on GDP. A chi-square test of weak exogeneity for long-run parameters within the Johansen's framework indicates that agriculture exports variable is endogenous for long-run parameters, agriculture's share on GDP is exogenous. This implies that the agriculture's share of GDP for maintaining such equilibrium by responding to the fluctuations can occur by agriculture exports (see Table 2). As expected, the parameters representing long-run series used links suggest that an increase in agricultural exports will cause an increase in agriculture's share of GDP as well, which may result in higher acceptance and compatible with Bulagi et al (2015), and Sanjuan-Lopez and Dawson (2010). This is not surprising since the agricultural economy in Egypt depends on agricultural exports, especially the European market. Given that rice represents almost 40% of total Egypt's exports, the well-known Egyptian cotton is imported to India, Pakistan and China. The European market is the major absorber of potatoes and oranges; its represents 42% of the country's exports.

Results obtained from applied ECM-GARCH (1,1) bivariate model are presented in Table 3. Short-run parameters show that current changes in agriculture's share on GDP have a negative relevant autoregressive component and also affected by agricultural exports. This supports the results mentioned above that agriculture's share on GDP is exogenous, while agriculture exports are weekly endogenous for long-run parameters. The speed of adjustment is negative and significant, which implies that in the long run the agriculture's share on GDP has adjusted yearly by 4%. The conditional variance equation shows that past shocks contribute to

Table 3. Result for the bivariate ECM-GARCH (1, 1) model for Agriculture GDP - Agriculture Export

Variable	Agriculture GDP	Agriculture Export
C	-0.001 (0.021)	-0.557** (0.027)
$\Delta AgrGDP_{t-1}$	-0.186** (0.103)	0.438 (0.878)
$\Delta AgrGDP_{t-2}$	-0.347** (0.110)	-0.510** (0.910)
$\Delta AgrExp_{t-1}$	0.008** (0.004)	-0.076 (0.195)
$\Delta AgrExp_{t-2}$	0.006** (0.003)	0.213* (0.140)
$\nu_{GDP.ExpAgr,t}$	-0.004** (0.002)	-0.039 (0.002)
ω_i	1.580e-6 (0.032)	0.023** (0.008)
ω_{i1}	7.556e-4 (1.925)	0.467** (0.258)
ω_{i2}	0.972** (0.005)	0.030 (0.227)
Ljung-Box Q(15)	14.368	13.254

Note: (*) ** denotes statistical significance at the (10%) 5% level.

increase agriculture's share on GDP volatility. Since $\omega_1 + \omega_2 < 1$, we can conclude that the GARCH process is stationary, being the unconditional long-run variance $\left(\sigma_i^2 = \omega_i /(1-\omega_{i1}-\omega_{i2})\right)$ around 5.701e-6.

Current changes in the agricultural exports are influenced by past realizations of agricultural exports and negatively by the deviations from the long - run equilibrium, which indicates that the long run the agricultural exports have adjusted yearly by 4% , while the agricultural exports are not influenced by agriculture's share on the GDP (Table 3). The conditional variance equation shows that past market shocks contribute to destabilize the agricultural exports. The bivariate GARCH (1,1) model process provides evidence of a stationary volatility process, and GARCH parameters lead to an unconditional variance $\sigma^2 = 0.047$.

The Ljung-Box test was done using the bivariate model (ECM-GARCH) and the results do not allow rejecting the null hypothesis of no autocorrelated residuals from lags 1 to 15 at 5% level. This implies that the ECM-GARCH is specified well.

CONCLUSION AND POLICY IMPLICATIONS

While Egypt is one of the African countries exporting agricultural products, but the current direction of the Egyptian government is to pay more attention to industrial exports. This paper studies the contribution of the agricultural exports to agriculture's share of GDP by using the Johansen (1988)'s cointegration technique to examine the relation between agricultural exports and agriculture's share on GDP. The ECM-GARCH bivariate model was also used to assess the short term relationship between agricultural exports and agriculture's share on GDP. This also allows us to evaluate the time-varying and clustering volatility. The analysis was based on the time series data, annual Egyptian agriculture's share on GDP and agriculture exports for the period 1970-2013. The results indicate that there is long-run equilibrium relationship between agricultural exports and agriculture's share on GDP. The agricultural export elasticity of agriculture's share on GDP was 0.62. The agricultural exports and agriculture's share on GDP were influenced negatively by the speed of adjustment. This indicates that in the long term the agricultural exports have adjusted agriculture's share on GDP yearly by 4%. Results also indicate that increases in agricultural exports were followed by increases in agriculture's share of GDP. The conditional variance equation shows that past shocks and agricultural exports contribute to increase agriculture's share on GDP volatility.

Currently, Egypt is experiencing high dollar price against the local currency, which requires increasing exports to provide a strong foreign reserves. According to our findings above, increases in agricultural exports lead to increases in agriculture's share of GDP, and thus increases in the growth rate of the economy as a whole.

Therefore the application of some of the policies through the intervention of the Egyptian government or by the relevant bodies to increase agricultural crops exports could lead to the strengthening of the Egyptian economic performance. To implement some of the policies that could be used to increase the export of agricultural products, it is relevant that the problems faced by farmers to export their products be solved. The most important of these problems are the lack of exporters' commitment to forward contracts; thus these contracts need to be controlled by the government and the application of fines for breach of the contracts.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Using the *p*-median location model to set up aerodromes for coverage fertilization of eucalyptus plantations

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In this study an economic analysis was conducted to evaluate problem associated with a geographical information system (GIS) using facility location models for the p-median in order to optimize the location of aerodromes for the aerial fertilization (coverage fertilization) of eucalyptus plantations. The location model was tested on a 9,095.65 ha farm located in the Três Lagoas municipality in the Mato Grosso do Sul State, in Brazil. The non-capacitated p-median location model, available in ArcGIS, was evaluated in the location-allocation module. Simulations were performed based on one to five aerodromes. The fertilization and setup costs were calculated for each scenario. The results showed that the p-median location model was efficient in determining the optimal location of aerodromes. The economic analysis of the location model found that the lowest costs are incurred when using three aerodromes.

Key words: Combinatorial optimization, operational research, aerial fertilization.

INTRODUCTION

Forest management can be regarded as management on multiple analysis levels, each involving many decisions based on several resources, most of which are scarce (Church et al., 1998). The productivity of a particular plantation is limited by one or more nutrient sources and forest nutrition is a key part of managing commercial

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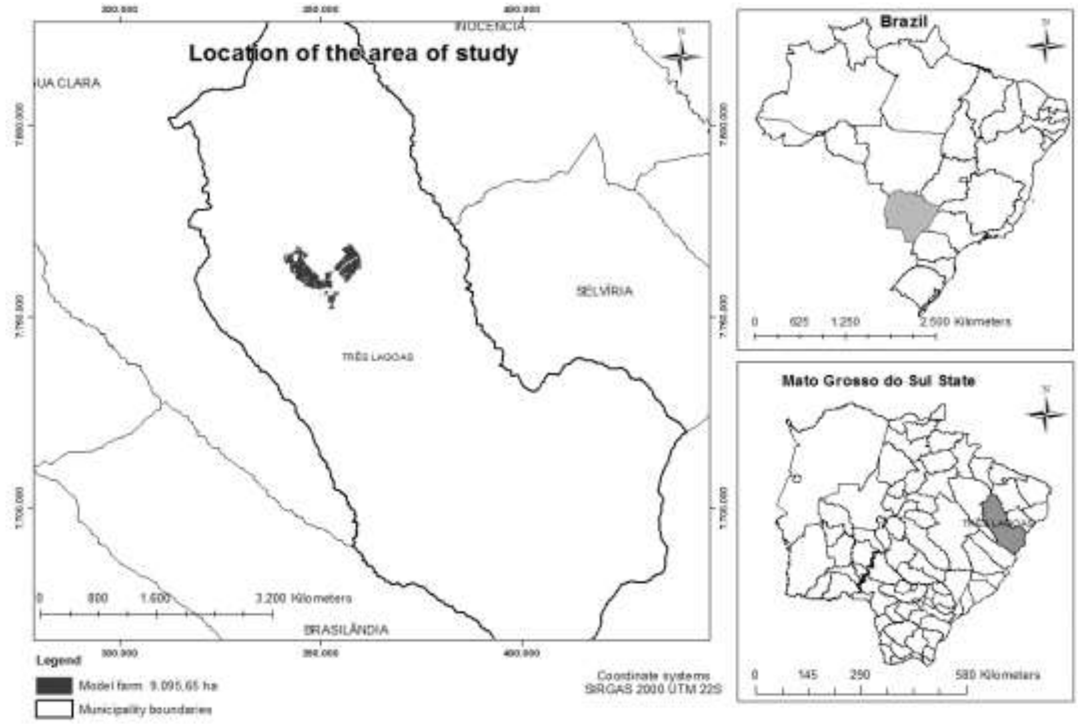

Figure 1. Location of the clonal *Eucalyptus* plantations.

forests (Stape et al., 2006). Fertilization is required because the soil is not always able to provide all the nutrients required by the plants to grow properly (Gonçalves, 1995).

Several strategies can be used for the distribution of fertilizers, but the importance of aerial fertilization has been growing owing to the rapid expansion of cultivated areas and the subsequent need for fertilization. Aerial fertilization is highly efficient, particularly in comparison with using terrestrial machinery.

One of the main factors that affects the efficiency of aerial fertilization is the distance between the aerodrome and the application area. The ideal aerodrome location is a combinatorial problem involving several possible choices, with limitations on flight distance, refueling, and operational stations, among other restrictions.

The network p-median problem, introduced by Hakimi (1964), identifies facility locations in order to minimize the total weighted distance for trips between the demand areas and the facilities. This problem may be formulated using integer linear programming (Owen and Daskin, 1998) and is useful for predicting the location of industrial plants, warehouses, and public installations (Mladenovic et al., 2007). The tool identifies the locations of facilities in order to minimize the average distance between clients and the nearest service point (Daskin, 1995).

The p-median problem has great practical importance. In Brazil, studies have used the technique to examine, for instance, locations for public schools (Pizzolato et al., 2004; Pizzolato and Menezes, 2010), telecommunication antennas (Lorena and Pereira, 2002), public healthcare stations (De Rosário et al., 2001), and urban leisure areas (Brondani et al., 2013; Lorena et al., 2001), as well as for evaluating the integration of location models and Geographical Information Systems (GIS). With regard to forestry areas, the method has been used to identify optimal wood storage locations (Junior et al., 2014; Martinhago, 2012), allocating fire lookout towers in a natural reservoir (Juvanhol, 2015), and for the spatial stratification of compartments in forest harvesting (Gomide, 2013).

This study evaluates using the mathematical model associated with the p-median problem to identify optimal aerodrome locations in eucalyptus plantations. In addition, an economic analysis is conducted to find the ideal number of aerodromes for the study area.

MATERIALS AND METHODS

This study focuses on an area of 9,095.65 ha containing clonal eucalyptus plantations in the Três Lagoas municipality in the Mato Grosso do Sul State , Brazil (Figure 1).

In these plantations, 200 kg of nitrogen and potassium per hectare are applied between the third and fifth months after planting, using coverage fertilization. The aircraft used is an AirTractor 502B, which has a load capacity of 1,800 kg. The specifications of the aircraft are shown in Table 1. The runways have standard dimensions (that is, 1,200 m long and 40 m wide), and always run in a north/south direction.

Table 1. AirTractor 502B specifications.

Engine	P&W PT6A-34AG	Empty weight, including pulverization equipment	4,860 lbs (2,204 kg)
Engine SHP	750 at 2,200 RPM	Useful load	5,403 lbs (2,450 kg)
Propeller	Hartzell HC-B3TN-3D/T10282NS+4	Hopper capacity	500 U.S. gal(1,893 L)
Takeoff weight	9,400 lbs (4,263 kg)	Fuel capacity	170 US gal (644L)
Landing weight	8,000 lbs (3,628 kg)	Wing area	312 sq. ft (29.01 m²)
Wingspan	52 ft (15.84 m)	Dimensions of main wheels	29.00 × 11
Dimensions of rear wheels	5.00 × 5		

The optimal aerodrome location problem is modeled as a location-allocation problem, solved using the p-median model of the Location-Allocation module in the extension Network Analyst of ArcGIS version 10.2.2. The available algorithm combines several techniques, adopting vertex substitution heuristics and fine-tuning metaheuristics in order to achieve a satisfactory, optimal, or near-optimal solution (Sultana and Kumar, 2012; Costa, 2014).

The areas containing clonal eucalyptus plantations are represented by polygons, but in a network context, it is necessary to define demand points in order to draw the routes connecting them to the facility locations. In this case, the demand points are defined as centroids in the intersections between the features of the subject plantation and a grid of 300 m × 300 m polygons created using the Fishnet tool available in ArcToolbox. This made it possible to represent the plot areas on locations corresponding to 9.0 ha plantations, generating a total of 1,013 demand points for the 32 facilities (Figure 2).

The study uses the geographical information system ArcGIS® version 10.2.2. The data were created and stored in a geobasis, a native structure of ArcGIS, and stored in a Feature Dataset of the SIRGAS 2000 UTM 22S coordinate system. The extensions Spider Tools, Data Management Tools, Editing Tools, and Network Analyst were used for database processing and structuring, as well as for the required feature editions.

According to Revelle and Swain (1970) and Church and Revelle (1976), in a network context, the p-median problem can be defined as follows: minimize the total weighted distance of the trip associated with a network of demand nodes to locate p-facilities in the network (on vertices or on nodes), where each demand vertex is served by its nearest facility.

In the following mathematical model, i denotes the group of demand points (nodes); $i \in I$ is a defined client or vertex; $j \in J$ is a potential facility or median; p is the number of service facilities or medians to be located; w_i is the weight or importance of client $i \in I$; $[d_{ij}]_{I,I}$ is a symmetrical matrix of the distances between each client i and facility $j \in J$; $[x_{ij}]_{I,I}$ is an allocation matrix for client i, where x_{ij} = 1 if a facility is located at candidate node $j \in J$ and 0 otherwise; y_{ij} = 1 if demand node $i \in I$ is assigned to facility at candidate node $j \in J$ and 0 otherwise. According to Revelle and Swain (1970), the problem may be formulated with objective of minimizing the demand-weighted total distance as follows:

$$\text{Minimize} \sum_{j \in J} \sum_{i \in I} w_i d_{ij} y_{ij}$$

s.t.

$$\sum_{j \in J} y_{ij} = 1 \forall i \in I,$$

$$y_{ij} - x_j \leq 0 \forall i \in I, \forall j \in J,$$

$$\sum_{j \in J} x_{ij} = p,$$

$$x_{ij} \in \{0,1\} \forall j \in J,$$

$$y_{ij} \in \{0,1\} \forall i \in I, \forall j \in J.$$

The solution to a facility location problem can be found using a geographical information system integrated with optimization or simulation algorithms. ArcGIS uses heuristic methods to solve the *p*-median problem, because most location problems are classified as NP-hard. These heuristics were developed by Densham and Rushton (1992), Teitz and Bart (1968), and Arakaki and Lorena (2006).

In order to perform the economic analysis, the costs associated with setting up an aerodrome are calculated. Fertilization costs were provided by the company. The cost of coverage fertilization per hectare varies with the coverage radius of an aerodrome. Here, the distances from the plots are distributed into four classes: 2,500, 5,000, 7,500, and 10,000 m. The values provided by the company for the fertilization activity costs, as a function of the distance between the aerodromes and the plots, for radii of 2,500, 5,000, 7,500, and 10,000 m are R$97.5, R$110.0, R$126.9, and R$143.8 per ha, respectively.

The total cost of the activity is the sum of the aerodrome setup cost (the same for all points in the study area) and the fertilization cost per hectare.

RESULTS

In order to identify the lowest-cost configuration and number of aerodromes, the evaluated location models are used to calculate the aerodrome setup cost and the coverage

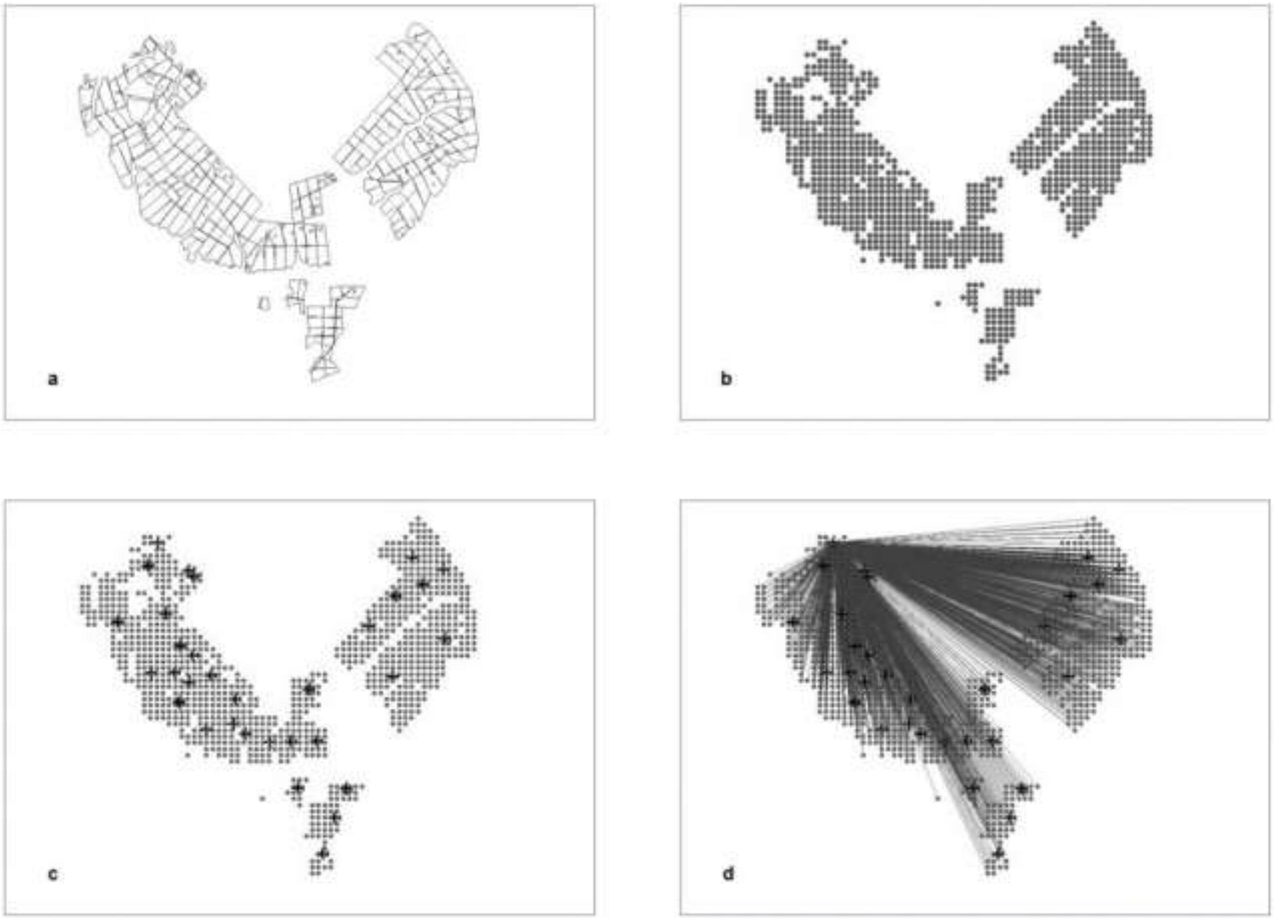

Figure 2. Polygons denoting the plantations (a), 9.0 ha demand points (b), candidate aerodromes (c), and routes between the candidate aerodromes and the demand points (d).

fertilization cost, which are added together to give the total cost of the activity. Table 2 presents the items making up the aerodrome setup cost, as well as their respective values.

A summary of the activity costs is as shown in Table 3. The results show that the scenario with the lowest costs, according to the *p*-median model, comprises three aerodromes, with a total cost of R$1,031,980.5.

When conceptualizing the setup of aerodromes for aerial fertilization, the use of a GIS is important because it enables the results to be presented as illustrative maps. These maps help with the interpretation and comprehension of the results, which are as shown in Figure 3. These results refer to the simulations of setting up one to five aerodromes and to the spatial distribution given by the *p*-median model.

DISCUSSION

The location of facilities is a critical problem in strategic planning for several public and private companies. For example, this may involve a producer choosing where to build a warehouse serving a new market in a retail chain, or an urban planner selecting locations for fire stations. In each case, decisions are constrained by the allocation of spatial resources (Owen and Daskin, 1998). Mathematical modeling and optimization have proven to be effective in helping decision-makers with location and transport matters (Kelley et al., 2013).

Several recent studies have attempted to define and characterize localization problems and have proposed models to approach and solve these problems (Daskin, 1995; Eiselt and Marianov, 2011). A number of studies use geographical information systems, developing localization models for the establishment of biomass industries (Zhang et al., 2011; Sultana and Kumar, 2012; Costa, 2014; Teixeira et al., 2018).

Serra and Marianov (1998) formulated the *p*-median problem for the location of new facilities in the case of uncertain demand, in terms of time or the distance of trips, where it is possible to define scenarios that represent differences in travel times or demand in the region of interest. For example, the model has been

Table 2. Composition and values of the items in the aerodrome setup cost.

Items	Unit	Value
Width	m	40.00
Length	m	1,200.00
Total area	ha	4.80
Terrain price	R$/ha	5,000.00
Construction costs	R$/ha	20,000.00
Annual interest rate	%	12
Road duration (years)	year	20.00
Depreciation	ha/year	1,000.00
Interest on the construction value	R$/ha/year	1,200.00
Interest on the terrain value	R$/ha/year	600.00
Maintenance	R$/ha/year	2,000.00
Cost per ha	R$/ha/year	4,800.00
Total Cost	Per aerodrome	23,040.00

Table 3. Fertilization, implantation, and total costs results as a function of the number of aerodromes.

Name	Number of aerodromes	Fertilization costs (R$)	Aerodrome setup costs (R$)	Total costs (R$)
p-medians	1	1,153,514	23,040	1,176,554
p-medians	2	1,012,449	46,080	1,058,529
p-medians	3	962,861	69,120	1,031,981
p-medians	4	941,633	92,160	1,033,793
p-medians	5	923,847	115,200	1,039,047

applied to identify the optimal locations of fire brigades in Barcelona. Note that for this study on the location of aerodromes, uncertainty was not taken into account in the evaluated models.Even though there is considerable research on applying the *p*-median problem in different scenarios, no studies have examined the setting up of aerodromes in the context of the aerial fertilization of eucalyptus plantations. This technique has proven to be very efficient in finding optimal locations for aerodromes, helping to reduce the associated costs. The results showed that the lowest cost is achieved with three aerodromes, with a reduction of 12.3% in the allocation costs of using one aerodrome (Table 3).

