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Short Communication

Dissipation of fenpropathrin residues in squash fruits intercropped with garden rocket

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The dissipation and residue of fenpropathrin in squash fruits intercropped with garden rocket under field conditions were studied. Samples were collected periodically on the sampling days after applications. The residue data revealed the half-life values of fenpropathrin in Squash fruit and garden rocket were found to be 1.78 and 1.85 days, respectively. The residues of fenpropathrin were more greatly concentrated in the squash fruit shell than that squash fruit pulp. The initial concentration level of fenpropathrin in squash fruit was lower than in the garden rocket plants. Fenpropathrin levels in squash fruit or garden rocket below maximum residue level (1.0 mg/kg) were detected 3 days after application and no residues were detected on the 10th day.

Key words: Dissipation, fenpropathrin, squash fruits, garden rocket, intercropping.

INTRODUCTION

In Egypt, squash fruit and garden rocket are important vegetables for human consumption in mature stages. The need to maximize food production in a limited cultivated area encourages the use of intercropping system in agriculture (that is, squash fruit with garden rocket). The aim is to gain more production per unit area in a limited time. Both squash fruit and garden rocket are liable to be infested with different insect pests and diseases which usually cause serious injury and reduction to the final yield. Among the classes of pesticides commonly employed in controlling crop pests are the synthetic pyrethroids, whose use has increased over the past decade. They are being used extensively due to their effectiveness against a broad spectrum of insects, the low dosage required, and their advantageous environmental properties such as photostability and nontoxicity to mammals (Navickiene et al., 1999; Albadri et al., 2012). Fenpropathrin (a-cyano-3-phenoxybenzyl-2, 2, 3, tetramethylcyclopropanecarboxylate), a typical pyrethroid insecticide used as an acaricide insecticide, classified as class II “moderately hazardous by the World Health Organization (Anonymous, 1991). It is used to control many species of mites and insects like whiteflies, cotton field crops, glass house crops, vegetables. Appreciable levels of pyrethroid residues can occur in food commodities from crops, food of animal origin (eg. milk, eggs and meat), soils, sediments, and surface, ground and drinking water (Priya et al., 2007). This experiment was carried out to investigate the residues of Fenpropathrin in a squash fruits intercropped with garden rocket.

MATERIALS AND METHODS

Experimental

Field experiments were conducted in Aboutouala, Mania El-kamh

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Table 1. Residues of fenpropathrin in Squash fruit and garden rocket.

Days after application	Garden rocket		Squash fruits shell		Squash fruits pulp	Whole squash fruits	
	Residue level (mg/kg) Mean ± SD	Dissipation (%)	Residue level (mg/kg) Mean ± SD	Dissipation (%)	Residue level (mg/kg) Mean ± SD	Residue level (mg/kg) Mean ± SD	Dissipation (%)
Initial[a]	1.76±0.06	0.00	1.52±0.05	0.00	0.01±0.01	1.53±0.08	0.00
1	1.02±0.06	42.05	0.90±0.04	40.78	0.10±0.01	1.00±0.06	34.64
3	0.67±0.04	56.8	0.33±0.02	78.28	0.21±0.01	0.54±0.04	64.71
5	0.32±0.02	81.81	0.15±0.02	90.13	0.10±0.01	0.25±0.02	83.66
7	0.05±0.02	97.15	0.01±0.01	99.34	0.02±0.01	0.03±0.01	98.04
10	BDL	100	BDL	100	BDL	BDL	100
t½ h		1.85		1.79	-		1.78
ATL		1.0					1.0

ATL, Allowable tolerance level; BDL, below detectable level; Initial[a], 1 h post treatment.

province, Sharkia governorate, Egypt, on 2 Jun 2012.

Fenpropathrin 20% EC was applied at the recommended rate of application that is, 100 g ai per feddan (1 feddan = 4,200 m^2) on the squash fruits (Cucurbita pepo) intercropped with garden rocket (Eruca *sativa*) with Knap Sap sprayer in plots of 4 ×4 m size, along with a control plot. Garden rocket and Squash fruit were cultivated and intercropped interchangeably in the lines of each plots. Squash fruit or garden rocket in triplicate was collected randomly from each plot at 0 (1 h), 1, 3, 5, 7 and 10 days after applications for dissipation study. Samples were collected randomly and periodically from each plot in triplicate along with control.