The limitation of using the *p*-median mathematical model is the need to specify the number of facilities being established. In other location models, such as the coverage model, this information is not required; that is, the number of aerodromes is not an input variable in the model. However, this limitation can be overcome by performing simulations that consider different scenarios.

The optimal number of aerodromes depends on the plot distribution in the area. In the present study, the distribution favored the location of three aerodromes. Therefore, the decision on runway allocation is directly correlated with the hierarchical planning. Restricting the number of harvest blocks may favor a smaller number of aerodromes, while excessive specialization may result in the allocation of more aerodromes.

Even though they are not analyzed in the present work, the spatial distribution and the number of aerodromes also depend on the physiographical characteristics of the region where the plantations are located, as well as on the size of the forest. However, the methodology employed in this study remains valid and enables the determination of the number and optimal distribution of runways.

Only one aircraft type was taken into account in the present study. Given the possibility of acquiring more than one model, the choice of which aircraft to buy can be made based on the total cost (Ellram, 1993), while also considering the useful life of each aircraft type.

Conclusions

The mathematical location model associated with the *p*-median problem proposed in the present study is efficient in identifying the optimal location of aerodromes for the coverage fertilization, by aerial fertilization, of eucalyptus plantations.

For the model farm evaluated in this study, the optimal number of aerodromes that minimizes the total cost of the

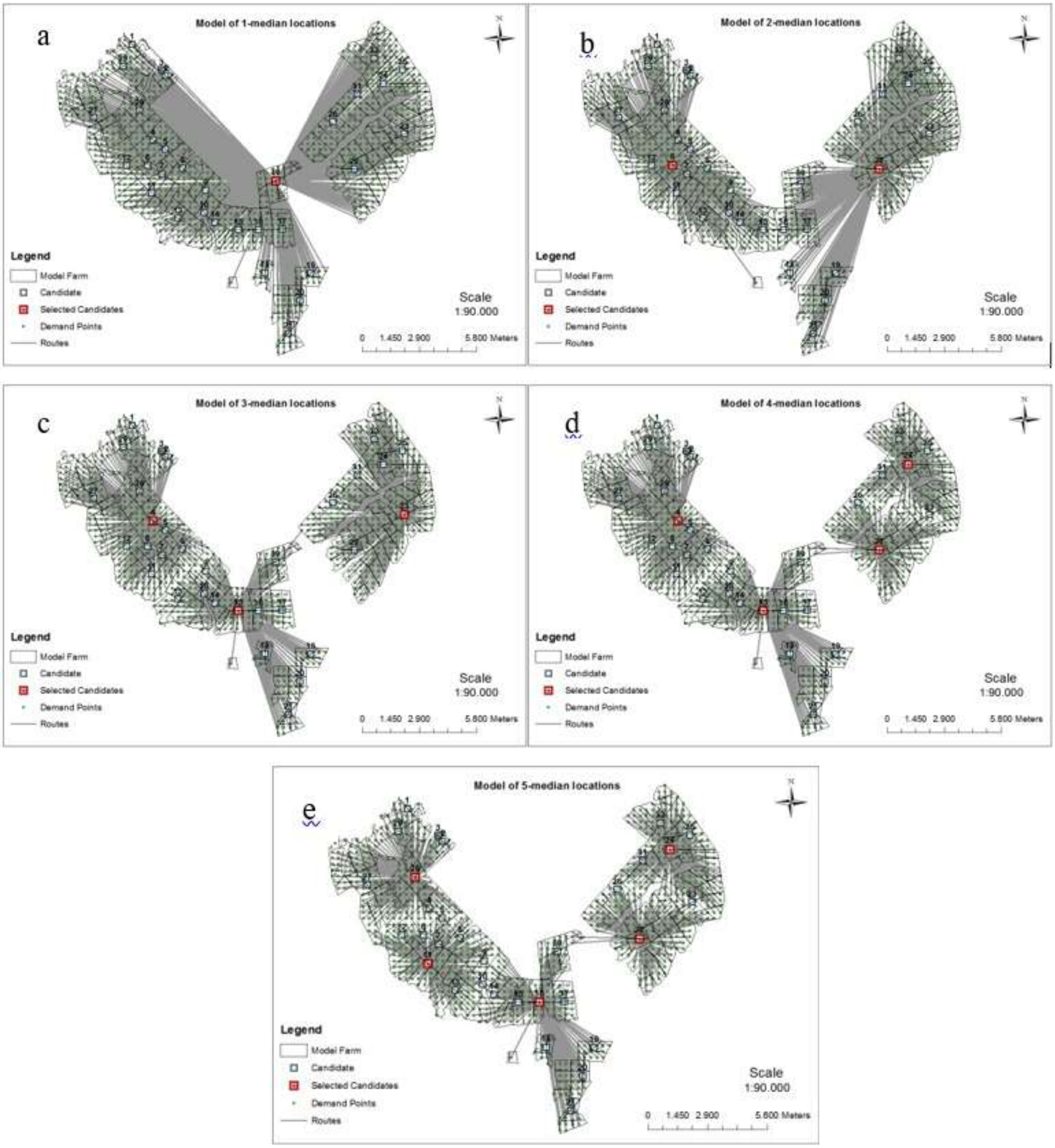

Figure 3. Simulation results, using the p median model, of setting up one to five aerodromes (a to e).

fertilization activity is three.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Optimum plot size for experiments with papaya genotypes in field

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The objective of this study was to determine a suitable plot size for field experiments with papaya genotypes. Two experiments were carried out using a randomized complete block design with 11 and 12 papaya genotypes, respectively. In both experiments, plots consisted of one row, with 10 plants each. Spacing between rows was 3.5 m, with 1.5 m between plants. The characteristic evaluated was fruit production in t ha^{-1} in first year of cultivation, and the basic unit used was one plant. Suitable plot size was estimated using Lin and Binns, and Hatheway's methods. These methods are complementary and should be used together in the determination of the optimum plot size. The results of these tests showed that the optimum plot size for the evaluation of yield in papaya was four plants by plot with four replications each assuming 30% of the precision for establishing differences among the means of two genotypes.

Key words: Breeding, *Carica papaya*, intrablock correlation.

INTRODUCTION

Papaya is one of the main tropical fruits produced in the world. World papaya production reached 12.6 million tonnes in 2014, with India, Brazil, Indonesia, Nigeria and Mexico as its main producers (FAO, 2014).

Field experimentation with papaya has been carried out quite frequently in order to implement new technologies for the crop (Cortes et al., 2017; Santos et al., 2017) and to evaluate plant productivity (Oliveira et al., 2014; Dantas et al., 2015; Luz et al., 2015) and disease resistance (Poltronieri et al., 2017) of new genotypes. In experiments carried out to evaluate the productivity of new genotypes, Oliveira et al. (2014) used 5 plants per

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plot, while Dantas et al. (2015) used 6 plants per plot and Luz et al. (2015) 10 plants per plot, both with 4 replications in a randomized block design. This variable number suggests the convenience in carrying out a sound investigation to establish optimum plot size for papaya field experiments.

Several authors emphasize the importance of plot size determination in experiments for the evaluation of new genotypes obtained in plant breeding (Leite et al., 2006; Casler, 2013; Silva et al., 2016). Many methods have been assessed with this aim, either from blank test (Meier and Lessman, 1971; Paranaíba et al., 2009; Lorentz et al., 2012) or from experiments involving analyses of variance (Pimentel-Gomes, 1984; Lin and Binns, 1984; Barbosa et al., 2001). The method proposed by Lin and Binns (1984) is used to estimate intra-block correlation and heterogeneity index, which is easier to perform than the methods involving blank assays. This method is commonly used in conjunction with Hatheway's method to determine optimum plot size in experiments involving the evaluation of genotypes as has been assayed in bean (Storck et al., 2007) and soybean (Storck et al., 2009).

Khan et al. (2017) mention that, Hatheway's method is one of the best options for calculating the size of the plot, since this method determines the optimum plot size considering the experimental design, the number of treatments, the coefficient of variation, the expected difference between treatments and the number of replicates (Alves and Seraphim, 2004). This is because there is no linear relationship between the variability measured by the coefficient of variation and the optimum plot size (Khan et al., 2017), and therefore the methodology used should consider this factor as Hatheway's method does (Alves and Seraphim, 2004).

In papaya, the experimental plot size has been determined for comparing seedlings performance in greenhouses (Lima et al., 2007; Brito et al., 2012; Celanti et al., 2016 a, b) and also for adult plants in the open field (Schmildt et al., 2016), but all these works were performed with blank test, test that evaluates only one genotype at a time.

The aim of this work is to determine the optimum plot size for experiments involving several genotypes of papaya in the field, using the methods proposed by Lin and Binns (1984) and Hatheway (1961).

MATERIALS AND METHODS

The plot size determination was realized for two papaya experiments which are part of the partnership between the Federal University of Espírito Santo and the company Caliman Agrícola S.A. aiming to obtain new papaya cultivars (Silva et al., 2017). The experiments were performed from 15 July 2012 to 15 July 2013 at the Santa Terezinha Farm of Caliman Agrícola S.A., sited 150 km away from the town of Vitória, in the state of Espírito Santo (ES), Brazil (19°11' 49" S, 40°05' 52" W, at an altitude of 30 m.a.s.l.).

In both experiments, the experimental design was a randomized block with four replications. The first experiment was carried out with 11 papaya genotypes (New hybrids: CR3 x SSAM; CR3 x UENF/Caliman 01; CR3 x JS 12; CR3 x Improved Sunrise Solo Line 72/12; CR3 x Progeny Tainung; CR1 x Sekati; CR1 x Progeny Tainung; CR1 x JS 12; CR2 x SS32; JS12 x SSAM. Commercial hybrid: UENF/Caliman 01), while in the second experiment 12 genotypes were used (New hybrids: CR1 x São Mateus; CR1 X Improved Sunrise Solo Line 72/12; CR2 x São Mateus; CR3 x São Mateus; CR1 x Maradol; CR2 x Sekati; CR3 x Maradol; CR1 x UENF/Caliman 01; CR3 x Sekati; CR1 x SSAM; BSA x Golden PC. Commercial variety: Golden THB). In order to obtain the new hybrids, the genotypes CR1, CR2, CR3, JS12, Sekati and Maradol are from the Formosa group and the other genotypes are from the Solo group.

The plots consist of one row of 10 plants. Spacing between rows was 3.5 m, with 1.5 m between plants. The characteristic evaluated was fruit production in t ha^{-1} in the first year. The basic unit (BU) was one plant. Based on Lin nd Binns (1984), the statistical model adopted in both experiments, referring to a randomized block design, was (Equation 1):

$$Y_{ij} = m + g_i + b_j + e_{ij} \quad (1)$$

Where: Y_{ij} = the yield obtained from genotype i, in block j; m = general mean; g_i = effect from genotype i (i = 1, 2, ..., I genotypes); b_j = effect from block j (j = 1, 2, ..., J blocks); e_{ij} = experimental error.

From the adopted statistical model, an analysis of variance was carried out considering the fixed model (Cruz, 2016) according to Table 1. From the analysis and components of variance (Table 1), the intra-block correlation ($\hat{\rho}$) was estimated according to the Equation 2:

$$\hat{\rho} = \frac{\sigma_b^2}{\sigma_b^2 + \sigma^2} \quad (2)$$

From of Equation 2, the heterogeneity index (b) of Lin and Binns (1984) was determined according to the Equation 3:

$$b = \frac{\log[I - (I-1)(I-\hat{\rho})]}{\log(I)} \quad (3)$$

Where: log = logarithm to the base 10; I = treatments number; $\hat{\rho}$ = the intra-block correlation.

From the analysis of variance, the CV_{exp} that is the estimate of the experimental coefficient of variation in percentage, was determined by Equation 4:

$$CV_{exp} = 100\frac{\sqrt{MSR}}{\bar{Y}} \quad (4)$$

Where: MSR = mean square residual showed in the Table 1; $\bar{Y}$ = the general mean.

The plot size (X_0) in the evaluation of yield in the papaya was calculated using Hatheway's method (Hatheway, 1961), by Equation 5:

Table 1. Variance analysis and mathematical expectations of the mean squares to fixed model.

Source of variation	Degrees of freedom	Mean square (MS)	Expectation (MS)	F
Blocks (B)	$(J-1)$	MSB	$\sigma^2 + I\sigma_b^2$	-
Genotypes (G)	$(I-1)$	MSG	$\sigma^2 + \frac{J}{I-1}\sum_i c_i^2$	$\frac{MSG}{MSR}$
Residual (R)	$(J-1)(I-1)$	MSR	σ^2	-

σ_b^2 = variance between blocks obtained by $\sigma_b^2 = (MSB - MSR)/I$; σ^2 = variance relative to the experimental error.

$$X_0 = \sqrt[b]{\frac{2(t_1 + t_2)^2 CV_{exp}^{\ 2}}{J\,d^2}} \quad (5)$$

Where: b and CV_{exp} are defined by Equations 3 and 4, respectively; J = the number of replications considered; d = the difference between genotypes mean to be detected as significant at the 5% probability, and expressed as a percentage of the expected detected mean; t_1 = the critical value of Student's t distribution for the level of significance of the test (type I error) of α = 5% (bilateral test at 5%), with df degrees of freedom and t_2 = the critical value of the Student t distribution, corresponding to 2 (1-*P*) (bilateral test), where *P* is the probability of obtaining a significant result, that is, the power of the test (*P* = 0.80, in this study), with df degrees of freedom.

The tabulated values of t distribution were obtained with residual degrees of freedom, according to the treatments I and J replications, where $df = (I-1)(J-1)$ for a randomized block design. As reported by Cargnelutti Filho et al. (2014), the parameter d measures the precision, being that a small percentage of d indicates greater precision; in other words, small differences between treatments means will be considered significant. In the simulations, the criteria for combinations take into consideration d values as 20, 30 and 40% and the other criteria were used according to Celanti et al. (2016b): the lowest number of treatments was three (I = 3), whereas the detection of the difference between two means can now be made by analysis of variance; the smallest number of replications was 2 (J = 2), because this is the minimum for detecting the experimental error; the I treatments and J replications were combined to provide a minimum of 20 plots per experiment, according to Pimentel-Gomes (2009) recommendations; since this is a discrete random variable, the optimum plot size was presented by integer number, rounding to the closest whole number.

For a better understanding of the variability of the studied genotypes, the comparison of the average productivity was shown by Scott-Knott's clustering test. Statistical analyses were performed using Genes (Cruz, 2016) and Excel® software.

RESULTS AND DISCUSSION

The coefficients of variation in this experiment were CV_{exp} = 19.92 and 26.36% in Experiments 1 and 2, respectively (Table 2). Other researchers also found CV_{exp} with values between 20 and 30% in the evaluation of papaya genotypes (Oliveira et al., 2014; Dantas et al., 2015; Luz et al., 2015). In both experiments, there was a significant difference between the means for the assayed genotypes with productivity of the first trial of 79 and of 66 t ha^{-1} in the second experiment, always for the first year of cultivation. There was a significant difference between the means by the Scott-Knott grouping test in two experiments (Table 3).

Productivity ranged from 55 t ha^{-1} (for UENF/Caliman 01 genotype to 97 t ha^{-1} and CR2 x SS32 genotype in experiment 1) to 37 t ha^{-1} (for Golden THB genotype to 104 t ha^{-1} and CR3 x Maradol genotype in experiment 2). Most genotypes have a productivity average above Brazilian and world average of 50 and 31 t ha^{-1}, respectively (FAO, 2014) are higher than the productivity of other genotypes verified in different studies (Oliveira et al., 2014; Dantas et al., 2014). Consequently, from the point of view of the experimental quality, the results of both experiments present credibility for study of the determination of optimum plot size.

The analyses of the data show that intra-block correlation ($\hat{\rho}$) was 0.1809 and 0.1045 in experiments 1 and 2, respectively, which allowed to obtain soil heterogeneity index (b) 0.5693 and 0.6901, respectively (Table 2). As recommended by Lin and Binns (1986) when b value is between 0.2 and 0.7, the researcher should plan a suitable combination between the number of replicates and plot size.

In research involving yield production of papaya in the field, one of the researcher's wishes is also to reduce the experimental area. This can be obtained, according to equation 5 presented by Hatheway (1961): through, reducing the value of t_1 which is achieved by increasing the number of treatments and/or repetitions; increasing the number of repetitions (J); by decreasing the accuracy or increasing the difference between the means (increasing the value of d). These options can be taken individually or all together as presented in Table 4, when b = 0.6307 and CV_{exp} = 23.14%.

Table 2. Number of genotypes (ng), genotypes mean square (GMS), blocks mean square (BMS), residue mean square (RMS), productivity (Prod, in t ha^{-1} in the first year), intra-block correlation ($\hat{\rho}$), heterogeneity index (b) and coefficient of variation (CV_{exp} , in %) in two experiments of papaya genotypes following an experimental randomized blocks design.

Experiment	ng	BMS	GMS	RMS	Prod	$\hat{\rho}$	b	CV_{exp}
1	11	856.83	807.66**	249.86	79.34	0.1809	0.5693	19.92
2	12	727.54	1,834.30**	303.13	66.05	0.1045	0.6921	26.36
Average	-	-	-	-	72.70	0.1427	0.6307	23.14

** significant at 1% probability by F test.

Table 3. The first year average productivity of the genotypes evaluated in two papaya experiments.

Experiment 1		Experiment 2	
Genotype	**Average**	**Genotype**	**Average**
CR3 x SSAM	73.62[b]	CR1 x São Mateus	58.54[b]
CR3 x UENF/Caliman 01	93.52[a]	CR1 x Improved Sunrise Solo Line 72/12	60.81[b]
CR3 x JS 12	84.29[a]	CR2 x São Mateus	64.56[b]
CR3 x Improved Sunrise Solo Line 72/12	94.21[a]	CR3 x São Mateus	64.03[b]
CR3 x Progeny Tainung	87.02[a]	CR1 x Maradol	86.84[a]
CR1 x Sekati	81.33[a]	CR2 x Sekati	96.01[a]
CR1 x Progeny Tainung	56.35[b]	CR3 x Maradol	104.18[a]
CR1 x JS 12	76.89[b]	CR1 x UENF/Caliman 01	45.56[b]
CR2 x SS32	97.12[a]	CR3 x Sekati	80.14[a]
JS12 x SSAM	73.32[b]	CR1 x SSAM	49.98[b]
UENF/Caliman 01	55.06[b]	BSA x Golden PC	45.41[b]
		Golden THB	36.59[b]

Averages of genotypes followed by the same letter but do not differ by Scott-Knott's cluster test at 5% probability.

When working with d, the optimum plot size (X_0) is larger and the value of d is lower (higher precision) considering the same number of treatments and replications (Table 4). In the experiment, considering 10 genotypes and 4 replications, X_0 is 2, 4 and 16 plants by plot for d = 40, 30 and 20%, respectively. It seems reasonable for the researcher to assume a value of d = 30% because any further increase in the accuracy will result in a large increase in plot size. Similar results were observed by other researchers using Hatheway's method (Muniz et al., 2009; Celanti et al., 2016b).

Hence, assuming d = 30%, and if the researcher intends to use 10 genotypes, the optimum size of two plants per plot in seven replications implies the use of 14 plants per genotype in the experiment. In order to keep d = 30%, the researcher could use 3 plants per plot and five replications (15 plants per genotype in the experiment), or 7 plants per plot and three replications (21 plants per genotype) (Table 4). Therefore, for the same precision, smaller plots and larger number of replications are more efficient for the use of the same experimental area, as observed by Muniz et al. (2009) in eucalyptus and Souza et al. (2015) in sunflower.

Concerning the number of genotypes involved, with d = 30% and four replicates, X_0 is four plants per plot when evaluating 8 to 35 genotypes in the experiment in a randomized blocks design (Table 4). Schmildt et al. (2016) suggested 6 plants per plot using 3 replications and a difference of 30% between means (d), similar to the results obtained in this work using 25 to 35 genotypes per block (Table 4). However, for better use of the experimental area, it is recommended to design experiments with four replications and four plants per plot because this will require 16 plants per genotype, while using only 3 replicates of 6 plants per plot it require 18 plants per genotype.

From the results presented in Table 4 we deduce, larger changes in the optimum plot size with changes of d and J than with changes of I, as observed by other researchers with different crops (Storck et al., 2007; Cargnelutti Filho et al., 2014; Souza et al., 2015). The results showed that Lin and Binns (1984) and Hatheway (1984) methods should be used together as observed by Storck et al. (2007, 2009). The results of the present

Table 4. Optimal size of plots (X_0), in number of plants per plot estimated by the method of Hatheway in an experimental randomized blocks design, in different scenarios formed by the combinations of I genotypes, J replications, and d differences between the means of the genotypes, to be detected as significant at the 5% probability, expressed as a percentage of the overall mean of the experiment (precision) for yield produced by different papaya genotypes.

I	J	d = 20%	d = 30%	d = 40%	I	J	d = 20%	d = 30%	d = 40%
3	7	7	2	1	15	2	52	14	6
4	5	13	4	1	15	3	25	7	3
4	6	9	2	1	15	4	15	4	2
4	7	7	2	1	15	5	10	3	1
5	4	18	5	2	15	6	8	2	1
5	5	12	3	1	15	7	6	2	1
5	6	9	2	1	20	2	49	14	5
5	7	7	2	1	20	3	24	7	3
6	4	17	5	2	20	4	15	4	2
6	5	11	3	1	20	5	10	3	1
6	6	8	2	1	20	6	8	2	1
6	7	6	2	1	20	7	6	2	1
7	3	29	8	3	25	2	48	13	5
7	4	17	5	2	25	3	23	6	3
7	5	11	3	1	25	4	14	4	2
7	6	8	2	1	25	5	10	3	1
7	7	6	2	1	25	6	7	2	1
8	3	28	8	3	25	7	6	2	1
8	4	16	4	2	30	2	46	13	5
8	5	11	3	1	30	3	23	6	3
8	6	8	2	1	30	4	14	4	2
8	7	6	2	1	30	5	10	3	1
9	3	27	7	3	30	6	7	2	1
9	4	16	4	2	30	7	6	2	1
9	5	11	3	1	35	2	46	13	5
9	6	8	2	1	35	3	23	6	3
9	7	6	2	1	35	4	14	4	2
10	2	60	17	7	35	5	10	3	1
10	3	26	7	3	35	6	7	2	1
10	4	16	4	2	35	7	6	2	1
10	5	11	3	1					
10	6	8	2	1					
10	7	6	2	1					

study are useful to guide researchers in papaya field experiments with several genotypes, since there is no standard number of plants by plot (Oliveira et al., 2014; Luz et al., 2015; Silva et al., 2017).