Extraction, clean-up and analysis

The method of extraction used was that published by Luke et al. (1981). A sample of squash fruit or garden rocket, shell and pulp (50 g) was shaken mechanically with acetone (100 ml) for 1 h. The mixture was filtered through a filter paper into a 1 L separating funnel and the filter washed with acetone (2×10 ml). Saturated sodium chloride solution (10 ml), hexane (60 ml) and dichloromethane (60 ml) were added and the mixture was shaken vigorously for 2 min, then the organic layers were filtered through anhydrous sodium sulfate (10 g) into a round-bottomed flask. This partition step was repeated twice using hexane (60 ml). The extract was concentrated in a rotary evaporator at low pressure at 40.8°C. The extract was finally made up to 2 ml and added to the liquid – solid chromatography column. The concentrated extract was transferred to the top of a glass chromatographic column (30 × 1 cm i.d.) pre-packed with 2 g of florisil heated 24 h at 130.8°C and brought to 3% moisture before use and 1 g of anhydrous sodium sulfate. The elution was processed with 20 ml hexane: ethyl ether (7:3, v/v) at 2 ml min^{-1}(Navickiene et al., 1999). The elute was evaporated to dryness, rinsed with high performance liquid chromatography (HPLC) grade methanol and filtered (0.2 µm) for direct HPLC analysis.

The residues of fenpropathrin in different samples were directly determined according to Zhou et al. (2008) after extraction and clean-up using HPLC (with a UV-detector set at the wavelength 210 nm. A reversed-phase VP-ODS C18 column (250 × 4.6 mm i.d., particle size 5 mm) was used and the mobile phase was acetonitrile/water (74/26, v/v, 10% methanol was included in water) at 1.0 ml min^{-1}. The injection volume and detection wavelength were 10 µl and 210 nm, respectively. The percent recovery of fenpropathrin in squash fruit shells, squash fruit pulp and garden rocket were 91.63, 90.12, and 89.13, respectively.

RESULTS AND DISCUSSION

The persistence behavior of fenpropathrin in squash fruit or garden rocket samples at different day's interval has been summarized in Table 1. The initial deposits (1 h after spraying) of fenpropathrin in squash fruit and garden rocket were found to be 1.53 and 1.76 µg g^{-1}, respectively. However, no residue was detected in the untreated control samples. The residues of fenpropathrin in Squash fruit and garden rocket samples declined progressively with time. About 66.4364.71 and 56.8% of the initial residue was dissipated after 3 days of application which further increased to 83.66 and 81.81% after 5 days irrespective of the application doses. In the Squash fruit and garden rocket fenpropathrin were not detected on the day 10 after application. The calculated half-life values of fenpropathrin in squash fruit and garden rocket were found to be 1.78 and 1.85 days, respectively (Table 1). In the field, the dissipation of pesticide residues in/on crops depends on physical and chemical factors, including climatic conditions, type of application, plant species, dosage, interval between application, growth dilution factor and time of harvest (Khay et al., 2008). It was reported that the half-life value of fenpropathrin was 3.4 to 4.2 days in the tomatoes and 4.0 to 4.5 days in the green beans (Galera et al., 1997).

Experimental data (Table 1) on the fate of fenpropathrin residues between shell and pulp in squash fruit show that fenpropathrin residues were more greatly distributed in the squash fruit shell than that squash fruit pulp. These results indicated that fenpropathrin residue was concentrated in squash fruit shell; this may be due to physicochemical properties of fenpropathrin such as, water solubility, 0.33 mg/L at 25°C (Tomlin, 2004). Pesticides with 100% of the residues distribute in peel. This kind of pesticides included pyrethroid pesticides, pp-DDE, chlorfenapyr, pyridaben, chlorpyrifos with weak solubility in water (or strong lipid solubility). They only stay in peel and are hard to migrate to pulp during the whole planting and storing processes (Xu et al., 2012). The same author found that the pesticides with average distribution ratios more than 90% in peels of grape were those with the solubility less than 2 mg L^{-1}. The factors affecting the pesticide distribution and migration between peel and pulp may include: (1) the pesticide preventing property of the grape peel; (2) physico-chemical properties of the pesticides (such as the polarity, solubility and special groups helping for pass though the peel); (3) contacting time after pesticide sprayed; (4) concentration in the peel; (5) degeneration by sunlight; (6) rinsing by rain, and so on (Xu et al., 2012).