Conclusion

The optimum plot size for field genotypes papaya experiments is four plants by plot, using four replications assuming a precision of 30% in the difference among means. Lin and Binns (1984) and Hartheway (1984) methods are complementary and should be used together in the determination of the plot size.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Performance of five potato varieties with regards to growth and production of mini-tubers under an aeroponic system in central highlands of Kenya

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There is limited information on the performance of Kenyan potato varieties under aeroponic systems. Experiments were therefore carried out at the Kenya Agricultural Research Institute (KARI), Tigoni, under an aeroponic system in 2012 and 2013 to evaluate the growth and mini-tubers production of five varieties commonly grown in Kenya and differ in vegetative and reproductive characteristics. The experiment was set up in a randomized complete block design (RCBD) replicated three times. Plant growth expressed by plant height differed among the varieties and these differences became more pronounced with plant age. The effect of variety on number of mini-tubers per plant and total weight of mini-tubers per plant was significant. The number of mini-tubers per plant ranged from 62.2 to 19.2 in season 1 and 56.8 and 17.1 in season 2. Correlations between the number of mini-tubers per plant and the total weight of mini-tubers per plant with days to tuberization, days to senescing, days to maturity, plant height measured at 80 days after transplanting and plant vigor, were positive and significant. The correlation between the number of mini-tubers per plant and total weight of mini-tubers per plant was also positive and significant. It is concluded that mini-tubers production under aeroponic system was variety dependent with Tigoni, Asante and Kenya Mpya being the most productive varieties irrespective of the season. Evaluation of a variety's suitability/adaptability to the system is therefore necessary to determine the most adapted varieties before embarking on large scale production as this will ultimately affect production costs, with higher yielding varieties more likely to result in lower mini-tubers production costs.

Key words: Aeroponics, mini-tuber production, vegetative growth.

INTRODUCTION

Potato is an important food security and cash crop in Kenya (Kaguongo et al., 2013). However, scarcity of quality seed is a perennial problem and a major hindrance to improvement of potato production in the country (MoA, 2009; MoALF, 2016). To boost production of seed, various strategies have been put in place including introduction of a mini-tubers production step during the early stages of commercial seed multiplication.

Mini-tubers have the combined advantages of *in vitro* plantlets (disease-free, rapid and year-round production) and tubers (easy storage and transport) and lack some of the disadvantages of *in vitro* tubers (low multiplication rate, small size and poor recovery from environmental stresses). The mini-tubers production phase should ideally generate a large number of mini-tubers so as to contribute not only to quicker bulking of seed and reduced exposure to diseases but also to reduce seed costs.

Methods of mini-tubers production include, high density cultures with non-destructive harvests (Lommen and Struik, 1992), hydroponic systems using different inert substrates, deep water culture systems (Chang et al., 2000; Lommen, 2007), the Nutrient Film Technique (NFT) system (Wheeler et al., 1990; Medeiros et al., 2002) and hydroponic systems with recirculating nutrient solutions in low volume substrates (Struik and Wiersema, 1999). Mini-tubers can also be produced in greenhouses in beds (Wiersema et al., 1987; Tierno et al., 2014) or in containers using different substrate mixtures (Struik and Wiersema, 1999).

Conventional substrate-based methods for pre-basic mini-tuber seed production usually have low productivity with a low average multiplication rates depending on the type of mother plant used and type of production system which contributes to increasing the production costs of a seed potato production program. Substrate based methods also have the inherent risk of infection from soil borne diseases and require sterilization which can be costly. The NFT system can suffer from deficient O_2 concentrations due to consumption by roots and microorganisms (Gislerod and Kempton, 1983), while deep-water culture systems can be prone to inadequate aeration to the root system (Jackson, 1980; Lommen, 2007).

To improve the efficiency of mini-tubers production newer technologies such as aeroponics have been introduced and are currently being promoted as one of the solutions for rapid and efficient production of mini-tubers (Otazu, 2010; Lung'aho et al., 2010; Muthoni et al., 2011; and Mbiyu et al., 2013). The advantages of aeroponics include optimization of root aeration resulting in a high yield of mini-tubers as compared to hydroponics (Soffer and Burger, 1988); limited water use, nutrient recirculation, and good monitoring of nutrients and pH (Otazu, 2010). Multiplication rates in aeroponics systems are reported to be significantly higher than those obtained in conventional systems (Ritter et al., 2001; Farran and Mingo-Castel, 2006; Teirno et al., 2014). The technology has the potential of reducing at least one generation of seed multiplication in the field, with lower costs and maintains high phytosanitary quality (Nichols, 2005). Production of mini-tubers can be increased and production costs lowered using aeroponics (Scherwinski-Pereira et al., 2009). Aeroponic systems have also been reported to have high production efficiency per unit area (> 900 mini-tubers m^{-2}) (Mateus-Rodriguez et al., 2013); (1268 to 1396 mini-tubers s m^{-2}) (Rykaczewska, 2016).

Despite the many advantages of the technology, there is little information on the comparative performance of different varieties under aeroponics production systems in Kenya. This study was therefore, undertaken with the objective of evaluating the performance of growth and production of mini-tubers of five varieties commonly grown in Kenya under an aeroponic production system.

MATERIALS AND METHODS

Study period and location of the experiments

This study was carried out during two growing seasons (season one: March to September, 2012 and season two: October, 2012 to April, 2013) at Kenya Agricultural Research Institute - Tigoni (KARI-Tigoni), located 10°8'S and 36°40'E, at an altitude of 2100 m, 4 km South East of Limuru town in Kiambu County of Kenya.

Preparation of planting materials

In vitro plantlets of 5 varieties (Tigoni, Asante, Dutch Robijn, Desiree and Kenya Mpya) differing in vegetative and reproductive characteristics were used for the experiments (Table 1). The plantlets had been previously initiated through meristem and shoot tip culture from plants that had been certified as disease free. The plantlets were then routinely sub-cultured every 3 to 4 weeks on normal propagation media with agar as the gelling agent (Espinoza et al., 1992) in Kilner jars using nodal cuttings in order to attain sufficient quantities for the experiments. The cultures were then incubated for 3 weeks in a growth room with temperatures of 22 ± 2°C, a 16-h photoperiod and a light intensity of 3,000 lux provided by Philips T12 'cool white' fluorescent tubes. The plantlets were then transplanted to crates containing sand under screen house conditions and regularly fertigated with ½ strength aeroponic nutrient solution (Table 2). When the plantlets were 14 days old, they were carefully transplanted into the aeroponics unit. At this time, the plantlets were approximately 10-15 cm tall with a root length of about 2.5 to 5.0 cm.

Description of the aeroponics system

The design of the aeroponic system was as described by Otazu (2010) but with some modifications. The aeroponic system consisted of an insect proof screen house measuring 9.4 m x 8.4 m and covered with clear sheets and a shade net on stop of the roof to lower the temperatures. The aeroponic boxes measured 6.4 m length x 1.5 m width x 0.95 m depth. The boxes were insulated with styrofoam to prevent developing roots from being affected by temperature variations in the screen house. The boxes had side

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Table 1. [1]Main characteristics of varieties used in the study.

Variety	Pedigree	Genetic gain in pedigree	Plant characteristics	Days to maturity
Tigoni (391391.13)	378493.15 × bk precoz	Andigena	Vigourous upright growing plants, can grow upto 1 m	120
Asante (391391.20)	378493.15 × bk precoz	Andigena	Vigourous plants upright growing plant, can grow upto 1 m	110
Desiree	Urgenta × Despesche	Tuberosum	Relatively short plants.	90
Dutch Robjin	Rode Star × Preferent	Tuberosum	Relatively short plants	100
Kenya Mpya (393371.58)	387170.16 × 387170.9	Andigena	Vigourous plants, can grow up to I metre	130

[1]Under field conditions in Kenya; Source: Onditi et al. (2013); NPCK (2013).

Table 2. Composition of 500-L full strength nutrient solution used in the study for mini-tubers production.

Nutrient	Quantity (g)	
	Half strength	Full strength
KNO3	126	252 g
$Ca(NO3)_2$	59	118 g
KH_2PO_4	34	68 g
$MgSO_4$	123	246 g
Fe(EDTA- Fe 6%)	4.5	9 g
[1]Microsol B	6	12 g

[1]The formulation of Microsol B is: Fe (5.0%), Cu (2.5%), Zn (1.0%), B (2.5%), Mo (0.035%) and Mn (2.5%); [2]Mention of a trade name does not constitute an endorsement or recommendation; [3]pH of the nutrient solution was maintained at 5.7

windows to permit harvesting of mini-tubers and monitoring of the growth of plants and the proper functioning of nebulizers. The inside of the boxes was lined with black plastic to prevent exposure of the root system of the plant to light. The internal bottom (floor) of the boxes was also lined with thick plastic (1 mm) to avoid leakage of nutrients. The external top lining was white plastic, so as to minimize accumulation of heat and also permit greater illumination of the growing plants. The internal lining of the top covers of the boxes was also lined with thin plastic cover. A similar thin black plastic was used to cover the windows of the boxes as double curtains. The internal curtain prevented nebulized nutrient solution from escaping from the boxes, while the external curtain prevented the entry of light into the boxes. The boxes were slanted towards the nutrient tank to allow excess nutrients to return back into the tank by gravity. To facilitate this, the nutrient tank was installed below ground level so that the lower part of each box was above the upper portion of the tanks.

The fertigation system consisted of an underground plastic tank (1000 L) in which the nutrient solution was stored/held for circulation though the closed system. The nutrient solution (Table 1) was pumped into growth chambers (boxes) using a system of pipes and nebulizers. The nebulizers in the boxes were spaced every 60 cm. The fertigation system was controlled by a timer and mists of nutrient solution were sprayed onto the growing roots for 5 min after every 15 min during the day and 5 min after every 45 min at night throughout the experiment This system was powered by electricity, but a generator was used in case of electricity failure. Measurements and corrections of the pH and electrical conductivity (EC) for the nutrient solution were done weekly. The pH was maintained in a range of 5.5 to 6.5 and the EC between 1.5 and 2.0 d Sm^{-1}. Fresh nutrient solution was prepared every month.

The lids of the growth chambers/boxes had small holes (25 mm diameter) through which a plastic pipe (25 mm in dimeter and 70 mm in length) was inserted such that it was flush with the lid of the growth chambers. The plantlets were then placed in the pipes (one plant in each pipe) with the roots hanging inside the box such that nutrients would reach the roots when applied. The upper part of the plantlet (approximately 3-8 cm) was left protruding above the pipe to ensure that the plant was able to photosynthesize. The plantlets were held firmly in an upright position using masking tape. The masking tape also served as a light blocker as it was used to cover each hole thus preventing light from penetrating into the box. The lowest leaf of the plant was cut off every 2 weeks for the next 2 months. This allowed the plants to be pushed deeper down into the growth chamber (equivalent to hilling in conventional potato production) to promote stolon development, this was done once a week for only 4 weeks after transplanting. As the plants grew, they were trained using a nylon trellises and tied with nylon for support.

Experimental design and data collection

The experiment was set up as a randomized complete block design (RCBD) replicated 3 times. Transplants of each of the 5 varieties were placed in an aeroponic box at 17 x 18 cm resulting in a plant density of 32 plants m^{-2}. Each box represented an experimental unit. Data on plant height was taken starting at 30 days after transplanting (DATP) into the aeroponic unit and thereafter at 10-day intervals until the earliest maturing variety started to senesce. A total of 6 measurements were made. Tubers were harvested sequentially starting at 40 days after transplanting, depending on the variety and thereafter every 10 days. The harvest criterion was to remove all tubers which were larger than 15 mm in diameter except during the final harvest when all tubers were removed from the plant regardless of size. During each harvest, the mini-tubers were graded into three sizes: size I (≤5 g), size II (5.1-12 g), and size III (12.1-20 g). The number of tubers in each size group and their weights was then recorded. The average number of mini-tubers s per harvest was computed by dividing the total number of mini-tubers harvested by the number of harvests per variety in a season. Plant vigor was recorded at 60 DATP on a five point scale where, a score of 1 signified a variety least vigorous, 3 signified a variety vigorous and 5 signified a variety very vigorous. Plants were considered to have senesced when 90% of the leaves turned yellow. Standard practices for control of diseases and pests were carried out during the experiment.

Data analysis

Data for each season was analyzed separately. Differences between varieties were determined by analysis of variance (ANOVA) procedures for a randomized complete block design experiment using GenStat 12th edition statistical software (GenStat, 2009) at $p\leq0.05$. When F values were significant, treatment means were compared using Fischer's protected least significant differences (LSD) test at $p\leq0.05$. The relationship between mini-tubers yield variables was determined using correlation analysis.

RESULTS

Plant height and vigor

The effect of variety on plant height was significant for all plant heights measured between 30 and 80 DATP in both seasons (Figure 1). At 80 DATP, varieties Tigoni and Asante were significantly taller than the other varieties during both seasons. During the same period, variety Tigoni was almost twice as tall as variety Desiree. Plants tended to be taller in season 2 than in season 1. The difference in plant height between the tallest and the shortest variety became more pronounced with time. For example at 30 DATP, the difference was 6 cm in season 1 and 10.1 in season 2. However, at 70 DATP, the difference was 37 cm in season 1 and 43 cm in season 2. During both seasons, the varieties Tigoni, Asante and Kenya Mpya were rated as very vigorous with high amounts of plant foliage whereas Dutch Robjin and Desiree were rated as vigorous with moderate amounts of foliage.

Days to tuberization, senescing and maturity

The number of days to tuberization were shorter in season 1 than in season 2 whereas, days to senescing and maturity were longer during season 1 as compared to season 2 (Table 3). The difference in days to tuberization during the first and second season was observed in all the 5 varieties but was more pronounced in varieties Tigoni, Asante and Kenya Mpya which had at least a 9 day difference in days to tuberization between the 2 seasons. Variety Desiree took the least number of days to tuberize by about 1-7 days in season 1, and 3-14 days in season 2 as compared to the other varieties. The varieties senesced in between 102.7-168.0 days after transplanting, in season 1 and in between 94.7 -153.0 days in season 2. On average, all varieties matured about 14 days after they started to senesce. Variety Kenya Mpya showed the longest maturity period of 180.3 days during season 2 and 190.3 days during season 1. In contrast, variety Desiree showed the earliest crop maturity of 109.3 days after transplanting in season 2 and 116.3 days after transplanting in season 1.

Number of mini-tubers harvests per season, mini-tubers per plant and mini-tubers > 5 g per plant

The varieties showed variability in the number of mini-tubers harvests per production season (Figure 2). All the varieties had 2 less harvests during the second season as compared to the first season. In season 1, the number of harvests per variety ranged from 9 to 15, while in season 2, it ranged from 7 to 13. Varieties Desiree and Dutch Robijn had the lowest number of mini-tubers harvests in both seasons. The number of mini-tubers harvested was generally low during the first harvest but increased with each harvest, peaking at the 5-7th harvest depending on the variety and season. Thereafter, the number of mini-tubers harvested gradually declined until the last but one harvest and increased again at the final harvest. For all the varieties, the number of mini-tubers harvested at the final harvest was greater than that harvested in each of the previous harvests and ranged from 3.8 to 10.2 mini-tubers per plant in season 1 and 4.2 and 10.6 mini-tubers s per plant in season 2.

Figure 3 shows that number of mini-tubers per plant was higher in season 1 than season 2 for all varieties with a difference that ranged from 2.1 (Desiree) to 7.4 (Asante) mini-tubers per plant. Varieties Tigoni and Asante had the highest number of mini-tubers per plant, at 62.2 and 51.3, respectively during season 1 and 56.8 and 43.9, respectively, in season 2. Desiree performed poorly with less than 20 mini-tubers per plant in both seasons. The number of mini-tubers per plant of variety Tigoni was more than 3 times that of variety Desiree in both seasons.

Figure 4 shows that the effect of variety on the number of mini-tubers >5 g was significant in both seasons. The number of mini-tubers >5 g varied between 15.9 and 53.8 mini-tubers per plant in season 1 and between 13.3 and 50.5 mini-tubers per plant in season 2. Varieties Tigoni, Asante and Kenya Mpya significantly out yielded the

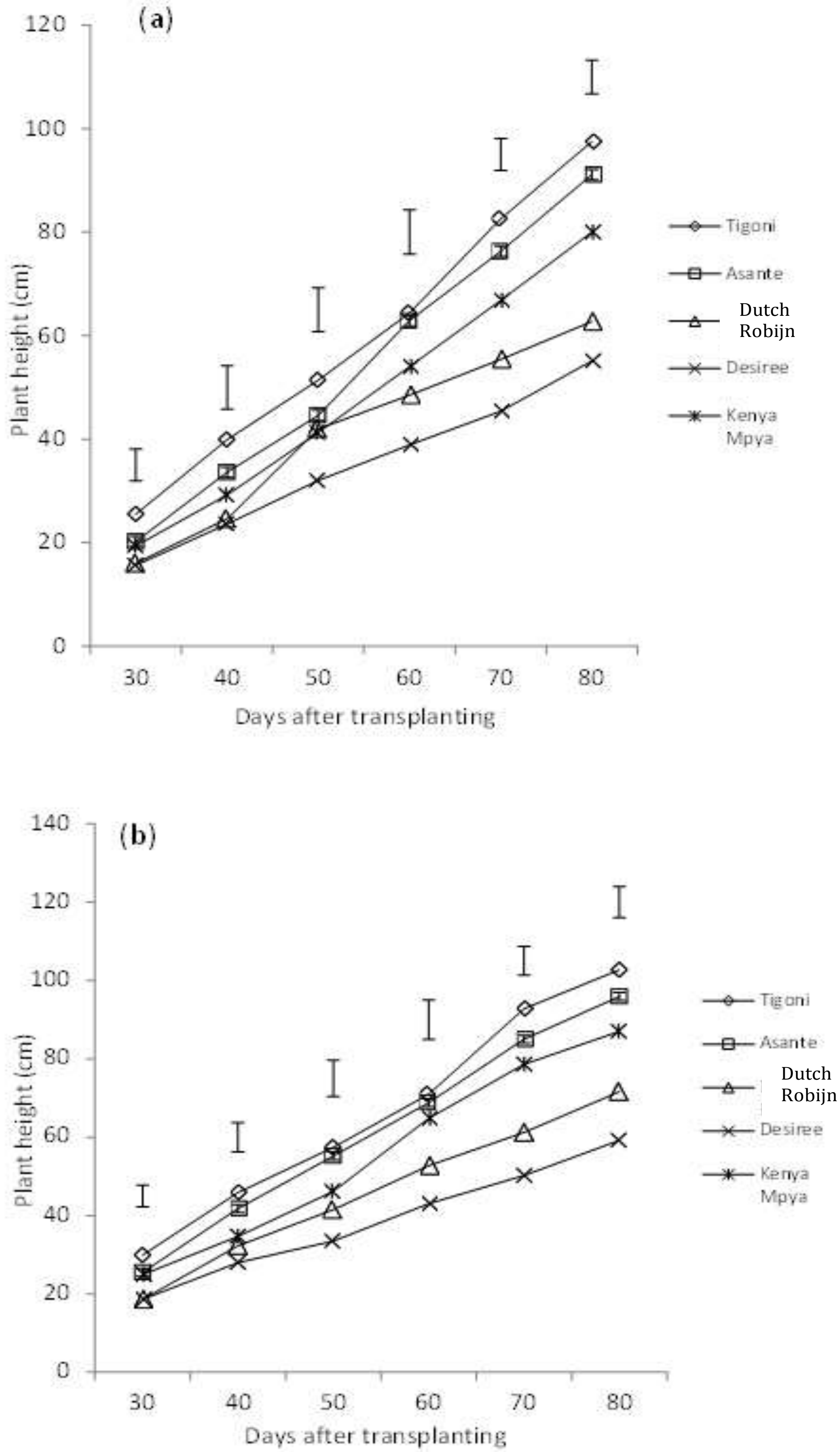

Figure 1. Plant height (cm) during the first 80 DAP of five varieties planted in season 1 (a) and season 2 (b).

Table 3. Effect of variety on days to tuber induction, days to senescing and day to maturity.

Variety	Days to tuberization		Days to senescence		Days to maturity	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Tigoni	43.4	34.4	160.0	151.3	174.7	165.3
Asante	40.6	31.3	140.7	133.3	157.7	150.3
Dutch Robjin	35.1	28.3	113.0	106.0	130.3	120.7
Kenya Mpya	46.4	35.5	168.0	153.0	190.3	180.3
Desiree	32.0	27.5	102.7	94.7	116.3	109.3
Mean	39.5	31.4	136.9	127.7	153.9	145.2
LSD (p=0.05)	2.5	2.4	7.1	5.2	4.6	5.0
CV (%)	3.4	4.0	2.7	2.1	1.6	1.8

[1]Average of 10 plants.