Table 1 shows that the initial concentration level of fenpropathrin in squash fruit was obviously lower than in the garden rocket plants. These results suggest that, the amount of fenpropathrin may be affected by the kinds of crop. Garden rocket exposed to liquid spray directly while in the squash, the fruit be protected by the broadleaf. The dissipation rate of pesticides following application depends mainly on many parameters, including chemical and photochemical degradation, volatilization, climatic conditions, plant species, formulation type and pesticide application method (Sur et al., 2000).

As shown in Table 1, the allowable tolerance level of fenpropathrin in squash fruit and garden rocket was 1.0 mg/kg, respectively as adopted by the FAO/WHO Codex Aliment Arius Commission (CAC, 2008). It can thus be concluded that fenpropathrin levels in squash fruit or garden rocket below maximum residue level (1.0 mg/kg) were detected 3 days after application and no residues were detected on the 10th day. Based on this value, it might be stated that fenpropathrin may not pose any residual toxicity problem in Squash fruit or garden rocket samples during 3-day of application. Rafiei et al. (2010) showed that fenpropathrin levels below maximum residue level (0.5 mg/kg) were detected 3 days after application in a cucumber cultivar in greenhouse.

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African Journal of Agricultural Research

Full Length Research Paper

Determinants of smallholder commercialization of horticultural crops in Gemechis District, West Hararghe Zone, Ethiopia

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Transforming the subsistence-oriented production system into a market-oriented production system as a way to increase the smallholder farmer's income and reduce rural poverty has been in the policy spotlight of many developing countries, including Ethiopia. However, there are no adequate studies in Ethiopia, particularly, in study area of West Hararghe zone that focusing on the determinants of smallholder commercialization in horticultural crops. This study has identified household level determinants of the output side commercialization decision and level of commercialization in horticultural crops in Gemechis district, West Hararghe zone, Oromia National Regional State of Ethiopia. The study used cross-sectional data obtained from a sample of 160 smallholder horticultural farmers selected randomly from four peasant associations in the district. A double hurdle model was applied to analyze the determinants of the commercialization decision and level of commercialization. In first hurdle, the result of Probit Regression Model revealed that, gender, distance to the nearest market, and cultivated land played a significant role in smallholder commercialization decision. In the second hurdle, the result of Truncated Regression Model revealed that, household education, household size, access to irrigation, cultivated land, livestock, and distance to the nearest market were the key determinants of the level of commercialization. Synthesis of double hurdle model result showed that farm size and distance to the nearest market were cross-cutting determinants of smallholder horticultural crops commercialization. The study recommends the need for designing appropriate intervention mechanisms focusing on the abovementioned factors so as to improve the performance of horticultural crops commercialization.

Key words: Smallholder, commercialization, market participation, double hurdle.

INTRODUCTION

Ethiopia is one of the Sub-Saharan Africa countries which liberalized their economies and developed poverty reduction strategies that underpin market-led strategies for broad based agricultural development and economic growth. Agricultural development is viewed as a means to improve the living standards of smallholders and general economic growth. In Ethiopia the agricultural sector contributes about 43% of the Gross Domestic Product

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(GDP), 80% of employment, and 90% of export (Demese et al., 2010). Smallholder farmers account for the majority of the rural population and more than 85% of the rural population relies on agricultural production for its livelihood. However, in agriculture-based economies the smallholder agricultural production is characterized by low output, poor access to land, and poor access to inputs, poor irrigation system, little access to know-how (risk management, technology, and skill), low level of market orientation, poor infrastructure and institutional factors (Leggese and Burton, 2004; MoFED, 2005; Bezabih and Hadera, 2007; Moti, 2007; CSA, 2008/2009; Tilaye, 2010).

Recently, the governments of developing countries have sought to promote diversification of production and exports away from the traditional commodities in order to accelerate economic growth, expand employment opportunities, and reduce rural poverty (Solomon et al., 2010). Market oriented production can allow households to increase their income by producing output with higher returns to land and labor and using the income generated from sales to purchase goods for consumption (Schneider and Gugerty, 2010). Similarly, in Ethiopia, the current policy environment and in its Growth and Transformation Plan (GTP) launched for the period 2010 and 2011 up to 2014 to 2015, the Ethiopian Government attempts to promote production and marketing of high value agricultural products with a view to increase competitiveness in domestic, regional, and international markets.