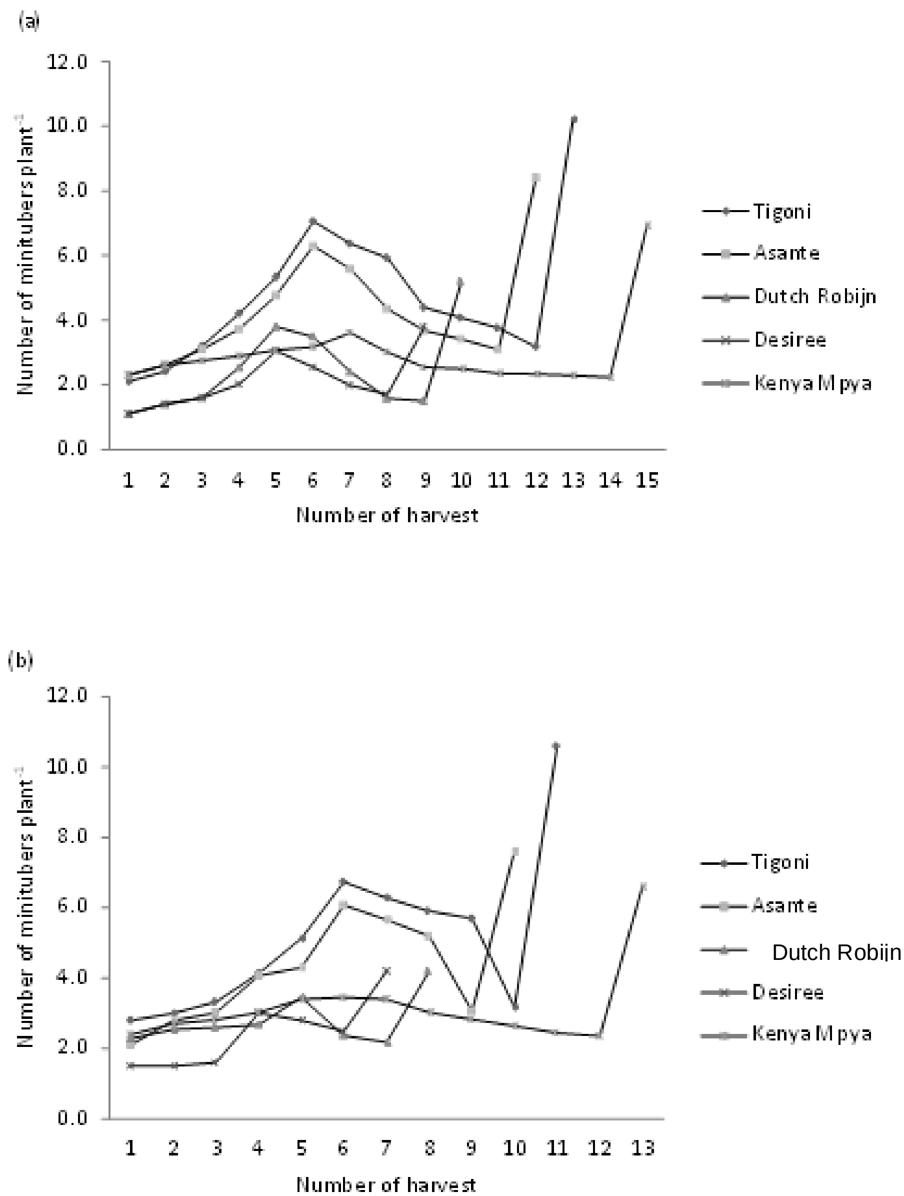

Figure 2. Number and distribution of minitubers during each harvests in season 1 (a) and season 2 (b).

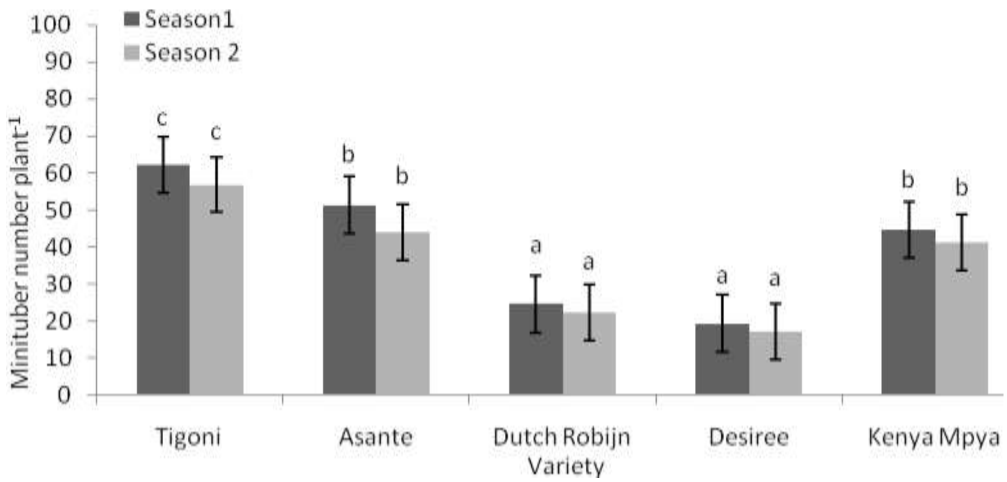

Figure 3. Effect of variety on minituber production. Error bars show LSD values.

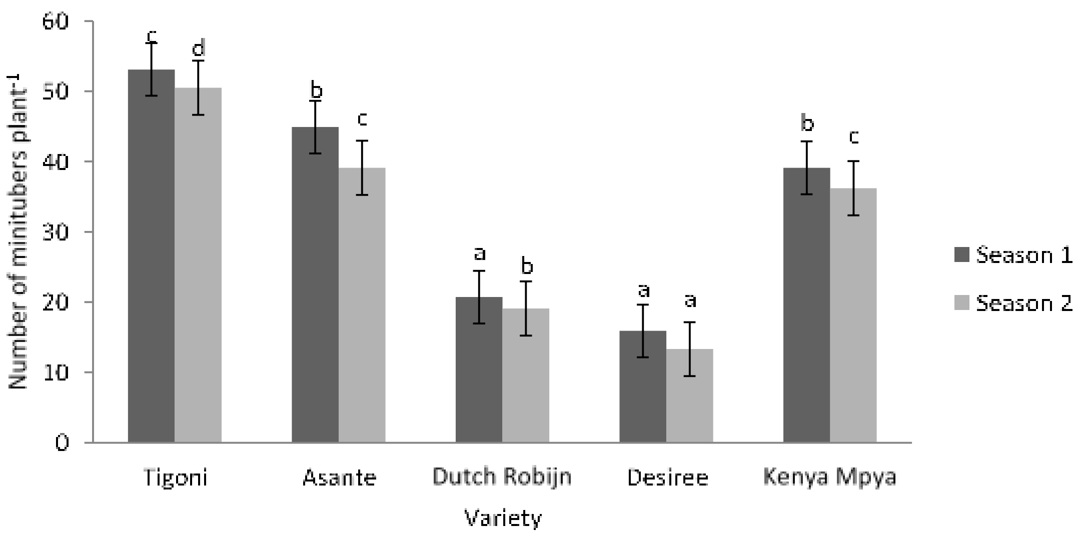

Figure 4. Effect of variety on number of minitubers >5 g. Error bars show LSD values.

other varieties during both seasons. The effect of varieties on the proportion of number of mini-tubers >5 g relative to the total number of mini-tubers produced by a variety was however, not significant in both seasons and varied from 83.7 to 88.1% in season 1 and from 78.0 to 89.4% in season 2.

Average number of mini-tubers s per harvest, weight of total yields and graded yields and average mini-tubers tuber weight

Varieties Tigoni and Asante had the highest number of mini-tubers per harvest in both seasons (Table 4). Variety Tigoni had an average of 4.8 mini-tubers per harvest and 5.2 mini-tubers per harvest in seasons 1 and 2, respectively while Asante had an average of 4.3 mini-tubers per harvest in season 1 and 4.4 mini-tubers per harvest in season 2.

Figure 5 shows that the average mini-tubers weight was significant among the varieties in season 1 but not season 2 and ranged between 7.8 and 9.9 g in season 1 and from 7.4 and 8.8 g in season 2. Total weight of mini-tubers per plant varied across the varieties (Figure 6). The highest yielders were varieties Tigoni and Asante with total mini-tubers yields of 537.7 and 396.7 g per plant, respectively in season 1 and 492.9 and 345.6 g per plant, respectively in season two. Between 83.8 and 88.3% of the mini-tubers yield in season 1 was greater than 5 g, while in season 2, the range was 78.0 and 89.4% (Figure 7). For all the varieties, the largest graded weight of the mini-tubers was size II (5-12 g). The

Table 4. Number and distribution of mini-tubers during each harvest in five cultivars grown during seasons 1 and 2.

Harvesting period (at 10-day intervals) DATP	Season 1					Season 2				
	Tigoni	Asante	Dutch Robjin	Desiree	Kenya Mpya	Tigoni	Asante	Dutch Robjin	Desiree	Kenya Mpya
40		73.5	35.2	35.2					48.0	
50	67.2	83.6	44.8	44.8	73.6		67.2	73.2	48.0	
60	77.2	99.2	51.2	51.2	83.6	89.6	89.6	81.2	51.2	76.8
70	102.4	119.4	81.2	64.6	88.1	96	96.6	83.2	96.4	86.6
80	134.6	152.4	121.6	97.6	92.5	106.4	130.4	85.6	89.6	90.2
90	170.6	201.5	111.5	81.4	98.4	132.5	137.6	110.6	79.6	96.8
100	225.8	178.4	76.8	63.4	101.6	164.3	194.5	75.8	134.4	108.8
110	203.6	139.2	50.6	54.6	115.4	215.6	181.2	69.6		110.6
120	189.6	117.6	47.9	121.6	96.3	201	166.4	134.4		108.8
130	140.5	109.2	166.4		81.4	189.2	98.1			96.8
140	130.4	98.8			80	182.4	243.2			90.6
150	120.4	268.8			75.4	101.4				84.4
160	101.7				74.6	339.2				78.2
170	326.4				73.3					75.4
180					71.4					211.2
190					221.6					

[1]Shaded area indicates that no harvesting was done for a particular variety; [2]Harvesting of mini-tubers was done at 10-day intervals; [3]Number of mini-tubers harvested per m^2; [4]average of 3 replications.

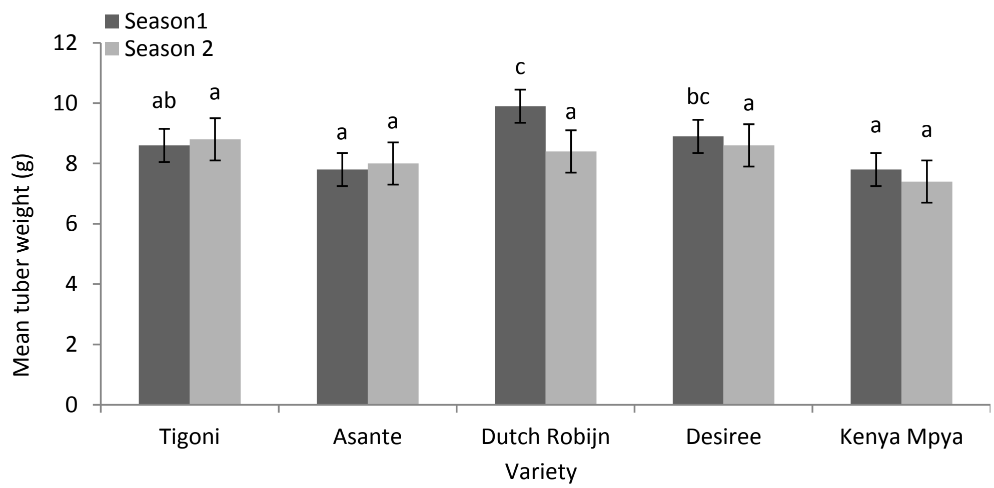

Figure 5. Effect of variety on mean tuber weight (g). Error bars show LSD values.

differences among the varieties were not significant in season 1. In season 2, variety Kenya Mpya had the highest proportion of size II tubers (83.0%) and significantly out-yielded variety Tigoni and Desiree.

Correlations

The number of mini-tubers s per plant and the total weight of mini-tubers s per plant correlations with days to tuberization, days to senescing, days to maturity, plant height measured at 80 days after transplanting, plant vigor and number of the number of mini-tubers > 5 g were positive and significant (Table 5). The correlation between the number of mini-tubers s per plant and total weight of mini-tubers s per plant was also positive in both seasons (r^2= 0.967 in season 1 and r^2= 0.969 in season 2). The average mini-tubers weight was negatively correlated with plant vigor and the total number of mini-tubers per plant, although the relationship was not

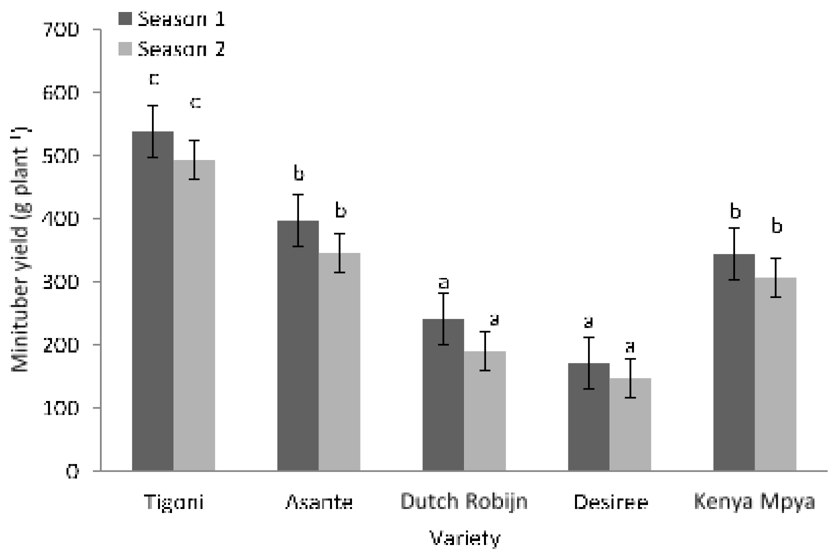

Figure 6. Effect of variety on tuber yield (g plant^{-1}). Error bars show LSD values.

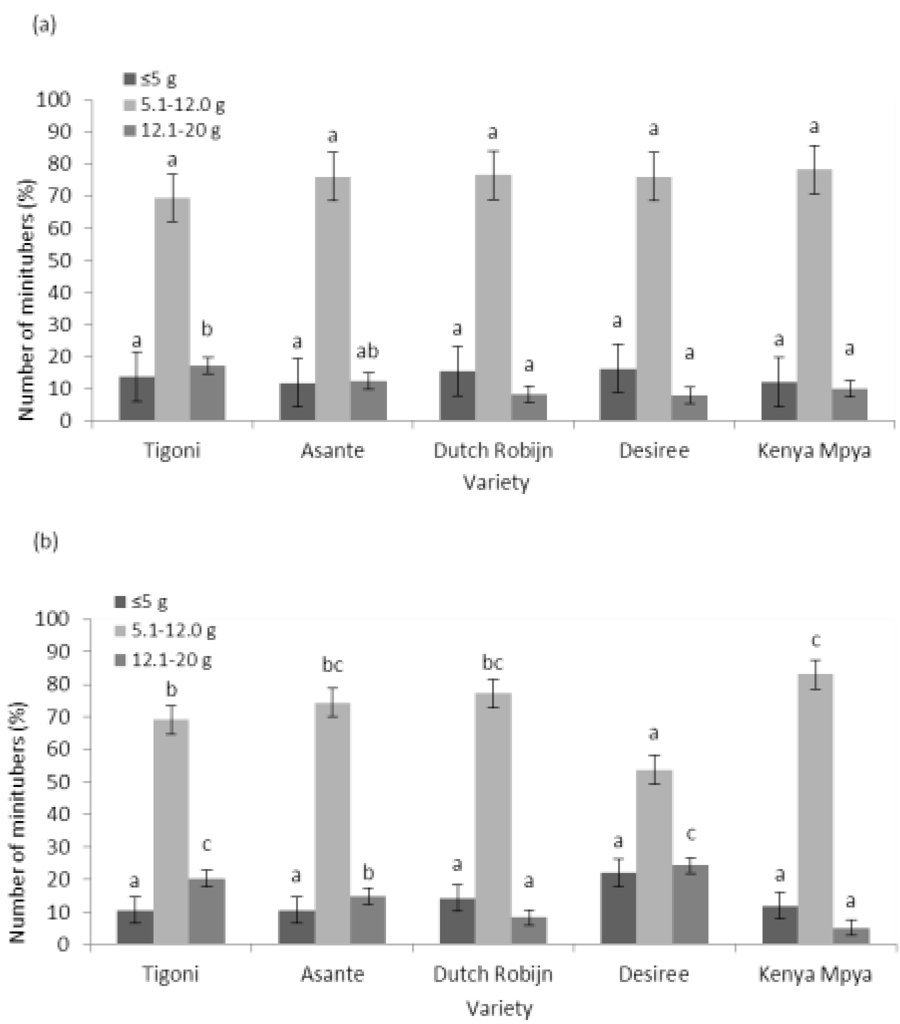

Figure 7. Minituber size distribution expressed as a percentage of total minitubers produced per plant in season 1 (a) and season 2 (b). Error bars show LSD bars

Table 5. Correlation coefficients describing the relationships among mini-tubers yield variables.

	Season 1								Season 2							
	Average mini-tubers weight (g)	Days to maturity	Days to senescing	Days to tuberization	Plant height (80 DATP)	Plant vigour	Number of mini-tubers > 5g	Number of mini-tubers s/plant	Average mini-tubers weight (g)	Days to maturity	Days to senescing	Days to tuberization	Plant height (80 DATP)	Plant vigour	Number of mini-tubers > 5 g	Number of mini-tubers/plant
Average mini-tubers weight (g)	-								-							
Days to maturity	0.576*	-							-0.389 ns	-						
Days to senescing	-0.533*	0.991**	-						-0.308 ns	0.978**	-					
Days to tuberization	-0.491ns	0.951**	0.959**	-					-0.316 ns	0.905**	0.854**	-				
Plant height (80 DATP)	-0.501ns	0.779**	0.810**	0.757**	-				-0.042 ns	0.803**	0.866**	0.720**	-			
Plant vigour	-0.695ns	0.907**	0.991**	0.951**	0.911**	-			-0.302ns	0.920**	0.940**	0.789**	0.900**	-		
Number of mini-tubers > 5 g	-0.494ns	0.803**	0.831**	0.762**	0.976**	0.920**	-		-0.118 ns	0.843**	0.911**	0.762**	0.958**	0.903**	-	
Number of mini-tubers/plant	-0.544*	0.789**	0.810**	0.738**	0.966**	0.904**	0.984**	-	-0.154 ns	0.838**	0.897**	0.785**	0.938**	0.917**	0.994**	-
Total weight of mini-tubers/plant	-0.327ns	0.727**	0.763**	0.692**	0.944**	0.823**	0.968**	0.967**	0.084 ns	0.756**	0.837**	0.709**	0.941**	0.839**	0.975**	0.969**

*Indicates significance at $p \leq 0.05$; ** indicates significance at $p \leq 0.01$; ns indicates non-significance at $p \leq 0.05$. DATP- Days after transplanting.

significant for plant vigor in both seasons (r^2=-0.695 for season 1 and r^2=-0.302 for season 2) and for total number of mini-tubers per plant in season 1 and 2 (r^2=-0.544 for season 1 and r^2=-0.154 in season 2).

DISCUSSION

The pattern of mini-tubers production among the varieties was similar across the 2 seasons. In general, production of mini-tubers for all the varieties increased up to a peak then declined up to the second last but one harvest, then increased again. The initial increase of the number of mini-tubers produced by a variety may be attributed to the combined influences of: (i) the removal of the most dominant tubers during each harvest, resulting in more potential tuber sites that were not subjected to the dominance of rapidly growing tubers, and (ii) pushing of the stem downwards into the aeroponic box after every two weeks (up to 50 days after transplanting) which resulted in more nodes being exposed to stolon inducing conditions. Similar observations were made by Lommen and Struik (1992) who observed increased production of mini-tubers with repeated harvesting followed by deeper re-planting after each harvest. After peak production, the number of tubers at each harvest started to decline.

According to Lommen and Struik (1992), this may probably be due to (a) a limited number of possible tuber sites, (b) the dominant effect of the tubers that remain in the plant after a harvest (because they have not reached the desired size) before new tubers are initiated, (c) resorption of newly initiated tubers. Increase in the number of tubers harvested at the final harvest as compared to the last but one harvest was because during the last harvest, all the mini-tubers on a plant regardless of their size was harvested.

Differences in yield performance with regards to the yield variables, total tuber weight and number of mini-tubers per plant among the varieties evaluated were attributed to genetic differences between the varieties. Previous studies have reported large variations in mini-tubers yield among varieties (Tierno et al., 2014). The difference in performance of the varieties across seasons was attributed to differences in growing environment during the two growing seasons. This observation is consistent with Mateus-Rodriguez et al. (2014) who reported strong environmental effects on plant development and mini-tubers production of a diverse group of potato genotypes grown under an aeroponic system. The yields per plant obtained in this study are in agreement with previously reported work (Mateus-Rodriguez et al., 2014) and are attributed to the increased availability of nutrients (Balamani et al., 1986) and sequential harvesting which eliminates the dominant tubers allowing the development of existing tubers and stimulating the production of new tubers (Lommen, 1992). Tsoka et al. (2008) and Tierno et al. (2014) also obtained higher yields by aeroponics than using conventional technologies for the production of seed tubers.

The slight increase in plant height and delayed tuberization observed during the second season are probably due to temperatures effects. High temperatures are known to induce tall plants by causing greater translocation of photosynthates towards the vegetative organs (stems and leaves) (Wolf et al., 1990). Our results are in agreement with that of Mateus-Rodriguez et al. (2014) who observed considerable increases in the length of the vegetative cycle and plant height in genotypes grown in warmer environments. Long days, high night temperatures and high nitrogen fertilization inhibit or delay tuberization whereas, short days and cool night temperatures promote tuberization (Menzel, 1980, Sattelmacher and Marschner, 1978). Low temperatures are known to stimulate tuberization (Ewing, 1981) and such conditions may probably have occurred at the time of tuberization during the first season.

The increase observed in the vegetative cycle for all the varieties as compared to their known maturity period when grown under field conditions is consistent with results obtained by Tierno et al. (2014) who reported an extended vegetative cycle of between 12 and 36% (17 and 50 days) in plants grown under an aeroponic system as compared to the plants cultivated in greenhouse beds. Otazú (2010) reported similar extensions of the vegetative periods (1 to 2 months when plants are grownunder aeroponic conditions). Kang et al. (1996) also reported an increase in the vegetative period of potato plants when grown in an aeroponics system and attributed his effect to the high availability of nutrients, especially nitrogen.

The positive correlations between number of mini-tubers per plant and the total weight of mini-tubers per plant with the traits days to tuberization, days to senescing, days to maturity, plant height measured at 80 days after transplanting, plant vigor and number of mini-tubers > 5 g indicates that these traits exert considerable influence in the number of mini-tubers and total weight of mini-tubers produced by a variety. The fact that these traits were also correlated positively with each other, also suggests that their interrelationship could act in combination to influence both the number and weight of mini-tubers produced by a variety.