In addition, the shift in the paradigm of strategy for food security from food production oriented to improving food access through improving household income and promoting market oriented production has opened the window for engagement of smallholder farmers in market oriented production (MoFED, 2010).

Nowadays, horticultural crops is becoming attractive for many poor farmers around the world thus worldwide production of fruit and vegetable crops has grown faster than that of cereal crops (Lumpkin et al., 2005). Horticultural crops play a significant role in developing country both in income and social spheres for improving income and nutrition status. Farmers involved in horticultural production usually earn much higher farm incomes as compared to cereal producers and per capital farm income has been reported up to five times higher. In addition, horticultural products are considered to be income-boosting alternatives to basic grains for smallholder farmers, and they contribute to increasing employment opportunities (World Bank, 2004).

In Ethiopia, the importance of horticulture to the livelihoods of the rural populations in the country accentuates its role as a crop whose production and marketing could be a potential pathway of improving rural livelihoods. Horticulture production in Ethiopia is undertaken dominantly by smallholder farmers, few private sectors and its overall contribution to the economy of the country is limited. The number of small-scale producers engaged in horticulture production is estimated at around 6.0 million (CSA, 2008/2009). The production estimate of fruit and vegetables, including root crops, is 2.16 million tons (9.2% of total national peasant crop production of the season) constituting about 351 thousand tons of fruits (16%), 600 thousand tons of vegetables (28%), and 1.2 million tons of root crops (56%). This volume is produced on 356 thousand hectares (2.4% of total cultivated land in 2008/09) of peasant holdings.

For most Ethiopian smallholders, fruit and vegetable cultivation is not the main activity rather it is considered supplementary to the production of main crops and the cultivation is on a very small plot of land and is managed by a household. This low priority for horticultural crops cultivation was mainly due to the traditional food consumption habits that favor grain crops and livestock products in most parts of the country resulting in weak domestic market demand for horticultural products. Horticulture production is an important source of income for smallholder farmers and demand for the products is raising in both domestic and international markets thus increase smallholder farmers' participation in the market (Dawit et al., 2004; Bezabih and Hadera, 2007; Yilma, 2009).

Although there is a wealth of literature on smallholder commercialization in Ethiopia, it is mainly on grain crops and livestock and livestock product however market participation of the smallholder horticultural crops farmers in the country is still limited. Accordingly, various empirical studies pointed out that, in Ethiopia, smallholder commercialization determined by institutional factors, infrastructural and market related factors, household resource endowments, and household specific characteristics (Pender and Dawit, 2007; Berhanu et al., 2009; Goitom, 2009; Adam et al., 2010; Berhanu and Moti, 2010).

In Ethiopia, particularly eastern and western Hararghe zones have good potential in horticultural crops production for which smallholder farming have diversified from staple food subsistence production into more market oriented and higher value commodities. Despite this production potentials and importance of horticultural crops for the country as well as the study area, there has been limited study with regard to the status and level of smallholder commercialization of horticultural crops and implications of the challenges on decision making.

Smallholder access to markets for higher-value agricultural products is recognized as a vital opportunity to enhance and diversify the livelihoods of lower-income farm households and reduce rural poverty more generally (World Bank, 2008). Past studies, have not addressed the study area. To the best of my knowledge, there is little empirical evidence on factors governing smallholder horticultural crops commercialization in developing countries, particularly, in Ethiopia. Therefore, improvements

Table 1. Sampling frame and sample size determination.

Name of selected peasant association	Horticultural households (number)	Proportion of sampled household (%)	Numbers of sampled households
Kuni sagariya	858	40.6	65
Sororo	397	18.8	30
Wellenso harabafanno	383	18.1	29
Homocho sokido	475	22.5	36
Total	2113	100.0	160

Source: DOA, 2012 and own computation.

in market participation are necessary to link smallholder farmers to markets in order to expand demand for horticultural products as well as set opportunities for income generation. Thus, appropriate studies are crucial to identify commodities and location-specific factors triggering the commercialization process and the findings of this study would provide some insights towards designing appropriate policy intervention mechanisms to enhance small-scale horticulture in Ethiopia.

Objectives of the study

The general objective of this study was to describe the characteristics of farm household's market participation in horticultural crops and explore strategies necessary to promote smallholder farmers' participation in market-oriented horticulture in Gemechis district of West Hararghe zone of Oromia National Regional State, Ethiopia. The specific objectives were:

i) To explore factors determining the smallholder farmers' market participate decision in horticultural crops output,
ii) To identify the determinants for the level of commercialization among smallholder horticultural crops market participant in the study area.

RESEARCH METHODOLOGY

Description of the study area

The study was conducted in Gemechis district of the West Hararghe zone of the Oromia National Regional State. Gemechis district is one of the 14 districts in West Hararghe zone which is located at 343 km east of Addis Ababa and about 17 km south of Chiro, capital town of the zone. It shares borders with Chiro district in the west and north, Oda Bultum district in the south and Mesala district in the east (DOA, 2012). The district covers an area of 77,785 ha and it has 35 rural and one urban Peasant Association. The total population of the district is 184,032 of which 93,659 are males and 90,373 are females (CSA, 2007). The number of agricultural households in the district is estimated to 38,500 with 32,308 male headed and 6,192 female headed (DOA, 2012). The average family size is estimated to be 6 and 4 per household in rural and urban areas respectively. The district is the first mos densely populated district in the zone.

The district is found within 1300 to 2400 m above sea level (m.a.s.l). It receives an average annual rainfall of 850 mm. The district has bi-modal distribution in nature with small rains starting from March/April to May and the main rainy season extending from June to September/October. The average temperature is 20°C.The land use pattern of the district, 32,994.5 ha is cultivable, 6185 ha is grazing land, 1385 ha is covered by forest, bushes and shrubs, 6603.62 ha is not arable and 17949.34 ha is being used for other purposes such as encampments, infrastructure facilities. The black, brown and red soils are the three dominant soil types constitute 55, 25 and 20%, respectively (DOA, 2012). The district is known for its predominance of horticultural production in west Hararghe zone then followed by Oda Bultum, Boke, and Darolabu.

Sampling procedure

A two stage sampling procedure was followed to select sample households. In the first stage, horticultural crops growing peasant associations were identified in collaboration with leader and concerned experts of district office of agriculture and four peasant associations were selected randomly. In the second stage, households growing horticultural crops were identified with development agents of the respective peasant association. The list of households growing horticultural crops were obtained from official records in selected peasant association of the district and 160 farm households were selected from the identified horticultural households randomly. The sample sizes in each peasant associations were determined using Probability Proportional to Size (PPS) of the identified horticultural households as presented in Table 1.

Data source and method of data collection

The study used household survey data that were collected from Gemechis district during December 2011 and January 2012. Both qualitative and quantitative data were collected from secondary and primary sources. The secondary information regarding the types of horticultural crops, area coverage, and challenges, horticultural crops growing peasant associations and etc. that are relevant for this study was collected from West Hararghe zonal office of Agriculture, Gemechis district office of agriculture, Central Statistically Agency (CSA) and from published and unpublished sources.

Primary data were collected from sample households by well-trained enumerators using a structured questionnaire under the supervision of the researcher. The questionnaire that contained both open and closed-ended questions was designed and pre-tested to ensure validity and reliability, and to make overall improvement of the same and in line with the objectives of the study.

Econometric model specification

Econometric models were used to assess the household characteristics, resource endowments, market access and institutional factors that are hypothesized to determine the smallholder farmers decision to participate (or not) in output markets and the level of market participation. The double hurdle model was applied to analyze determinants of horticultural crops commercialization in terms of output market participation. This double hurdle model involves two-step estimation procedure. In first stage, probit model was used to explore factors governing market participation decision for a given reference period which is referred to as commercialization decision in this study.

The probit model

Standard probit model to assess the household market-entry decision and its specification is given below following Wooldridge (2002), the decision to commercialize can be modeled as a:

$$y_i^* = x_i\beta + \varepsilon_i \quad \varepsilon_i \sim N(0,1) \qquad (1)$$

$$y_i = \begin{cases} 1 & \text{if } y_i^* > 0 \\ 0 & \text{if } y_i^* \le 0 \end{cases}$$

where, y_i^* is a latent (unobservable) variable representing households' discrete decision whether or not to participate in the horticultural product market; x_i is a vector of independent variables hypothesized to affect household's decision to participate in the market; β is a vector of parameters to be estimated; y_i is a discrete response variable for status of households' participation in the market which takes value of 1 if the household participates in the market and 0 if the horticultural households reported no sale. Probit model was estimated using maximum likelihood estimation using STATA Version 11. Maximum likelihood estimates are consistent, asymptotically normal, and asymptotically efficient.