Mini-tubers are a valuable and expensive category of early generation seed and it is necessary to maximize their production and utilization. In addition, using varieties best adapted to the technology, optimum production season and a high multiplication rate, the size of the mini-tubers produced in aeroponics systems is very important because of its effect on storage and subsequent field performance. Tubers weighing at least 5 g usually constitute the size that can be used for further bulking in the field in the Kenyan potato program. Smaller sized mini-tubers are more difficult to store as they show larger losses during storage than larger mini-tubers (Lommen, 1993) The size of the mini-tubers affects the duration of the dormancy, the vigor of the seed tuber, the number of stems that can be successfully produced, the rate of emergence, the number of surviving plants and stems, and the vigor of the individual stem. Smaller seed tubers usually emerge later, have single stems, and are more susceptible to pests, diseases and environmental stresses. Their overall performance and yielding ability is poor (Lommen and Struik, 1994, 1995; Karafyllidis et al., 1997). Thus, an increase in tuber number per plant in an aeroponic system should be accompanied by a simultaneous increase in the proportion of tubers > 5 g.

The proportion of mini-tubers <5 g relative to the total number of mini-tubers produced by a variety observed in this study (a range of 11.7 and 16.2% in season 1; and 10.6 to 22.0% in season 2) suggests that the system used in this study could be further improved to optimize the production of larger sized mini-tubers possibly by modifying the nutrient media during the growth cycle according to changing plant demand, instead of maintaining the same concentrations throughout growth or prolonging the harvest intervals. Small mini-tubers can, however, be planted under protected screen houses to produce larger sized mini-tubers using a variety of methods including sand hydroponics or as a source of mother for aeroponic mini-tubers production (Otazu, 2010; Rykaczewska, 2016).

The higher mini-tubers yields of varieties Tigoni, Asante and Kenya Mpya may be due to their abundant vegetative growth and longer productive time. In contrast, the relatively poor performance of varieties Desiree and Dutch Robijn may be due to their poor adaptation to the aeroponics system in the study area and lower production of stolons. In crops grown from seed tubers, the number of tubers produced per plant is determined by the number of tubers per stolon, the number of stolons per stem and the number of stems per plant (Haverkort et al., 1990). Furthermore, the abundant vegetative growth observed for varieties Tigoni, Asante and Kenya Mpya can be exploited to harvest stem cuttings from such vigorous varieties during aeroponic mini-tubers production so that the cuttings can be used directly for further mini-tubers production (Bryan, 1981; Lung'aho et al., 1997) in beds or pots or they can be used for aeroponics mini-tubers production (Otazu, 2010). The use of such an integrated approach can result in a many fold increase in mini-tubers production.

Conclusion

It was observed that mini-tubers production under the aeroponic system used in this study was variety dependent with Tigoni, Asante and Kenya Mpya being the most productive varieties irrespective of the season. Evaluation of a variety's suitability/adaptability to the system is therefore necessary to determine the most adapted varieties before venturing into large scale production as this will ultimately affect production costs, with higher yielding varieties more likely to result in lower mini-tubers production costs. Because of their positive association with the number of mini-tubers and total weight of mini-tubers per plant produced by a variety, the traits: days to tuberization, days to senescing, days to maturity, plant height measured at 80 days after transplanting, plant vigour and number of mini-tubers > 5 g could be used as predictors for the yield of mini-tubers produced by a variety.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Assessment of the knowledge and use of pesticides by the tomato farmers in Mwea Region, Kenya

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Current cultivation of vegetables to meet food security standards requires the use of pesticides which reduce losses from pests and diseases. A cross-sectional survey for pesticides use in tomato farms was conducted in Mwea, Kenya to assess the practices and constraints faced by the farmers. Gender, level of education, the use of pesticides in farms, experience in tomato farming, list of common pesticides, periodicity of pesticides spray in farms, approximate last day for pesticides spray, reason for pre-harvest period and pesticides spray in post-harvest time were investigated. Results revealed that, 90% farmers were men and 10% were females; 38.5% and other 38.5% attended primary and ordinary schools; 15 and 4% had advance and university levels. About 69% of respondents knew pesticides through other farmers; 31% through agrovets, extension officers and agricultural experts. Around 56% farmers knew the names of pesticides through other farmers, 44% got them from agrovets, agricultural officers and chemical companies. About 98% respondents use pesticides approved by government, 96.2% listed each between 2 and 11 names of pesticides mostly used in tomato farming. Almost 93% spray pesticides once a week in farms and 76.9% observe at least 7 days for the pre-harvest period. Relatedly, 84.8% assert that waiting for the pre-harvest time is the culture of farmers in the region. Surprisingly, 6% spray pesticides in the post-harvest period, while 84.6% assert that the pre-harvest moment is to avoid pesticides in post-reap. Although key questions found good answers from farmers, the quality of their knowledge is limited, shows missing information and needs reinforcement. Agrovets appear as the legal authority and act as key informants for most farmers. Most farmers rely on other farmers or agrovets-displacing the low or nonexistent contribution of agricultural extension officers. Capacity building and periodic updates for agrovets and farmers are required.

Key words: Pre-harvest, pesticides, organizational, awareness, appropriation, harmonization.

INTRODUCTION

Securing food to control hunger and food scarcity after the Second World War led the Food and Agriculture Organization (FAO) to adopt tools and measures for a permanent solution to the problem of production of raw food in agriculture. From the archaic to the modern agriculture, the use of pesticides in farms to control pests invading the area (such as *Tuta absoluta*, Thrips, Leave chlorosis, Mites, Nematodes, Bollworm) and diseases (Stem rot, bacteria wilt, early blight, late blight, leaf rust) on crops under food security program appeared as the ultimate solution. No matter the case, food remains the priority of the primary inevitabilities without which humans cannot survive (Caprihan, 1975). Current food is likely to contain chemicals and chemically contaminated diet is rather a soft and silent killer unconsciously taken voluntarily by the consumers. Pesticides adopted for crop protection become harmful as early depicted in the fifties by Rachel Carson (Peshin and Dhawan, 2009; Amuoh et al., 2011; Nunifant, 2011; Pujeri et al., 2015) if the farmers have little and incomplete information not only on their best use but also on the potential consequences of misuse (Mutai et al., 2015).

The intensive use of pesticides in tomato farms (Asante et al., 2013) seems to provide nice and best quality of produce at sight for the markets and makes good deals for both the farmers and vendors. But, this seems to have contributed in the increase of food hazards responsible for 200 diseases spanning from diarrhea to cancer and diabetes in humans (WHO, 2015). To reduce the risk to health from pesticides contaminated products and therefore to reduce the socioeconomic burden of diseases, the European Union (EU) has designed criteria on pesticides residues to meet the quality for a healthy diet. Also, the biological fight uses harmless pests to control. The retailers and consumers of the harvested produce have little or no relevant information. They are deprived of knowledge on contaminated food and have no idea, no capacities to either detect or act and take appropriate stands against chemically contaminated food. The solution for the raw tomato is to trace back information from the tomato farmers. The aim being to see whether the end tomato produce can be qualified without test as free of chemicals contamination in markets for instance and thus, safe for the consumers such as the city dwellers.

Tomato was introduced in Eastern Africa by the colonial power in early 1900 (Wachira, 2012). Real national interest on the horticultural crop for profit making started in the 1980s with the socioeconomic progress of one of the pioneer in Mwea-Kirinyaga (Muru, 2009). Tomato is actually cultivated in both open air and greenhouses. The major producing areas of the good include Mwea, Nakuru, Meru, Nyeri, and TaitaTaveta (Wachira, 2012). The produce is cultivated all over the national boundaries at an altitude 1150 and 1800 m above the sea. Almost 300,000 farm families earn the major part of the revenue through vegetable cultivation (Mutuku et al., 2014). In 2011, the area under tomato farming was around 19,000 ha from which 600,000 metric tons were harvested releasing an income of KES 14.2 billion (Mbaka et al., 2013).

Tomato is one of the most consumed and cultivated vegetables in the world eaten either raw or processed. The fruit is second in the worldwide productivity of vegetable with 458.2 million ha used for farming and 32.8 tons/ha (Abdulkareem et al., 2015). Tomato contains the P3 substance which prevents platelets clot and curbs death from heart diseases and strokes (Tarla et al., 2015). The fruit is the source of many antimutagenic, anticarcinogenic, anti-inflammatory and anti-allergic phytochemicals (quercetin, kaempferol and myricetin). New tomato varieties continue to be developed by plant breeders and geneticists (Dave, 2012). The markets are demanding best quality produce at sight. Tomato is now an important cash crop improving the leaving standards and creating employment (Shankara et al., 2005; Wachira et al., 2012). Therefore, looking to fulfill the needs of the families under the rampant poverty in farming areas, cultivators misuse pesticides in tomato ranches to keep the competitive level imposed by the demand. From this point of view, a survey was conducted in Mwea to assess farmers' practices on the use of pesticides in tomato farms, their knowledge on the chemicals, their quality of interactions with the chemical providers, as well as the whole chain included in the tomato industry from the ground production to the sales points including the processors.

MATERIALS AND METHODS

Study site

The study was purposively conducted in Mwea region situated in Kirinyaga County in the central province of Kenya. It is a region of small-scale tomato farmers partitioned into Mwea East and West. The population in Mwea is at around 150,000 persons. An estimate of 73% of the population is fully engaged in agriculture (Mwangi, 2014). The majority of dwellers are Kikuyu; Gikuyu and Kiswahili are the most spoken languages. Tomato production is a major business utilizing more than one third of the total cultivated land of the district. The district is among the four major production areas of tomato in Kenya (Mueke, 2007). The agricultural activities have profoundly transformed the region structurally and economically. Water flowing in the rivers is from Mount Kenya; this has always been of great interest for farming tomato in the area.

The locality is at about 100 km in the south east of Nairobi City. The district is bordered by latitudes 37°13'E and 37°30'E and longitudes 0°32'S and 0°46'S. The district is known as a tropical area with a semi-arid weather, the average annual temperature is

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approximately 23 to 25°C. This temperature differs by 10°C between the minimum noticed in June and July and the highest seen from October to March. The region is positioned at a high altitude at around 1,800 m above the sea and at 50 km south of the Equator (Muuru, 2009). Its climate is both cool and sunny; this provides natural good conditions for farming. The region has an annual average rainfall fluctuating between 1,000 and 1,800 mm (Ndiiri et al., 2013).

Experimental

A semi-structured questionnaire was designed for the collection of data from the tomato farmers. Preliminary field visit to Mwea was done for meeting with some agricultural extension officers for more information on the farming site. This included, the average number of tomato farmers, pesticides regularly used, the contribution of the business in the area and the challenges faced by the tomato farmers. Information was obtained through literature review and random semi-structure questionnaire to some researchers who conducted studies in the area. The Pests Control Product Board (PCPB) and Kenya Plant Health Inspectorate Service (KEPHIS) were visited for meeting with some experts. Some agrovets were interviewed in Nairobi to understand their implication in the management of pesticides with the tomato farmers. The tomato agribusiness in Kenya was also studied by meeting with some middlemen and tomato retailers.

The questionnaire was pretested in Kamulu and improved according to observations and findings after meeting with some tomato farmers. Some questions were discarded while others were added to fit with the understanding of farmers. An effort to obtain close or same results if the questionnaires are to be reproduced was made. A M.Sc. student was recruited during this field work for translation from English to Kiswahili and vice versa. The study was conducted in February and March 2017. Two key interviewers were recruited in Mwea and trained to administer the questionnaire. Consent and voluntary participation were always obtained from the interviewees after the introduction of the aim of the study. The interviewers were requested to collect data equally from both sides, Mwea East and Mwea West. The design effect was included during the recruitment and conversations with the farmers. Data were collected from the peasants who only cultivate tomato all year round and during all seasons. The number of farmers to interview was obtained on the basis of information given by the agricultural extension officers. The formula of Fisher was used with the tolerance limit sets at 10% significance (Mutete, 2005) on the basis of the estimated population fully engaged in agriculture in Mwea (Mwangi, 2014). The formula of Fisher was followed by the formula of Yamane (1967) and was modified as done by Inonda et al. (2015).

Reliability

The reliability of a questionnaire stands as its ability to reproduce similar results if the same questionnaire is repeated to the same participants under the identical situations on two diverse occasion and compare the scores (Melike and Ayten, 2013). This questionnaire was first pretested to know whether the farmers will be able to understand the questions. Secondly, pretesting also served to see whether the expected answers from farmers will be achieved. After administering the questionnaire, the validity has been achieved as the expected responses were in line with the expectations. From this, the questionnaire is reliable because if taken once more to the same participants, they will lead towards the same answers under similar conditions. Using the statistical tool for analysis, this questionnaire is moderately consistent at a Cronbach's alpha r = 0.409.

Data analysis

The Statistical Package for Social Sciences (SPSS) software was used for data analysis. The data was entered and cleaned. Some analytical tools were used. The mean were used to get the average age of farmers and standard deviation to measure the dispersion. The descriptive statistics were used to generate the picture of farmers and their knowledge on the use of pesticides in tomato farms. The linear regression contributed to show that the middlemen use the level of education of farmers to buy the tomato. The Bivariate correlation based on Pearson's was used to measure the association between two variables. The level of significance was tested at 95% confidence.

RESULTS AND DISCUSSION

Sociodemographic characteristics of the study

Characteristics of tomato farmers

The study done covered Mwea East and West. Out of all participants, 90% were males and 10% females. The age of interviewees was between 22 and 70 years old with an average of 42 years and a standard deviation of ±10.236. The survey reveals that, 8% of the farmers were between 18 and 28 years old, 23% between 29 and 35 years, 44% between 36 and 49 years, and 25% is for 50 years and above. Around 83% of the respondents had other business such as buying and selling rice, 14% were employed in jobs such as driving, providing casual labor and 3% had no other business.

The high involvement of males in tomato farming in this community could be linked to some factors which mostly require men in this venture. Males were mostly responding to the questionnaire (with the wife standing close to him) in most farms. Maybe, the culture of the community requires men to step forward on behalf of the family in any given occasion involving the family such as for this interview. Factually, the couples (husbands and wives) were both included in tomato farming. As rooted in African culture, females cannot take the lead of an activity when the husband is fully connected. Surely, reasons elucidating the utility of men may also engulf the needs for good organizational skills, quite number of workers, financial input and attention to details (Rutledge et al., 2015).

These results confirm studies in India by Himani et al. (2015) and in Cameroon by Tarla et al. (2015). They contrast the studies of Ayandiji and Omidiji (2011) in Nigeria who did not found a great difference (51% males versus 49% females) among gender in their survey.

Level of education: Most of the farmers had primary (38.5%) and secondary (38.5%) levels of education. 15% had tertiary, 4% university and 4% never attended any school. Most farmers from this region can read and write. This appears to be an asset for the use of pesticides in tomato farming by farmers. Easy communication can be established in both English and Kiswahili for the majority during capacity building and easy translation can be done to the lowest of non-educated farmers. For the minimum who have never attended any school, it is expected that information received by the literate on pesticide used in tomato farms can easily be transmitted to those unable to read and write. These results confirm the studies done in India by Himani et al. (2015).

Tomato pesticides management

Attitude, awareness, knowledge

The first time you heard about pesticides for protecting tomatoes in farms: Around 69% of farmers acknowledge to have seen pesticides for the first time from other farmers and 31% mentioned different sources including agrovets, agricultural expert, agricultural extension officer and during training. The sourcing for pesticides varies. The multiple source of information is a possibility for accurate, different or confusing information. The single source of information may stand as erroneous, improper and non-updated information. Farmers may be dealing among themselves either due to unavailability of agricultural extension officers (too few to serve all the farmers) as noticed in Vietnam by Huynh (2014) or because, the evidence of the good production seen from fellows' farms may influence their behavior and increase their reliability on other farmers.

Also, agricultural officers may be favoring some areas or farmers while neglecting others. Tawiah (2011) in Ghana revealed complaints that, the agricultural agents follow and advise some tomato farmers on the basis of prepaid or post-paid contracts. This practice is unfortunate as the farmers may end up spraying pesticides in farms according to inadequate information and finally produce unsafe tomato harming the health of consumers. This confirms that, the farmers are not trained at the same level and consequently do not have the same understanding of the use of pesticides. Pesticides use in tomato farms here is therefore confusing among farmers themselves. This confusion raise the necessity for the harmonization of information leading to appropriation based on the same official knowledge.

These results contradict with both the findings from Tawiah (2011) in Ghana where 48% of cultivators received their first information from other farmers and from Bandara et al. (2013) in Sri Lanka where 48.9% knew pesticides for the first time from neighbors and 51.1% got the first information from multiple sources (Extension Officers, Farmers Cooperative and Dealers). But, they confirm the results from Jamali et al. (2014) in Pakistan where 25% deal with multiple source of information.

The source from which farmers know how to use pesticides: Around 63.5% of participants said that, they learn how to use pesticides from the agrovets and 36.5% mentioned both agrovets and other farmers. The agrovets are the references for farmers and this gives them the legal authority among farmers. The extension officers and industries (which usually promote their chemicals) were ignored by the participants. This might happen because the agrovets are permanently present in the region and have proved their efficacy on pesticides use in crops. The source for the use of pesticides seems appropriate but requires clarifications on the quality of information provided by the agrovets.

The synthetic chemical shops called “agrovets” are business oriented. They may not have enough time to train or transfer information required for the best use of pesticides to the beginners in tomato farming for instance. If not reminded, agrovets may assume that, the tomato farmers buying the chemicals already have appropriate knowledge before ordering. This can be crucial as pesticides mismanagement by farmers is decried by a number of studies (Mutuku et al., 2014; Tandi et al., 2014; De Bon et al., 2015). This is delicate at the moment when chemical industries are manufacturing an endless number of pesticides for crop protection.

Assessments of pesticides use by farmers and their source differ and reveal several limits worldwide. Wasudha et al. (2015) in Surinam found for instance that, farmers knew pesticides to use in vegetable by knowledge received from parents, other farmers and pesticides shops. Such practices may either be accurate or contain missing information and gaps for the new generation of farmers. Periodic follow-up and capacities reinforcement should be inserted in strategic plans of governments. These can include information such as the last spray and withdrawal period; essential actions while spraying and after spraying; recommended pesticides to use in tomato farms; and potential health risks and exposure from misuse of pesticides in crops, environment and on farmers. Maybe, some of these points and precautions may either be known but neglected, unknown, or forgotten.

Above this, the chemical shops might not be qualified enough to provide accurate, complete and pertinent information to the farmers for the best use of pesticides in tomato farms. If trust should be on agrovets, criteria and evidence for the level of education of personnel in agrovets shops should be defined; a roadmap established and, quality assessment and audit adopted by the government. Such strategy or measures can be applied worldwide in countries with economies in transition or, in developing countries. These results are consistent with the research done by Tarla et al. (2015) in Cameroon where farmers rely on chemical vendors. Also, they confirm the work from Jamali et al. (2014) in Pakistan where 81% of farmers receive knowledge through traders.

Pesticides approval by the governmental institution Pest Control Products Board (PCPB): The farmers were asked whether they were aware of the approval of pesticides by the governmental institution Pest Control Product Board. Ninety eight percent acknowledged to be aware that the chemicals to use in the farms should be approved by the PCPB. This reveals a good sign of communication between farmers and farmers and between farmers and agrovets. It shows that, almost all farmers are using recommended agrichemicals.

The high level of regulatory requirement found in the present study is however not common. For instance, such knowledge is not the same in some sub-Saharan African countries (Tarla et al., 2015). The misappropriation of recommended pesticides by the legal authority might have led farmers in some nooks and crannies to consider pesticides as an instrument that helps to produce more tomato (May Lwin et al., 2012). It should be made clear that, pesticides are not fertilizers; they are only pests and diseases repellents or killers. Therefore, this must be considered and included as a topic during capacity building of tomato farmers. These results support the findings in Pakistan by Jamali et al. (2014). But, contradict those released by Tarla et al. (2015) in Cameroon where 69.9% of the farmers were not aware of the relevance of pesticides approval by the government and only 15% knew that they had to look at the registration number before getting pesticides needed from the agrichemicals shops.

Names of the mostly used pesticides in tomato farming: A total of 96.2% cited between two and eleven names of pesticides mostly utilized (Oshothion, Coragen, Alpha, Genomite, Dynamech, Confidor, Diacrid, Ridomil, Oshotane, Alphatox, Mistress, Milraz, Anthracol, Malathion and Karate for example) using the commercial name of the available pesticides and 3.8% were unable to cite any. These farmers know which pesticides to use when needed through a routine probably developed from their experience in tomato farming. Citing these names easily may reflect knowledge of how to use these pesticides. But still, details on some key aspects such as the safety/care in the way chemicals are used, the quality of protective clothing of farmers (rubber boots, impermeable trousers, and waterproof coverings for instance) (Matthews et al., 2003), the number of times to spray from planting to harvesting and, the withdrawal period are important. The results in the present study are in agreement with the findings of Matthews et al. (2003) in Cameroon where pesticides listed by the farmers were classified as frequently and uncommonly used.

Awareness of the usefulness of pesticides: About 98% of the respondents are aware of the importance of pesticides in tomato farms. This means, it is a common and rooted tool for tomato farming in this community. Paiboon and Tikamporn (2014) argue that, awareness is the response based on previous experience and related to the effects that happened and which lead to be conscious of the situation. It thus becomes useful to interrogate the quality of awareness claimed by farmers on the usefulness of pesticides in tomato farms.

Based on their source of information, the usefulness of pesticides in farms goes from mouth to ear and spread easily among the farmers. The information content in such a chain might decrease, be distorted, be incomplete and contain incorrect advice leading to malpractices. This may lead the farmers into wrong, inappropriate, indecent and invalid use of synthetic chemicals in tomato farms. Additionally, the relevance of the content released may depend on who shared the information, the place where it was given, the status and mood of the person at the moment of sharing. As well, the quality of content of the message received previously by the informant, the level of understanding of the listener and his/her capacity of transmitting or applying the previous information received. The reliability of the speaker as perceived by the listener also affects the effectiveness of the information received.

Regarding this, simple additional information for a better understanding and good practice of the use of pesticides is needed. These results corroborate with the finding from Surinam by Wasudha et al. (2015) who reveal that 100% of the farmers were aware of the usefulness of pesticides.

Knowledge of the use of pesticides in tomato farms: One hundred percent of the respondents acknowledged that they know how to use pesticides in tomato farms. This acknowledgement expresses doubts related to the way they usually get information on pesticides use in tomatoes farms both for the first time and in the long run. Nonetheless, studies of chemical use in tomato farms in Kenya have revealed numerous shortcomings in the practices of farmers (Nyakundi et al., 2010; Mutuku et al., 2014).