In the second stage, Truncated Regression Model was employed to explore the determinants of the value of horticultural crops that are marketed which is referred to as the level of commercialization in this study.

Truncated regression

A truncated regression fits a regression model on a sample drawn from a restricted part of the population. Under the normality assumption of the whole population, the error terms in a truncated regression model have a truncated normal distribution, which is a normal distribution that has been scaled upward so that the distribution integrates to one over the restricted range. The intensity of commercialization is modeled as a regression truncated at zero:

$$Z_i^* = x_i\gamma + \mu_i, \quad \mu_i \sim N(0,\delta^2) \qquad (2)$$

$$Z_i = z_i^* \text{ if } z_i^* > 0 \text{ and } y_i = 1$$
$$\quad 0 \text{ otherwise}$$

where, z_i is the intensity of commercialization which depends on latent variable z_i^* being greater than zero and conditional to the decision to commercialize y_i; γ is parameter to be estimated. Truncation reduces variance compared to the variance in the untruncated distribution. As the result, the truncated regression model with the lower left truncation equal to 0 was used to determine factors influencing sales value of horticultural product (Table 2).

RESULTS AND DISCUSSION

The results of descriptive statistics analysis indicated that, about 80% of the respondents sold their output while the rest 20% did not sell horticultural products. On average the value of horticultural products sold per sample horticultural household head was estimated to be about ETB 4, 603.56. The mean age of the sample respondents was about 39 years with the youngest being 20 and the oldest 65 years. The average number of family size for the sample respondents were about 6. The average land size allotted under horticultural crops per sample household head was about 1.68 *timad* while the mean livestock possession was about 3.72 TLU. The average distance to all-weather roads and distance to the nearest market was estimated to be 1.3 and 1.48 walking respectively (Table 3).

Results of econometric model analysis

In a survey data set a researcher should expect to encounter many problems. The problems of multicollinearity and heteroscedasticity are very common in cross-section data. Data should be cleared before it is used for purposes of analysis. While fitting important variables in the models a test for multicollinearity problem among variables was performed using VIF and there was no serious problem as indicated in appendix Table 1. In estimating the preferred model, robust method was employed in order to correct the possible problem of heteroscedasticity. Outliers were checked using the box plot graph so that there were no serious problems of outlier and no data get lost due to outliers.

Determinants of household commercialization decision

The result of probit model estimation for the determinants of the probabilities of household to sell horticultural outputs or not are presented in Table 4. The decision to participate in the horticultural products market was estimated by maximum likelihood method. Marginal effect was used as a useful measure to explain the result as coefficients of the probit model are difficult to interpret since they measure the change in the unobservable y* associated with a change in one of the explanatory variables (that is, not partial effects). The model chi-square tests applying appropriate degrees of freedom indicate that, the overall goodness-of-fit of the probit model are statistically significant at 1% probability level.

Pseudo R^2 values indicate that, the independent variables included in the regression explain 22% variations in the likelihood to sale horticultural outputs. The result of probit estimation shows that, the likelihood of household participation in horticultural crop market as a seller was influenced by household gender, cultivated

Table 2. Description of the variables used in the regression models.

Variables	Description	Measurement
HORTMKT	Dependent variable indicating the probability of selling horticulture crop equal to 1 if household sell horticultural products ; 0 otherwise	D = 1 if yes; 0= if No
HORTVALU	Dependent variable indicating value of horticultural crops sold	Ethiopian Birr
Age (AGE)	Age of household head	Number of year
Gender (GEND)	Gender of the household head	D =1 if Male; =0 if Female
Education (EDUC)	Educational status of the household head	D =1 if literate; =0 if Illiterate
Household size (HHSIZE)	Household family size	Number
Farm size (FRMSZ)	Cultivated land under horticulture	*Timad*
Livestock (LVST)	Total livestock owned by household	TLU
Irrigation (IRRGA)	Household access to irrigation	D = 1if yes; 0 = otherwise
Distance to all weather road (DROAD)	Distance from household residence to all-weather road	Walking hours
Distance to the nearest market (DMRKT)	Distance from household residence to the nearest market	Walking hours
Credit access (CREDT)	Household access to credit	D =1if yes; 0 = otherwise
Extension access (EXTS)	Household access to extension services	D = 1if yes; 0 = otherwise
Market information access (MKTINFO)	Household access to market information	D = 1if yes; 0 = otherwise
Non-farm and off-farm income access (NOFINCM)	Household access to non-farm and off-farm income	D = 1if yes; 0 = otherwise