The claim of good knowledge of use of pesticides in tomato farms is questionable. Probably, a step by step procedure may reveal some flaws sustained by improper practices adopted or applied by some cultivators. This may include spray following the direction of wind, no break for cigarette smoking before ending with spray, changing cloths and washing them, taking a shower before eating and smoking; disposing empty containers of pesticides in the farms after usage and not throwing everywhere as seen in many farms, starting another task within the farms without taking a bath and changing the cloths (Paiboon and Tikamporn, 2014). These results contradict those from Pakistan by Jamali et al. (2014) who found many irregularities on the practices of the farmers in the use of pesticides in vegetables.

Knowledge of the names of pesticides used in tomatoes' farms (The farmers' realism): Results show that, 56% of the participants ask other farmers and 44% get the names from agrovets, agricultural extension officers and the agricultural chemical company. A large number of farmers purchase their pesticides based on concrete evidence in tomato farms. Probably, they witness the status of the produces in farms before asking the names. This shows the realism of farmers. Although it seems logical for the farmers to do so, this result may also be explained by the inability for some farmers to read properly the labels on the containers of pesticides or, their incapacity to remember the names of the pesticides due to illiteracy (Nyirenda et al., 2011; Tarla et al., 2015).

Relying on other farmers may show that, there is no constant chemical pesticide regularly used in the area. Probably, pests and diseases are either dynamic or, they are now resistant to pesticides. Nonetheless, attention should be paid as 67.3% of the farmers affirm that the agrovets always promote new powerful chemical products. A minority of the farmers got the names of pesticides from those accredited to provide the information (that is the right source including agrovets and agriculture extension). The farmers are most likely to rely on each other based on the success or the best yields witnessed in the neighboring farms as also shown in India by Himani et al. (2015). They learn how others have overcome some difficulties so as to harvest good tomatoes. This reveals the realism of the tomato farmers. Before ordering for a pesticide, the farmers have the reason and expected outcomes from the brand ordered. The results in the present study support both the finding from Jamali et al. (2014) who reminded that, the knowledge for chemicals spray in farms has a variety of origins and Tarla et al. (2015) who stated that farmers order their chemicals through advices from other farmers, suppliers and agricultural extension agent.

Knowledge and culture (An index to clarify for the 7 days of pre-harvest interval): Data reveals that 84.8% wait before harvesting after application of pesticide because it is the culture in the community, 6.5% say it depends of the days of the markets, 4.3% follow the instruction from the manufacturers, 2.2% used to be reminded by the agricultural extension officers and 2.2% do not know (Figure 1).

The farmers have insufficient knowledge. They should move from blind habit of culture to real understanding of pesticide practices and reality in the field. Insects' resistance to pesticides is currently decried (İnci and Ikten, 2017). In spite of this, farmers of this community are still stuck to culture which does not follow the dynamism of insects' pest depicted as more and more resistant to synthetic chemicals. This trend might lead into pesticides resistance and their misuse causing tomato contamination and health risk exposure. The farmers of this community seem not to be aware of the potential health's exposure for those consuming tomato contaminated with chemical residues above the maximum limits. Majority are followers of culture of tomato farming in the area. They have no idea on pesticide residues in post-harvest tomatoes and its effect on the health of consumers (Shashi et al., 2016). They apply pesticides and wait because they found it rooted in the community. Culture being the product between man and environment, farmers are just the followers of practices and do not have accurate knowledge. The pre-harvest interval here is not a precaution for the production of safe vegetable for human consumption. If the farmers' knowledge is uplifted, almost all the farmers will follow the rules. These findings are in agreement with those of Wasudha et al. (2015). They found that 100% of farmers in Surinam know the pre-harvest time through parents' experience and culture.

Famers' pesticides practices

Number of Years farmers have used pesticides in tomato farms: Sixty four percent of the farmers have more than 6 years in tomato farming, 16% have between 5 and 6 years, 6% has 3 to 4 years, while 14% have only 2 years. Tomato farming has been embraced by the community for quite some time. As such, practices as pesticides use in farms may have become a routine for most of these farmers. Despite this, a dual situation for this category is envisaged: on one hand, the large number of this group seems an asset for use of pesticides in tomato farming. On the other hand, this set can be a source for malpractices in case they did not have appropriate skills for pesticides management. They may have transferred incomplete or improper knowledge to the young generation and the socioeconomic fallouts will still be harmful for families and society as depicted by Huynh (2014). The necessity to understand the level of pesticides attained by the elders is relevant. Most of them may have worked for years, but their management of pesticides remains weak or shows gaps that may need capacity building.

Again, the source where they learned about the use of pesticides is crucial; this might unveil or give an idea of their real use of pesticides in farms. In spite of their long experience, capacity building for update and reconstitutions of the knowledge on pesticides use can be organized by the government and other stakeholders not only in Kenya, but everywhere such results are depicted. These results are consistent with those from Wasuhda et al. (2015) in Surinam where most respondents (66.7%) and Mispan et al. (2015) from Malaysia where majority of the farmers (60%) have a lot of experience in tomato farming and use of pesticides.

Periodicity for pesticides spray in the tomato farms: Analysis indicates that 93.9% of the farmers spray pesticides every week in tomato farms, 4.1% spray twice a month and 2% spray as they feel they have to protect the vegetable. A good percentage of farmers (93.9%)

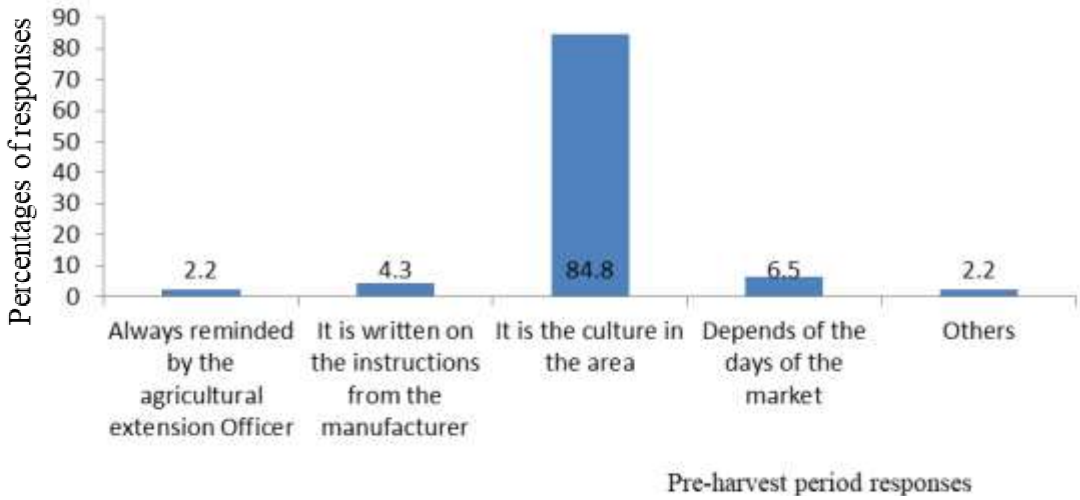

Figure 1. Justification for observing the pre-harvest period.

follow the same rule of spraying pesticides every week in farms. A routine has been established in the application of the chemicals in this community. This expresses a commune alignment toward the same action within the area. Although high proportion follows the same rule, the minority may have developed unsafe thoughts on the meaning of pesticides and its role in farms. For instance, 2% think synthetic chemicals spray is important for good yields and returns. The latter minority may also believe in addition that, the quantity of pesticides wrap in the containers is not enough to cover the surface of the farms for pests and diseases control (Shashi et al., 2016).

Institutions in charge of national approval of chemicals in developing countries should be equipped with laboratories for quality control of the chemicals before recommendation. These results agree with those from Mutuku et al. (2014) in Kaliluni-Kenya where 86.1% spray weekly, Lutap and Atis (2013) in Ilocos-Philippines with 90% of weekly application, and in India by Shashi et al. (2016) who found that 60% of farmers spray pesticides in a weekly basis in their farms. But, they contrast with those from Wasudha et al. (2015) in Surinam where 50% of farmers spray pesticides twice per day- early in the morning and late in the afternoon.

Quality of social interaction between farmers and the approximate last day or time for spraying pesticides on the tomato farm: Approximately, 76.9% of the farmers have at least seven days for pre-harvest period; 7.7% harvest 14 days after the last spray, 7.7% harvest four days after, 5.8% do harvest between 2 to 6 days from the final chemical protection and 1.9% follow instructions from the manufacturers (Figure 2). Six different answers were obtained from the participants. The disparity and inaccuracy for the pre-harvest period remains a challenge in this community. Farmers have limited awareness of pesticides residues effect and the appropriate pre-harvest period which results in exposure and potential health risk consequences on human, fauna and environment.

These answers raise doubt on the quality of the source of pesticides held by farmers and their awareness for the usefulness and good management. With no certainties for the knowledge received from agrovets and other farmers, the understanding of pesticides in this community remains precarious. There is a set of social knowledge that should be assessed from the farmers. They should reveal the place where they received the information, the mood of the fellow who delivered the knowledge and the quality of their relationship. These characteristics are useful social determinants that may influence the quality of knowledge transmitted from a farmer to another. A qualitative survey can be developed and tested in areas around the world. The aim is to find the trends and potential outcomes which might lead to a policy design for pesticides training or capacity reinforcement of the tomato farms.

These results are consistent with those reported by Himani et al. (2015) in India. They found that, 16% of farmers spray pesticides even during harvest and 37% leave a pre-harvest interval of 11 to 14 days. They also corroborate with those of Shashi et al. (2016) where 86% of farmers in open field wait for two days, whereas 71.42% of farmers in poly house allow a moment of seven days for the pre-harvest time. They contrast with the results from Ghana by Dankwah (2014) where 60% of farmers wait for 11 to 14 days and 30% allow a pre-harvest interval from 7 to 10 days.

Pesticides spray in post-harvest period: Although 94% do not spray pesticides after harvesting the tomato, 6% continue with post-harvest spray of pesticides to protect

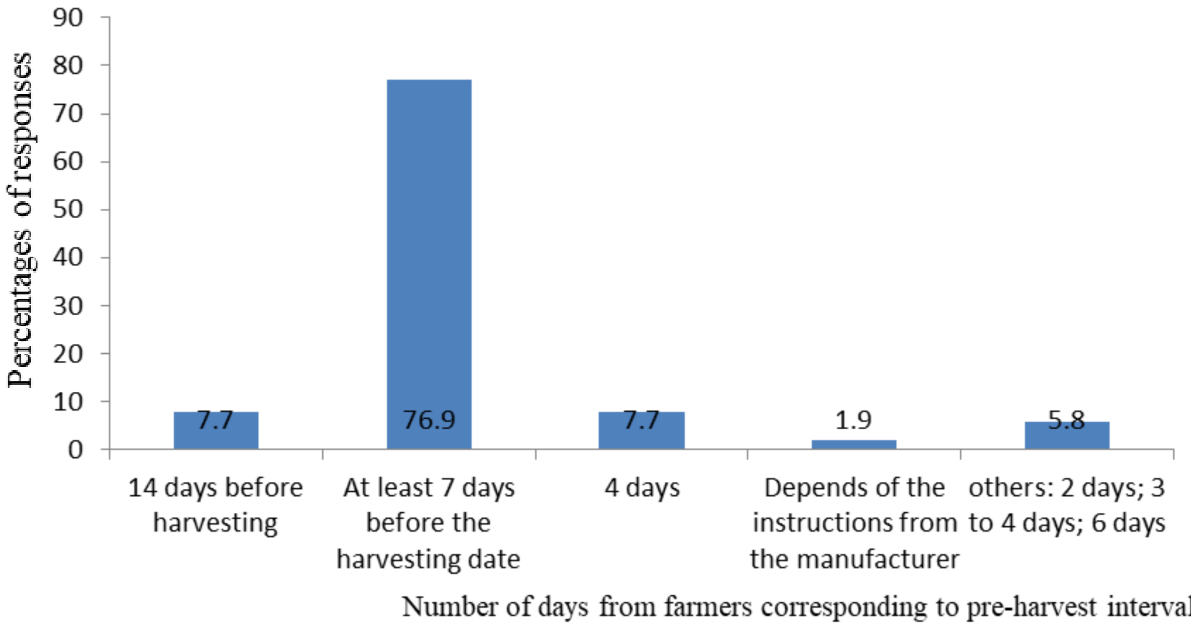

Figure 2. Pre-harvest interval after the last spray of pesticides in farms.

the produce. This may be explained by the need for making a good deal with the middlemen and the fear of postharvest diseases (*alternaria*, *buckeye rot*, *gray mold*, *soft rot*, *sour rot* and *bacterial soft rot*) attacking the crops (Rutledge, 2015). Other reasons may include: difficult access to the markets and worries of returns on investment to meet the financial households' needs. Postharvest spray of pesticides on tomato also signifies insufficient knowledge of the farmers. They ought to use chlorine gas, thiabendazole, calcium hypochlorite, calcium chloride ($CaCl_2$), 1-methylcyclopropene (1-MCP) and sodium hypochlorite (Arah et al., 2016; Rutledge, 2015). This result confirms the finding in India by Himani et al. (2015) revealing that 16% of the farmers do spray pesticides on tomato after harvesting.

Level of education, preference of middlemen and farm size as determinants of pesticides management in tomato farms

The level of education plays a great role in tomato farming and the middlemen are the assessors determining the welfare of the tomato farmers in the farming areas. The regression analysis between the independent variable (preferences of the middlemen) and the dependent variable (level of education) when tested is at 0.05 significant. The model statistically tested at 95% level is significant ($p= 0.0015$). It can then be said with confidence that, the preference of the middlemen depends on the level of education of the farmers

There is a strong correlation between the annual income and the farm size ($r= 0.51$) in which the middlemen still play a key role by determining the variety of tomato they prefer at post-harvest. It can confidently be asserted that, the regression explains the independent variable (farm size) on the variability of the dependent variable (annual income). This may show that, more investment in tomato farming may lead to more benefits. This can then be related to the intensive use of pesticides for the return on investment as the middlemen are unpredictable on their choice. This may lead to the misuse of pesticides if farmers do not have good knowledge on potential repercussions on consumers at post-harvest. The Pearson's correlation coefficient applied to income and farm size discloses a strong positive association at $r= 0.71$. This shows that, the farmers may likely misuse the chemicals if they are not fully aware of their negative aspects in post-harvest. This trend reveals the influence of poverty on the use of pesticides in tomato farms.

Conclusion

This study has reviewed some key points able to come with an appraisal on the use and knowledge of pesticides in the tomato farming community Mwea. The current results disclose gaps in understanding the use of pesticides in tomato's farms. Farmers are convinced of their good practices, whereas lots are still to do. For a community rank among the top four of the highest producers of tomatoes in Kenya, capacity building is needed. Of course, the community is doing so well, the farmers are able to transfer skills on pesticides use and a strong collaboration does exist among them. This is why more efforts from the government and the international community should be added in order to meet the standards of chemical use in tomato farms and the quality requirements of the markets for tomato. Under this scheme, the burden of diseases will decrease in households and governments and a sustainable development will rise with healthy people consuming safe tomatoes.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Definition of smallholder Sheko cattle keepers' breeding objectives through phenotypic ranking and choice experiments in Ethiopia

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This study aimed at identifying Sheko cattle keepers' preferences by way of phenotypic ranking and hypothetical choice experiment in their habitat in order to define the indigenous selection criteria. The ranking experiment report was based on 15 cows and 6 to 9 bulls. Three animals of the same sex were randomly assigned in one group that resulted into five groups for cows and two to three groups for bulls. Thirty cattle keepers belonging to another community were invited to rank the groups of experimental animals according to their own preferences and give the reasons why they had chosen the animals as 1st, 2nd, and 3rd. Then they were provided with life history of each cow, including age, milk yield, parity, calving interval and heart girth measurements; while for bulls, age, milk yield of dam, sire fertility and heart girth measurements were described to determine whether she/he would consider re-ranking them. The results of farmers' preference for traits through both methods are not consistent. In phenotypic ranking, the results indicate that, milk yield, body conformation, body size and coat color were emphasized in the selection of cow while, body size, dairy character, draught character and coat color traits were important traits for selection of bull. Information on life history provided insight in the respondents' ranking decisions. In choice experiments, the maximum likelihood estimates of the parameters for cow selection were significant in both lowland and midland agro-ecological zones (AEZs), except for calving interval in midland. The trait mothering ability was the most preferred trait followed by milk yield in both AEZs. For bulls the estimates were significant with the exception of growth rate in midland. It was found out that by this method breeding bulls are chosen based on milk performance of mother and temperament in both AEZs.

Key words: Breeding objectives, choice experiment, lowland, midland, phenotypic ranking, Sheko.

INTRODUCTION

The taurine Sheko cattle breed is one of the identified indigenous cattle breed in South-west Ethiopia that have been traditionally kept by small number of local farmers in the warm and humid to per-humid Sheko and Bench districts under mixed crop-livestock farming systems. The breed is well adapted to live in warm and humid environment, produce and reproduce in tsetse infested areas and is known for their relative high milk and traction capacity. Sheko cattle are prominent eyes with folded eyelid, possess gently sloping rump, prominent and upward protruding poll, broad and short ear, broad muzzle, compact body size, small to medium sized hump, dominated by red colour, majorities are polled and the rest are stumpy or curved type of floating horns (Takele, 2005). The breed manifests strong favorable trypanotolerant attributes; and has good packed red cell volume (PCV), production and reproduction Stein (2011). There are today areas where it is almost impossible to keep livestock due to trypanosomosis. A broader use of the Sheko breed in tsetse infested areas could improve animal health and household welfare. Today the majority of Sheko cattle manifest small humps that they inherited from zebu cattle. Sheko is now considered endangered by gradual interbreeding with local zebu (Dagris, 2004). Small herd size, indiscriminate interbreeding with local Zebu, critical shortage of breeding bull in many of the herds, early castration of bulls, their unmanageable and aggressive behavior, utilization of breeding bull/s born within the herd, lack of awareness about inbreeding was also the major threats accelerating the extinction of the breed (Takele, 2005; Sten, 2011). Despite the fact that the superior performance of Sheko breed is widely recognized by Sheko keepers, local authorities and Sheko breeders outside the area, the breed faces a number of different threats to their survival. Considering the importance and their endangered status, there is an urgent need to develop a pure-breeding strategy accomplished by a well-organized community based breeding program supported by a nucleus herd of purebred Sheko animals is necessary for breed conservation and sustainable management of these resources. Ideally, both *in situ* and *ex situ* conservation approaches for preserving genetic material should be considered for simultaneous application. The *in situ* conservation is advantageous to conserve the existing genetic diversity and allows further development of adaptive attributes of the breed in its natural habitat; provide an opportunity for permanent observation; ensures continued participation of the community and conserves diversities at all levels of the ecosystem.

Therefore, to develop breed conservation and improvement program in effective and meaningful way farmers' trait preferences in terms of the benefits that they perceive as well as challenges of the production environment were required. In evaluating cattle keepers' traits preferences in breeding animals, two different methods of ranking experiments approach; group-animal ranking and hypothetical choice experiment were used in two different agro-ecological zones of Ethiopia to identify breeding objectives for community-based cattle breeding programs. Thus, this study was aimed at identifying trait preference of smallholder farmers in two different agro-ecological zones of South-west Ethiopia through the use of group-animal ranking and hypothetical choice experiment.

MATERIALS AND METHODS

Study area and sampling framework

The study was carried out in warm and humid to per-humid midland and lowland agro-ecological zones (AEZs) of three districts, namely Sheko, Semein Bench and Debub Bench of Bench Maji Zone (BMZ), South-western Ethiopia, representing mixed crop-livestock production systems. Two peasant associations (PAs) (1 from midland and 1 from lowland) from each district of Sheko (Shayita and Boyita of the corresponding AEZ), Semein Bench (Genja and Garikin) and Debub Bench (Kokin and Kitte) were selected purposively based on concentration of Sheko cattle, their suitability for cattle production, accessibility to market and road, availability of common grazing land and willingness of the farmers to participate in the programs. Bmzardo (2012) briefly described the study areas below.

Sheko: This district lies between a latitude and longitude of 6° 50' N and 35° 00' E coordinates, respectively, and at an altitude that ranges from 950 to 1800 m above sea level (m.a.s.l.). The major area is classified under warm and humid to peri humid. The mean annual temperatures were 22.6°C and the annual rainfall at Mehal Sheko town (the capital of Sheko district) ranges from 1200 to 2200 mm per year. The soil type includes red brown and sandy loam.

***Semein bench*:** This district is classified under humid to peri humid climatic condition. It lies at an altitude ranging from 1050-2400 m.a.s.l. Average annual temperature ranges from 21.3 to 26°C and the mean annual rainfall of the district varied from 1200 to 2200 mm per annum. The soil type includes red brown, deep reddish, sandy loam and clay.

***Debub bench*:** The major area of this district is classified under warm and humid zone to peri humid climatic condition. Its altitude ranges from 980 to 1900 m above sea level. The average total annual rainfall is 1800 mm and the mean annual maximum and minimum temperatures recorded in were 17.25 and 27.5°C. The predominant soil types of the area include red brown, deep reddish and sandy loam.

Phenotypic ranking

Fifteen Sheko cows were purposively selected from each PA, marked and randomly assigned into five sub-groups for each ranking experiment. The bull sample population was not uniform and fulfilled the required number of fifteen in each PA due to higher shortage of bull in the existing herd. A total of 48 bulls; 6 from each PA of Shayita and Garikin; and 9 from each PA of Kitte, Kokin, Boyita and Genja were selected from within and surrounding PA having same production system, marked and randomly assigned into two and three sub-groups of three bulls each, respectively, for

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Table 1. Traits and trait levels for cows and bulls used in the choice experiments traits levels.