ETB = Birr, D = dummy variable, *Timad* is a local unit for farmland measurement as per study area (1timadi= 0.125ha), Source: Own description, 2012.

land and distance to the nearest market, all with expected signs.

Gender of the household head was found to be a positive and significant factor in explaining horticultural crops commercialization decision at 1% level. The positive coefficient on gender indicated that, male headed households are more likely to sell horticultural crops. Male headed households were more likely to participate in horticultural crops marketing by about 33.8% points higher than that of female headed households. This may be due to the female headed households are vulnerable to resource constraint like labour, capital and skill for horticultural crops operation.

Farm size was also found to have a positive and significant influence on farmers' likelihood to participate in horticultural crops market at 10% level. The result implies that, a one timad (0.125 ha) additional land the household allocate for horticultural crops would increase the farmers' likelihood of market participation by 6.5%. This may be due to access to more arable land will encourage farmers to grow more horticultural crops, which leads to surplus production for the market.

Distance to the nearest market was negatively affect households' likelihood to sell horticultural crops and

Table 3. Descriptive statistics of selected variables used in the empirical analyses.

Variable	Mean	Std. Dev.	Min	Max
Decisions to participate or not in horticultural crops market (1 = Yes, 0 = No)	0.80	0.40	0	1
Value of horticultural crops sold (Birr)	4,603.56	4,219.23	0	15,500
Age of household head (year)	39.82	10.24	20	65
Sex of household head (1 = male, 0 = female)	0.79	0.41	0	1
Household size (no.)	5.71	2.30	1	11
Education of household head (1 = literate, 0 = illiterate)	0.62	0.49	0	1
Total cultivated land (*timad*)	1.68	0.82	0.13	3.5
Livestock owned (TLU)	3.72	2.31	0	9.76
Access to use irrigation (1 = yes 0 = no)	0.59	0.49	0	1
Access to nonfarm and off farm income (1 = yes 0 = no)	0.23	0.42	0	1
Distance from settlement centre to the nearest all weather road (hrs)	1.30	1.08	0.01	4
Distance from settlement centre to the nearest market place (hrs)	1.46	0.90	0.05	3.5
Access to market information (1 = yes, 0 = no)	0.58	0.49	0	1
Access to credit (1 = yes, 0 = no)	0.41	0.49	0	1
Involvement in extension services previous year (2010/11) (1 = yes, 0 = no)	0.68	0.47	0	1

Mean indicates the proportion of those variables coded 1 for dummy variable. Source: STATA result from survey data, 2012.

Table 4. Marginal effects of probit regression for commercialization decision.

Hortmkt	Coef.	Robust Std. Err	z	P > |z|	Marginal effect
AGE	-0.002	0.003	-0.15	0.880	-0.001
GENDR	1.128***	0.099	3.92	0.000	0.338
EDUC	0.358	0.066	1.37	0.172	0.086
HHSIZE	0.005	0.015	0.08	0.935	0.001
IRRGA	0.258	0.061	1.01	0.313	0.061
FRMSZ	0.282*	0.039	1.69	0.091	0.065
LVST	0.035	0.011	0.72	0.474	0.008
DROAD	0.101	0.032	0.71	0.476	0.023
DMKT	-0.416 **	0.041	-2.37	0.018	-0.096
MKTINFO	-0.086	0.061	-0.32	0.749	-0.020
CREDT	0.269	0.061	0.95	0.341	0.060
EXTS	-0.069	0.066	-0.23	0.816	-0.016
NOFINC	0.071	0.070	0.22	0.824	0.016
Cons	-0.307	0.790	-0.39	0.698	