Traits	Levels	Reference level
Size (bull and cow)	1=big, 2=small	Small
Coat color (bull and cow)	1=red 2= red-brown, 3=patchy red and brown 4=yellow 5=black	Black
Temperament (bull and cow)	1= docile 2= aggressive	Aggressive
Growth (bull)	1= fast 2= slow	Slow
Milk of mother (bull)	1= high 2= low	Low
Traction (bull)	1= suitable 2= unsuitable	Unsuitable
Mothering ability (cow)	1=good mother, 2=bad mother	Bad mother
Calving interval (cow)	1= short 2= long	Long
Milk yield (cow)	1= high 2= low	Low

each ranking experiment. Each respondent was asked twice to rank the animals within each pen/group; first based on the phenotype of the animals alone, and then after the cattle keepers were provided with additional information on each animal in the form of history previously collected from the owners. The history included for cows were age, milk yield, parity, calving interval and heart girth measurement, while for bulls age, milk yield of dam, sire fertility and heart girth measurement (as a proxy for body size) were described. Five sub-groups of 3 cows each in all the selected PAs and 2 sub-groups of 3 bulls each in Shayita and Garikin PAs; and 3 sub-groups of 3 bulls each in Kitte, Kokin, Boyita and Genja PAs were randomly assigned and then restricted in a pen. Randomization was repeated three times during the course of each experiment after respondents covered ranking of all groups of cows and bulls. Thirty farmers unfamiliar with the experimental animals from other communities were invited to participate in the experiment. Each respondent was asked by an enumerator to rank the animals from 1^{st} to 3^{rd} within each pen according to his or her own preference and then give reasons (attributes and their levels) for his/her rankings in each group. Each person was then provided with additional information on the history of each animal as described above and asked to rank the animals once again.

Choice experiments

Choice experiment (Scarpa et al., 2003; Wurizinger et al., 2006; Ouma et al., 2007; Roessler et al., 2008; Kassie et al., 2009) was used to elicit farmers breeding goals. Attributes and attribute levels for cows and bulls used in the choice sets were identified through choice experiment survey conducted from June 2010 to November 2010 with respondents being asked to list all the attributes of bull and cow that they think are important to them and to rank these attributes in order of importance. Six highest ranked attributes were identified for cows and bulls and then used to design the choice experiment, with five traits having two levels and one trait with five levels. Table 1 presents the various traits and their levels for cows and bulls. Given the number of total possible combinations of 160 (25 * 51, that is, five attributes with two levels and one attribute with five levels) profiles, 25 choice-sets (50 profiles) were generated for each sex. These 25 choice-sets were generated by following the D-optimality or D-efficiency of 99.6% and A-efficiency of 99.2% design criterion procedure in Statistical Analysis System algorithm (SAS, release 9.1, 2003) which enabled to capture the main effects plus two-way interactions (Kuhfeld, 2005). This high efficiency implies that the variance matrix has quite small value with positive implications on the reliability of the estimates to be generated. D-optimality or D-efficiency and A-efficiency design maximizes the determinant of the information matrix, which results in minimizing the variation of the parameter estimates. It is the most popular criterion for generating optimal designs, and it seeks the design that minimizes the variances of estimated parameters in the pre-specified model (Kuhfeld, 2005). After intensive training of enumerators and a pre-test, data were collected from the 30 member households in each PA by development agents (DA) from the department of animal production for a consistent and clear explanation of all the attributes and attribute levels considered. The interviewee was first introduced to the type of choice task required and then he/she was presented with a sequence of twenty five sets of pair-wise choices for bulls and cows each using the actual experimental cards generated from the design. The differences in the levels of traits in the choice sets were also demonstrated using words that supported oral descriptions. Each choice task required the respondent to choose one animal profile he/she would prefer for breeding from the two profiles presented for each choice task and an option to select neither.

Data preparation and analytical methods

Phenotypic ranking experiment

Reasons for ranking on phenotype characters in phenotypic ranking experiment were analysed using frequency procedure of Statistical Analysis System (SAS, release 9.1, 2003) and Chi-Square was calculated to evaluate the influence of attributes on decisions made by respondents. Quantitative characters provided as life history were analysed with MEANS and using the Generalized Linear Model (GLM) procedures of the Statistical Analysis System (SAS, release 9.1, 2003).

Choice experiment

PROC LOGISTIC regression in Statistical Analysis System (SAS, release 9.1, 2003) was used to analyse the data for choice experiments. The application of choice experiments arises from the consumer theory developed by Lancaster (1966) which assumes that preference for goods are a function of the attributes or characteristics possessed by the good rather than the good *per se*. A major implication of this theory is that the overall utility of a good can be decomposed into separate utilities for its constituent characteristics or attributes. According to the random utility model, an individual *n* facing a choice among *j* alternatives would obtain a certain level of utility or profit from each alternative (McFadden, 1974, 2001).

Suppose an individual q (q=1,…,Q) faces a choice amongst *I* alternatives in each of *T* choice situations. Individual *q* is assumed to consider the full set of offered alternatives in a choice situation *t* and has to choose the alternative with the highest utility. The utility associated with each alternative *i* as evaluated by each individual *q* in choice situation *t* is represented in a discrete choice model by a utility function of the general form:

$$Uitq=\beta qXitq+eitq \quad (1)$$

Where; X_{itq} is a vector of explanatory variables that are observed by the analyst and include attributes of the alternatives, socio-economic characteristics of the respondent and descriptors of the decision context and the choice task itself in choice situation *t*. $ß_q$ and e_{itq} are parameters to be estimated and error terms respectively. In cases, where an economic agent chooses from among a set of multiple choices, multiple choice models have been employed to model choice behaviour. Suppose observed choice *Y* has values 0, 1, …., *m* and X_i includes individual *q*'s characteristics while Z_i are the choice specific characteristics, the multinomial logit model to assess the effect of X_i on the probability that choice *Y* has trait *j*, can be presented thus (Greene, 1997);

$$Prob\ (Y_i = j) = \frac{e^{\beta`_j x}}{\sum_{k=0}^{m} e^{\beta`_k x_i}}, j = 0,1, \ldots..m \quad (2)$$

The independent variable X_i does not vary across choice alternatives but varies across individuals. Whereas the independent variables Z_i varies across individuals as well as choice alternatives. Therefore, to assess the impact of *Z* (choice-specific attributes) on *Y*, the appropriate model to use is the conditional logit model for a total of J alternatives, defined as:

$$Prob\ (y_i|x_i = j) = j\frac{e^{\beta` z_{ij}}}{\sum_{i=1}^{J} e^{\beta` z_{ij}}}, j = 1, 2, \ldots..J \quad (3)$$

In conditional logit, the estimator is the value of ß while in multinomial logit, the estimator is the value of $ß_j$. PROC LOGISTIC regression in Statistical Analysis System (SAS, release 9.1, 2003) was used to analyze the data. PROC LOGISTIC is one of the tools in SAS for multivariate modelling of categorical outcome variables. The most familiar reason to use PROC LOGISTIC is to model binary categorical outcome variables. However, PROC LOGISTIC can handle the case where the dependent variable has more than two categories. PROC LOGISTIC uses a cumulative logit function if it detects more than two levels of the dependent variable, which is appropriate for ordinal (ordered) dependent variables with three or more levels (Elkin, 2004).

RESULTS AND DISCUSSION

Preferences for Sheko cattle attributes using phenotypic ranking experiments

Preferences for Sheko cow attributes

Phenotypic attributes of Sheko cow in phenotypic ranking experiment are presented in Table 2. Milk yield of cow accounted the largest proportion for both midland and lowland Sheko cattle owners accounted for 20 and 20.4%, respectively. Body size, body conformation, and coat color were also identified as important cow attributes with proportion of 14.6, 11, and 8.9%, respectively in midland. In lowland body conformation, body size and coat colour were ranked second, third and fourth important traits each accounted for 12.1, 11.8, and 9.6%, respectively. Moreover, mothering ability, temperament, body width, polledness, reproduction potential, color pattern, appearance, wide hind quarter, longer navel flap and thin and long neck were all considered important in both AEZs. In contrast to our study, Tano et al. (2003) reported on important traits in cattle from West Africa, where reproductive performance was most preferred by farmers and was ranked highly over 6 other traits from both conjoint and explicit ranking. Other traits, body length, reduced hump, concave face, calf size/vigor at birth and age were mentioned in both midland and lowland areas for cow.

Preferences for Sheko bull attributes

The results indicate that body size, draught character, dairy character and coat color traits are the main reasons for selecting bull in both AEZs. These four traits accounted for 62 and 61.7% of the total descriptions used by respondents in midland and lowland agro ecological zones, respectively (Table 3). In midland, the above mentioned attributes appeared with proportions of 19.6, 16.6, 15% and 10.8%, respectively. While in lowland were 17.9, 12.8, 17.2 and 13.8%, respectively. In midland AEZ, appearance (6.9%), body width (6.3%), wide front body (3.9%), body condition (3.7%) and color pattern (3.1%) was also important. Whereas in lowland, respondents identified appearance (9.1%), body width (6.3%), temperament (4.2%), mating ability (3.3%) and body condition (3.1%). Other traits, body length, polledness, age, scrotum size, tail length, wide hind quarter, short tail, prominent neck, hump size and dewlap were mentioned in both midland and lowland AEZs. However, contrary to the present study of farmer preference in bulls was reported by Tano et al. (2003), where disease resistance was highly ranked in West African cattle. For Sheko cattle keepers conformation of a bull were assessed based on dairy character (e.g. milk yield potential, long tail, wide hind quarter and big scrotum) and draught character (e.g. wide front body, short tail and prominent neck). While body size of a bull were assessed based on milk yield. In both AEZs, Sheko cattle breeder prefers bigger size and bull having good conformation. Generally, the proportion for the frequencies of reasons given by cattle keepers for ranking of body size and coat color in bull were of higher magnitude to those in cow.

Generally evaluation of selection criteria in indigenous stocks using phenotypic ranking approaches is new and similar studies are not available so far in cattle. However, higher ranking values for both beauty (color) and size traits for cows and beauty traits (coat colour) for bulls were reported from results of other phenotypic ranking experiment with Ugandan Ankol cattle keepers (Ndumu et al., 2008). The influence of beauty traits (coat colour)

Table 2. Frequency for cow traits preferences with percentage of phenotype in the ranking of cows by agro ecological zones.

Traits	Midland		Lowland	
	Frequency	%	Frequency	%
Size traits				
Body size	591	14.6	479	11.8
Body length	75	1.9	21	0.5
Body width	201	5.0	190	4.7
Conformation traits				
Conformation	445	11.0	490	12.1
Appearance	120	3.0	129	3.2
Wide hind quarter	119	2.9	171	4.2
Longer naval flap	95	2.3	146	3.6
Thin and long neck	81	2.0	86	2.1
Reduced hump	26	0.6	38	0.9
Concave face	19	0.5	3	0.1
Mothering ability				
Mothering ability	263	6.5	195	4.8
Calf size/vigor at birth	65	1.6	71	1.8
Coat color				
Coat color	360	8.9	390	9.6
Colour pattern	123	3.0	146	3.6
Milk yield	809	20.0	827	20.4
Temperament	250	6.2	248	6.1
Reproduction potential	155	3.8	133	3.3
Polled	175	4.3	227	5.6
Age	78	1.9	58	1.4
Sum	4050		4048	

for bulls, and body size and beauty traits (coat colour) for cows as the more important selection criteria for ranking decisions of cattle keepers obtained in this study is in agreement with the results reported by Ndumu et al. (2008) for Ankole cattle. The importance of body size, coat color and milk yield for selection criteria obtained in this study is in agreement with other finding (Tadele, 2010) on different sheep breeds of Ethiopia.

Attribute-levels used by farmers to express their preferences of Sheko cow in phenotypic ranking

Based on the results obtained in Table 2, the total magnitude and order of recurrence was high in combination for milk yield (20 and 20.4%); body size (14.6 and 11.8%); body conformation (11 and 12.1%); coat color (8.9 and 9.6%) and temperament (6.2 and 6.1%) in midland and lowland, respectively. Farmers in both midland and lowland used qualitative descriptions for selection of attribute-levels preferences. Reasons of ranking for attribute-levels chosen relevant to milk yield trait was given in relation to body size and conformation. Generally bigger size and good conformation were preferred trait-levels for Sheko cattle breeder and assumed to result a good milking animal. Similarly, the attribute-levels used for description of cows were ‘big’, ‘moderate’ and ‘small’ for body size and ‘good’ and ‘bad’ for coat color, temperament and body conformation. The proportion of big-size cow was higher in midland AEZ in rank group 1 and 2 than in lowland AEZs. In the first and second rank groups the proportion of choosing medium-size cow was higher in lowland than obtained in midland, whereas, in the third rank group the percentage of medium-size cow were higher in midland than lowland. In both midland and lowland, the proportion of choosing good body conformation in the first rank group was same from each other whereas, the proportion in the second rank group was higher in midland AEZ. At the third rank group, the proportion was lower than obtained in lowland. In both AEZs, farmers gave more attention for the coat color of their animals. The proportion of choosing good coat color in the first and second rank group is almost similar. In case of temperament, the proportion of bad (aggressive) temperament was increased as the rank group decreased from the second to the third rank group in both AEZs. The proportion of the selected attributes and their levels of body size, body conformation, coat

Table 3. Frequency for bull traits preferences with percentage of phenotype in the ranking of bulls by agro ecological zones.

Traits	Midland		Lowland	
	Frequency	**%**	**Frequency**	**%**
Size traits				
Body size	353	19.6	322	17.9
Body length	23	1.3	22	1.2
Body width	114	6.3	114	6.3
Colour traits				
Coat color	194	10.8	248	13.8
Colour pattern	56	3.1	49	2.7
Production character				
Dairy character				
Milk character	270	15.0	309	17.2
Long tail	12	0.7	5	0.3
Wide hind quarter	49	2.7	44	2.4
Big scrotum	3	0.2	14	0.8
Draught character				
Draught character	299	16.6	231	12.8
Wide front body	32	3.9	31	1.7
Short tail	7	0.4	-	-
Prominent neck	50	2.8	21	1.2
Polledness	23	1.3	-	-
Temperament	23	1.3	75	4.2
Age	20	1.1	32	1.8
Mating ability	48	2.7	59	3.3
Body condition	66	3.7	56	3.1
Big hump	27	1.5	14	0.8
Large dewlap	7	0.4	-	-
Appearance	124	6.9	164	9.1
Sum	**1800**	**-**	**1800**	**-**

color and temperament within each rank group of Sheko cow in both midland and lowland AEZs are presented in Figure 1.

Attribute-levels used by farmers to express their preferences of Sheko bull in phenotypic ranking

The proportion of the selected attributes and their levels of body size, dairy character, draught character and coat color within each rank group for Sheko bull in midland and lowland are presented in Figure 2. Like in cow, the highly selected attributes in Table 2, further used by farmers to express their attribute-levels preferences of bull in both AEZs were body size, draught character, dairy character and coat color. The attribute-levels used for description of bull was ‘big’, ‘moderate’ and ‘small’ for body size and ‘good’ and ‘bad’/‘poor’ for coat color, dairy character and draught character. Generally, the proportion of choosing big-size bull was higher in midland at rank group one, two and three than in lowland. In both AEZs, good draught character at the first rank group was same from each other whereas, the second and third rank group had higher in midland than lowland. Whereas in lowland, the proportion of choosing good coat color was higher than obtained in midland at rank group one, two and three. In case of bull dairy character, the proportion of choosing good (docile) character was same in both AEZs at rank group one, whereas, the second rank group obtained in midland had lower percent value and further decreased as the stage of rank decreased to the third rank group of phenotype and results become higher than the lowland.

Sheko cattle having pure red, red-brown, patchy red

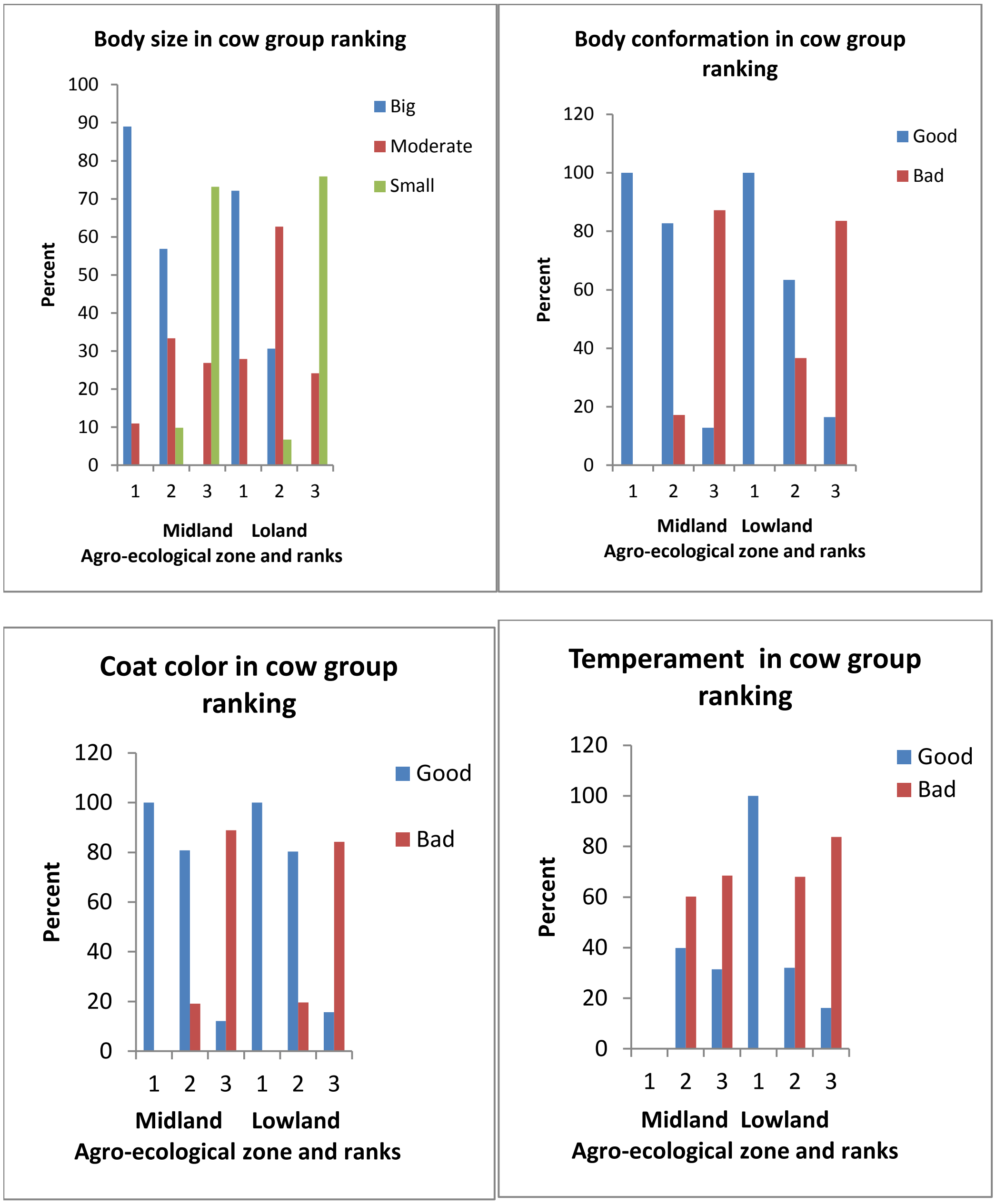

Figure 1. Attribute-levels of cow by agro-ecology and rank group.

and white and yellow in that order over black influenced the ranking decision of the respondents in both midland and lowland AEZs. Report by Ndumu et al. (2008) indicated that beauty traits like coat color and pattern play significant role in ranking decision of Ankole cattle. Ouma et al. (2004) noted Maasai pastoralists in Kenya and Ethiopia prefer dark coat colored. Tesfay (2008) revealed Menz sheep breeders prefer primarily plain white colored sheep and Afar pastoralists prefer creamy/white color with light red patch at the back and plain light red colored. Generally, the proportion of favourable descriptions of attribute-levels was higher in groups of animals ranked first and vice versa. In contrast to this study on body size of animal other than the two AEZs of mixed production environments, Ouma et al. (2004) reported that farmers preferred lighter (medium sized) animals which suit their pastoral system.

Comparisons of rankings with and without life history in cow

Ranking of cow attributes, on the basis of first, second and third rank categories before and after additional

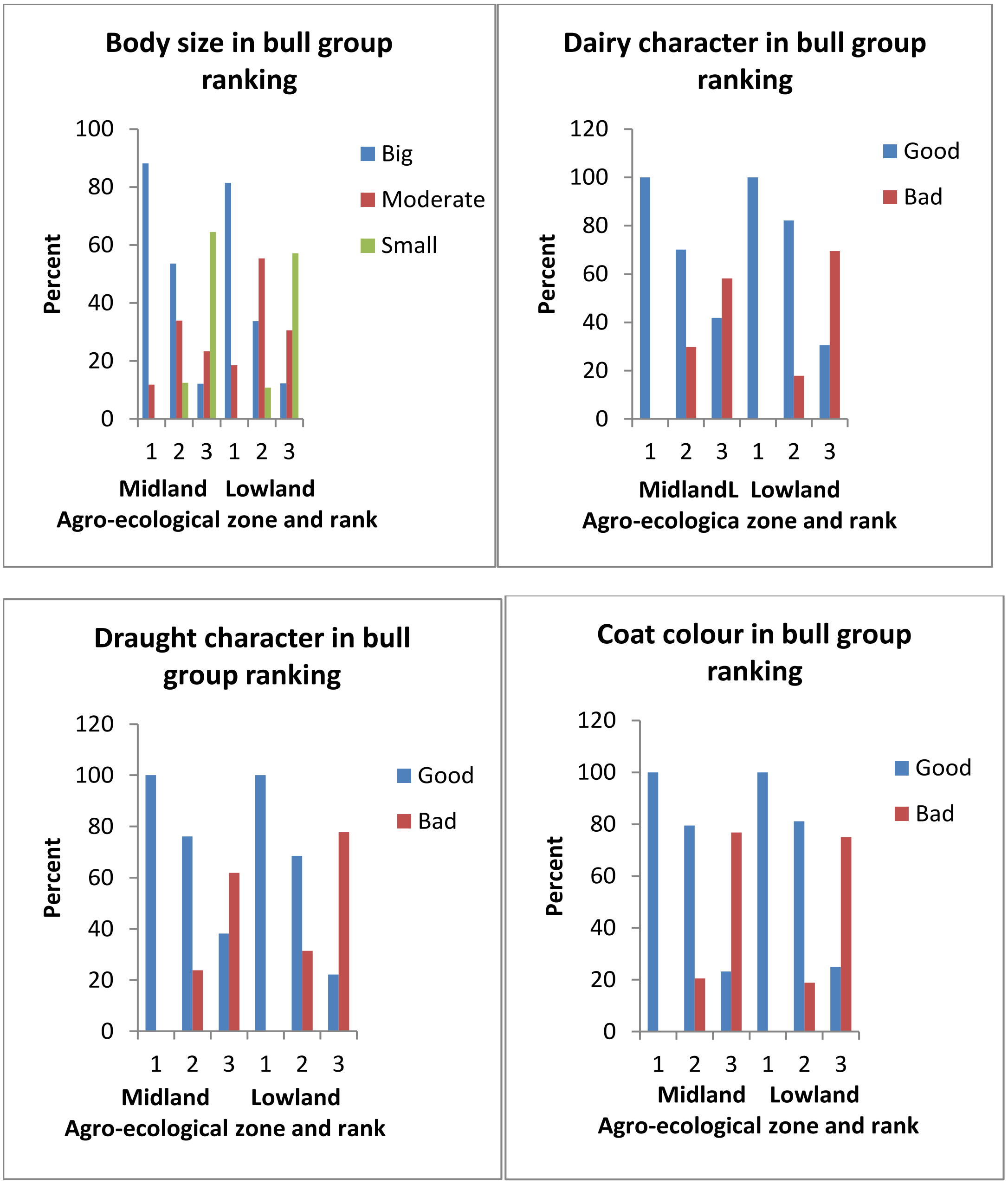

Figure 2. Attribute-levels of bull by agro-ecology and rank group.

information are presented in Table 4. Based on the total mean (standard deviation) obtained in rank groups of phenotypes all traits considered before and after provision of life history, remain significant ($p<0.05$ and $p<0.001$) in the ranking decision of respondents for both midland and lowland Sheko cattle keepers. In midland prior to life history, age, milk yield, parity and heart girth measurement of Sheko cow in the first rank group was significantly higher ($p<0.01$) than the value of the second rank group and third rank group, the third rank group having the least. After provision of life history, only milk yield and heart girth measurement showed the same trend for differences in the values between the rank groups of the first, second and third. The difference was, however, for age and parity between the second and third rank groups ($p>0.05$) after provision of life history. In this area, results without information related to calving interval in the first rank group was higher ($p<0.01$) than the value of the second rank group and third rank group but the first rank group didn't statistically differ with the third rank group. Corresponding results with life history was higher ($p<0.01$) between the first, second and the third rank

Table 4. Ranking of cows before and after provision of life history.

Agro-ecology		Without live history					With live history			
	Attributes	Overall mean	1	2	3	p-value	1	2	3	p-value
Mid	Age	8.19±1.48	8.45±1.41^{a}	8.19±1.39^{b}	7.93±1.59^{c}	***	8.50±1.33^{a}	8.06±1.42^{b}	8.02±1.63^{b}	***
	Milk yield	2.61±0.42	2.71±0.39^{a}	2.63±0.41^{b}	2.50±0.44^{c}	***	2.78±0.38^{a}	2.64±0.40^{b}	2.42±0.40^{c}	***
	Parity	3.02±0.93	3.16±0.87^{a}	3.03±0.87^{b}	2.88±1.01^{c}	***	3.18±0.82^{a}	2.93±0.86^{b}	2.95±1.08^{b}	***
	CI	1.65±0.23	1.66±0.24^{a}	1.64±0.22^{b}	1.65±0.23^{ab}	*	1.68±0.24^{a}	1.64±0.21^{b}	1.63±0.23^{b}	***
	Heart girth	130.82±3.86	131.69±3.7^{a}	130.92±3.62^{b}	129.84±4.03^{c}	***	131.87±3.55^{a}	130.58±3.60^{b}	130.00±4.15^{c}	***
Low	Age	7.96±1.40	8.13±1.38^{a}	7.86±1.34^{b}	7.88±1.45^{b}	***	8.16±1.4^{a}	7.85±1.32^{b}	7.87±1.44^{b}	***
	Milk yield	2.70±0.36	2.76±0.36^{a}	2.68±0.34^{b}	2.66±0.37^{b}	***	2.76±0.36^{a}	2.68±0.34^{b}	2.66±0.37^{b}	***
	Parity	2.89±0.95	3.02±0.95^{a}	2.84±0.92^{b}	2.82±0.95^{b}	***	3.04±0.97^{a}	2.83±0.92^{b}	2.81±0.96^{b}	***
	CI	1.64±0.24	1.64±0.25^{a}	1.61±0.23^{b}	1.66±0.25a	***	1.64±0.25^{a}	1.61±0.23^{b}	1.67±0.24^{c}	***
	Heart girth	133.70±3.93	134.28±3.93^{a}	133.48±3.71^{b}	133.36±4.08^{b}	***	134.33±3.98^{a}	133.39±3.65^{b}	133.37±4.08^{b}	***

Means with different superscripts within the same row and class are statistically different. Ns = Non significant; CI, calving interval; *significant at 0.05; **significant at 0.01 and *** significant at 0.001.

group while the latter two groups are not statistically different (p>0.05) from each other. While in lower altitude, prior to additional information, the results of age, milk yield, parity and heart girth measurement in cows, on thebasis of rank groups stay same trend after provision of additional information. However, provision of life history only altered respondents' decision on CI in rank group between the second and third. The provided life history did not influence the ranking decisions of the respondents' in both AEZs, as indicated no significant differences were observed between the rank groups of first, second and third categories before and after provision of additional information. The reason could be that they have more association with their livestock and consequently developed their own mechanisms of indigenous selection criteria that consider this. This result does not agree to those of Ndumu *et al.* (2008) who reported significant influence of additional information in the ranking decision of Ankole cattle on milk yield.

Comparisons of rankings with and without life history in bull

Results for various attributes before and after provision of life history in bull are given in Table 5. Results indicate all the attributes used in the ranking of bull before provision of additional information were significantly (p<0.05 or p<0.01 or p<0.001) influenced Sheko cattle breeders' preferences in both midland and lowland except for sire fertility (p>0.05) in lowland AEZ. However, the difference was observed for heart girth measurements when considered with additional information showed non-significant (p>0.05) influence in the ranking decisions of the respondents, indicating that variation in ranking results are due to the additional information on heart girth measurements of bulls. While age, milk yield and sire fertility remain significant implied that the provided information did not influence respondents' decision in midland AEZ. Whereas, in lowland after provision of additional information dams milk yield and sire fertility showed the same trend for differences in the values between the rank groups of the first, second and third. However, the differences were observed between ages and heart girth measurements, suggesting that life history influenced selection of bulls. On the other hand, in midland, prior to life history, age, milk yield of dam and sire fertility in the first and second rank groups were not statistically different (p>0.05) from each other, whereas, the third rank group had lower (p<0.01) than the first two. However, only milk yield of dam information altered respondents' decision in the first and second rank group. The significant influence of information in the ranking of bull on sire fertility and milk yield of dam reported by Ndumu et al. (2008) working on Ugandan Ankole cattle disagree with the results of the present study. In midland, milk performance of dam was decreased as the rank groups decreased from the first to the third rank group followed the logical trend in groups of bull ranked from first to third.

Table 5. Ranking of bulls before and after provision of additional information.

Agro-ecology	Without live history						With live history			
	Attributes	Overall mean	1	2	3	p-value	1	2	3	p-value
Mid	Age	6.77±2.43	6.95±2.46[a]	6.89±2.47[a]	6.46±2.34[b]	**	6.93±2.47[a]	6.85±2.47[a]	6.54±2.35[b]	*
	Dam milk	2.76±0.50	2.83±0.49[a]	2.79±0.49[a]	2.67±0.50[b]	***	2.84±0.48[a]	2.77±0.49[b]	2.69±0.51[c]	***
	Sire fertility	0.76±0.10	0.77±0.11[a]	0.77±0.11[a]	0.76±0.10[b]	*	0.77±0.12[a]	0.77±0.12[a]	0.75±0.98[b]	***
	Heart girth	130.91±6.11	131.36±6.15[a]	131.14±6.08[a]	130.24±6.04[b]	**	131.25±6.07	130.98±6.17	130.46±6.05	NS
Low	Age	6.99±2.40	6.89±2.47[b]	6.88±2.32[b]	7.20±2.38[a]	*	6.98±2.48[a]	6.91±2.35[a]	7.08±2.35[a]	NS
	Dam milk	2.65±0.54	2.60±0.50[b]	2.62±0.52[b]	2.73±0.59[a]	***	2.61±0.51[b]	2.63±0.51[b]	2.71±0.59[a]	**
	Sire fertility	0.76±0.13	0.76±0.12	0.77 ±0.13	0.77±0.13	NS	0.75±0.12[a]	0.77±0.13[a]	0.77±0.13[a]	NS
	Heart girth	129.68±5.82	129.39±6.0[b]	129.28±5.54[b]	130.37±5.86[a]	**	129.58±6.06	129.37±5.59	130.10±5.78	NS

Means with different superscripts within the same row and class are statistically different. Ns = Non significant;*significant at 0.05; **significant at 0.01 and *** significant at 0.001.

Table 6. Maximum likelihood estimates (± s.e) and their level of significance for cows traits.

Parameter	DF	Estimates (± s.e)	
		Midland	Lowland
Size	1	0.14±0.054 **	0.14±0.053 **
Coat color	1	-2.15±0.048***	-2.09±0.047***
Temperament	1	0.12±0.054*	0.18±0.533***
Milk yield	1	0.47±0.058***	0.33±0.055 ***
Calving interval	1	-0.10 ±0.051[NS]	0.21±0.054***
Mothering ability	1	1.51±0.082***	1.22±0.072***
Pseudo-R^2		0.348	0.335

DF=degree of freedom; ***p<0.001; **p<0.01; *p<0.05 NS = p>0.05.

Preferences for Sheko cattle attribute using choice experiments

Cow traits preferences

The results for cow are presented in Table 6. The pseudo-R^2 ranged from 0.335 to 0.348 for cow. The maximum likelihood estimates (MLE) of the parameters for cows were significant (P<0.05 or p<0.01 or p<0.001) in both AEZs except calving interval (CI) in midland AEZ. Attributes with unexpected signs were CI in midland and coat color in both midland and lowland areas. The trait mothering ability was the most preferred trait followed by milk yield in both AEZs.

Bull traits preferences

Results for bull are presented in Table 7. The pseudo-R^2 ranged from 0.247 to 0.288 for bull.

Table 7. Maximum likelihood estimates (± s.e) and their level of significance for bull traits

Parameter	DF	Estimates (± s.e)	
		Midland	Lowland
Size	1	0.29±0.052***	0.21±0.051***
Coat color	1	-1.84±0.046***	-1.44±0.044***
Growth rate	1	0.03±0.049[NS]	-0.11±0.048*
Milk per of mother	1	0.46±0.054***	0.62±0.056***
Temperament	1	0.71 ±0.058***	0.47±0.054***
Traction	1	0.34±0.053 ***	0.26±0.051***
Pseudo-R^2		0.288	0.247

DF = degree of freedom; ***p<0.001; **p<0.01; *p<0.05; NS=p>0.05.

Attributes with unexpected signs were growth efficiency in lowland and colour in both AEZs. The estimates were significant (p<0.05 or p<0.001) with the exception of growth rate in midland AEZ. Temperament was of high importance in midland and it ranked second in lowland next to milk performance of mother. Milk performance of mother was the most preferred attribute for breeding bull selection in lowland and the second most preferred trait in midland. This indicates that cattle keepers prefer bulls whose dams are high milk yielder. In midland AEZ, bull attributes influencing breeding candidates' selection were temperament, milk performance of dam, traction and body size in that order, whereas in lowland, milk performance of dam, temperament, traction and body size were the preferred traits in choosing breeding bull, respectively.

Cow trait-levels preferences

The results for cow are presented in Table 8. For breeding cow, the odds ratio estimates of the different attribute levels are very similar in both AEZs. Sheko cattle breeders in lowland AEZ, slightly more preferred cows with red–brown, pure red, plain yellow and patchy red and brown colors relative to black, in that order with an odds ratio estimates of 1.08, 1.06, 1.04 and 1.01, respectively. However, the attribute levels red-brown colour relative to black coat colored was only considered and less attention was given for the other attribute levels of pure red, plain yellow and patchy red and brown colors in midland AEZ. The attribute levels one calf a year, red-brown and two litre milk per milking of cows appear to be important for breeding cow selection with nearly comparable preferences in both AEZ. Large-sized and docile tempered cows are slightly more preferred than their counterparts in midland agro ecology. In both areas, it appears that less emphasis was given to cows' mothering ability as indicated by the odds of selecting good mother cows v. bad ones. The odds of choosing 2 L milk vs. 1 litre milk-producing cows remains almost equal in both AEZs.

Bull trait-levels preferences

The results for bull attribute-levels preferences are presented in Table 9. Like in cow, the odds ratio estimates for all attribute-levels of bull were very similar in both AEZs. The odds of choosing big vs. small-sized bulls remains almost equal in both AEZ, and it appears that less emphasis was given to bull body size as indicated by the estimates of odds ratio (Table 9). Farmers in midland area preferred pure red, plain yellow, patchy red and brown and red-brown in that order with an odds ratio estimates of 1.12, 1.11, 1.10 and 1.03, respectively. Whereas farmers in lowland area consider plain yellow, pure red, red–brown and patchy red and brown over black with an odds ratio estimates of 1.25, 1.19, 1.09 and 1.08, respectively. Docile tempered bull and 2lt milk performance of mother were slightly more preferred than their counterparts in lowland AEZ. Concerning traction, a slight more preference values for suitable traction are placed in midland area. Growth efficiency of the animal does not play a key role in the choice made by the cattle keepers in midlands while fast growing bulls are slightly more preferred than their counterparts in lowland AEZ.

The explanatory power of the model is good with a pseudo-R^2 ranging from 0.247 to 0.288 for bull and 0.335 to 0.348 for cow. Well-fitted models occur with likelihood ratio index or pseudo-R^2 greater than 0.2 (Hoyos, 2010). The trait body size, milk performance of mother, temperament and traction is strongly significant (p<0.001) and has the expected positive sign for breeding bull in both AEZs with nearly comparable coefficients which indicates homogeneous preferences implying that Sheko cattle keepers derive a positive utility from the attributes. Results also indicated that growth efficiency in lowland, and coat colour in both AEZs had negative coefficients but is significant (p<0.05 or p<0.001). The results of coat colour are inconsistent with our expectations that red,

Table 8. Odds ratio estimates of the different attribute levels against their reference categories and their confidence intervals for cows traits.

Effects	Point estimates (95% Wald CI)	
	Midland	Lowland
Size (1 *v*. 2)	1.01 (0.815 to 1.229)	0.972 (0.793 to 1.190)
Coat color (1 *v*. 5)	0.99 (0.710 to 1.353)	1.06 (0.761 to 1.482)
Coat color (2 *v*. 5)	1.02 (0.709 to 1.455)	1.08 (0.746 to 1.572)
Coat color (3 *v*. 5)	0.95 (0.659 to 1.384)	1.01 (0.696 to 1.476)
Coat color (4 *v*. 5)	0.98 (0.690 to 1.392)	1.04 (0.726 to 1.493)
Calving interval (1 *v*. 2)	1.04 (0.860 to 1.265)	1.07 (0.869 to 1.315)
Milk yield (1 *v*. 2)	1.07 (0.855 to 1.347	1.06 (0.853 to 1.310)
Temperament (1 *v*. 2)	1.00 (0.816 to 1.228)	0.96 (0.785 to 1.184)
Mothering ability (1 *v*. 2)	0.82 (0.578 to 1.148)	0.93 (0.687 to 1.246)

CI=confidence interval. Size (1=big, 2=small); colour (1=red, 2= red-brown, 3=patchy red and brown, 4=yellow 5=black for both midland and lowland); calving interval (1=one calf a year, 2=one calf every two years); milk yield (1=two litre per milking, 2=one litre per milking); temperament (1=docile, 2=aggressive); mothering ability (1=good mother, 2=bad mother).

red-brown, patchy red and brown or yellow coat colour types are preferred to black as usually the latter have higher chances of being bitten by the tsetse flies and as revealed by the production systems study. Attributes showing negative coefficients of MLE are not preferred by livestock keepers as they signify a negative utility from the attribute (that is, growth rate and coat colour). Growth performance in midland is positive but not statistically significant suggesting that respondents choices are not strongly influenced by growth rate. For the cow model, the derived MLE for the attributes mothering ability is one of the most highly valued attributes in both AEZ (Table 6). In the current study, milk production trait is the second most important attribute for breeding cows selection, had positive coefficient and statistically significant in both AEZs, suggesting that Sheko cattle keepers' choices are strongly influenced by milk yield or it likely be that the respondents gave more weight to milk production. The odds of choosing 2 L as opposed to 1 litre per milking were also very similar in both AEZs. With regard to calving interval, the odds of choosing short calving interval as opposed long one was very similar in both AEZs, whereas, temperament was favoured in lowland. Results indicated that body size in both AEZs, remains equal and had the expected positive sign and significant ($p<0.01$) suggesting that respondents choices are strongly influenced by big body size as opposed to small body sized cows. The available reports on cattle other discrete choice experiments conducted elsewhere indicated significant influence of reproductive potential (calving interval) for cows' in south-western Ethiopia and Kenya (Ouma et al., 2004); milk performance of mother and temperament for bulls and milk yield for cows (Wurzinger et al., 2006); body size for cows (Kassie et al., 2009) in central Ethiopia and bull (Zander and Drucker, 2008) in southern Ethiopia and bull and cow in

Table 9. Odds ratio estimates of the different attribute levels against their reference categories and their confidence intervals for bull traits.

Effects	Point estimates (95% Wald CI)	
	Midland	Lowland
Size (1 v. 2)	0.96 (0.79 to 1.18)	0.97 (0.79 to 1.18)
Coat color (1 v. 5)	1.12 (0.84 to 1.49)	1.19 (0.73 to 1.64)
Coat color (2 v. 5)	1.03 (0.75 to 1.41)	1.09 (0.71 to 1.69)
Coat color (3 v. 5)	1.10 (0.80 to 1 .51)	1.08 (0.71 to 1.68)
Coat color (4 v. 5)	1.11 (0.70 to 1.75)	1.25 (0.73 to 2.15)
Growth rate (1 *v*. 2)	0.96 (0.79 to 1.16)	1.02 (0.85 to 1.23)
Temperament (1 *v*. 2)	1.06 (0.84 to 1.33)	1.09 (0.88 to 1.35)
Traction (1 *v*. 2)	1.01 (0.82 to 1.24)	1.00 (0.81 to 1.22)
Milk of mother (1 *v*. 2)	1.02 (0.82 to 1.26)	1.05 (0.84 to 1.31)

CI=confidence interval. Size (1=big, 2=small); colour (1=red, 2= red-brown, 3=patchy red and brown, 4=yellow 5=black for both midland and lowland); growth rate (1=fast, 2=slow); temperament (1=docile, 2=aggressive); traction (1=suitable, 2=unsuitable); milk performance of mother (1=two litre per milking, 2=one litre per milking).

southern Ethiopia and northern Kenya; bull and cow (Ouma et al., 2007) in central Ethiopia and northern Kenya and suitable traction for bull (Zander and Drucker, 2008) on producers' decisions. Application of CE for the valuation of attributes of livestock is very recent and only a few employed it. The significant influence of milk yield and body size for cows on producers' decisions obtained in this study is in agreement with the results reported for milk yield (Tano et al., 2003; Wurzinger et al., 2006; Zander, 2006; Ouma et al., 2007; Kassie et al., 2012) and body size (Ouma et al., 2007; Zander and Drucker, 2008; Kassie et al., 2009). Contrary, Kassie et al. *(*2012) obtained non significant influence of body size on producers' decisions for cows working on indigenous breeds of cattle in Ethiopia. Similarly, for bulls, the significant influence of milk performance of mother, temperament, body size and traction on producers' decisions obtained in this study is in agreement with the results reported for milk performance of mother and temperament (Wurzinger et al., 2006), body size (Ouma et al., 2007; Zander and Drucker, 2008) and traction (Zander and Drucker, 2008; Kassie et al., 2012). In other studies, the significant influence of size and coat colour for bulls, and body size, colour, calving interval and mothering ability for cows on producers' decisions obtained in this study is in agreement with other finding of Duguma et al. (2011) on different sheep breeds of Ethiopia; Omondi et al. (2008a) for bucks in Kenya; and Roessler et al. (2008) for pigs in Vietnam working on body size.

Comparisons of phenotypic ranking and choice experiments

These methods directly measure preferences in the form of ranking as done by each individual respondent. The results of trait preferences of Sheko cattle keepers obtained in the present study using hypothetical choice experiments and phenotypic ranking methods were compared. The results of farmers' preference for traits are not consistent and varied accordingly among the methods. However, comparable result was established for production traits (like milk) regardless of the methods. For example, qualitative traits (like color) were the least preferred trait for both cows and bulls using choice experiments in both AEZs. However, in phenotypic ranking color of cows was ranked 4th in both AEZs whereas for bulls color was ranked 4th in midland and 3rd in lowland area. In Choice Experiments, mothering ability is the most preferred attribute for breeding cow selection followed by milk yield in both AEZs. However, in phenotypic ranking mothering ability ranked 5th in midland and 7th in lowland while milk yield ranked first in both AEZs followed by body size and body conformation for midland and lowland Sheko owners, respectively. Again in choice experiments, the influence of milk performance of mother followed by temperament on respondents' decision making was high for bulls in lowland and the reverse in midland. While using phenotypic ranking method, dairy character of bull was ranked 3rd in midland and 2nd in lowland. Temperament ranked 14th and 7th in midland and lowland, respectively, while body size was the most preferred attribute in both AEZs followed by draught character in midland.

Conclusion

Both phenotypic ranking and choice experiments can serve as tools for identifying indigenous selection criteria of Sheko cattle keepers with differences of emphasis between cows and bulls. Through both methods, the results were heterogeneous. Sheko cattle owners in both AEZs identified a large number of traits including traits of appearance, fitness for traction, production and reproduction with differences of emphasis that they would use for bull and cow selection reflecting the multi-functional nature of the Sheko cattle breed. However, only few producers' priority attributes should be used in designing breeding plans in order to make as simple as possible, easy implementation and to complement with the real life of the different communities. Therefore, the values of tangible attributes (production and reproduction traits) as well as important feature of the animal for herding and handling ease (temperament) considered in this study are particularly relevant, as they can be used in determining breeding programme goals and in selecting appropriate animals for breeding programmes. The methods of both phenotypic ranking and choice experiments approach are useful for identifying selection criteria for designing breeding plans and in selecting appropriate animals for breeding programmes of Sheko breed in their production environment.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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