***, ** and * implies statistically significance at 1, 5, and 10% level respectively, Log pseudolikelihood = -62.636, Pseudo R^2 = 0.218, Wald chi-square (13) = 42.16, Prob> chi^2 = 0.0001, N = 160. Source: Model result, 2012.

statistically significant at 5% level. An increase in the distance that the households would travel to arrive at the nearest market by one walking hours would decrease the probability of the households to market participation. In spite of the perishable nature of the products and the unavailability of post-harvest technologies that improve the shelf life of the crops resulted in increase in travel time and cost. Thus, those farmers located in distant and remote villages had less likelihood to participate in horticultural markets. This is consistent with the findings of (Moti, 2007; Sindi, 2008; Berhanu et al., 2009; Berhanu and Moti, 2010).

Determinants of the level of commercialization

This section deals with results of truncated regression model estimating the determinants of the level of commercialization that was measured in sells value of horticultural crops. It is worth mentioning at this stage that only farm households who sell horticultural crops are considered in this analysis. Results showed that, the

Table 5. Results of truncated regression for the level of commercialization.

Hortvalu	Coef.	Robust Std. Err.	Z	P > |z|
AGE	33.538	43.941	0.76	0.445
GENDR	328.401	946.841	0.35	0.729
EDUC	1625.654*	834.021	1.95	0.051
HHSIZE	-575.926***	174.445	-3.30	0.001
IRRGA	3043.466***	823.847	3.69	0.000
FRMSZ	2533.151***	507.064	5.00	0.000
LVST	759.627***	174.870	4.34	0.000
DROAD	541.834	568.965	0.95	0.341
DMKT	-1838.292**	756.959	-2.43	0.015
MKTINFO	961.458	836.935	1.15	0.251
CREDT	-677.397	822.858	-0.82	0.410
EXTS	-919.521	945.902	-0.97	0.331
NOFINC	-364.638	835.453	-0.44	0.663
Cons	-1743.137	2701.657	-0.65	0.519

***, ** and * implies statistically significance at 1, 5, and 10% level respectively, limit: lower = 0, N = 128, upper = + inf Wald $chi^2(13)$ = 88.70, log pseudolikelihood = -1184.996 Prob > chi^2 = 0.0000. Source: Model result, 2012.

model was statistically significant at 1% level indicating the goodness of fit of the model to explain the relationships of the hypothesized variables, in terms of at least one covariate. The estimation result also showed that, level of horticultural crop commercialization was influenced by household education, household family size, irrigation, farm size, livestock, and distance to the nearest market all with expected signs (Table 5).

The education of the household head was found to be of positive impact on the sales value of horticultural crops and statistically significant at 10% level. On average, literate household earn about ETB 1,625 more as compared to illiterate household head from sales of horticultural crops. Education increases the ability of farmers to gather and analyze relevant market information which would improve the managerial ability of the farmers in terms of better formulation and execution of farm plans, and acquiring better information to improve their marketing performance.

Household size was found to be negative and statistically significant influence on the sells value of horticultural crops. The negative impact of household size indicated that, the higher the number of household members, the more they will consume their production. In other way round, an increase in family size may also increase in the number of dependent family members which would in turn increase in the number of mouths to be feed and disproportionate volume of production and hence contribute to a decrease in the level of market participation. Adding an additional person to the household would decrease the value of crop sales by about ETB 575. This finding is consistent with the findings of Berhanu et al. (2009), stating that family size has negative implication on the degree of participation in crop market.

Irrigation was also found to be positive and statistically significant implication on the value of horticultural output sold at 1% level. Households with access to irrigation earn, on average about ETB 3,043 more than those households with no access to irrigation. Smallholder horticultural producers with access to irrigation have more opportunities to supply more horticultural products than farmers without access irrigation due to improvement in horticultural cropping intensity and economies of scale. This could have a big impact in the push for rural household's participation in horticultural commercialization to diversify their livelihood and generate better income. Consistent to this finding, Moti (2007) and Sindi (2008) underline that cash crop are mostly produced using irrigation, and irrigation assets are very important in the level of commercialization of horticulture.

Farm size under horticultural crops was positively and significantly associated with sales value of horticultural products at 1% level. This is expected since land is a critical production asset having a direct bearing on production of surplus due to economies of scale. An additional *timad* (0.125 ha) of the household allocate for horticultural crops would increase the value of horticultural output sold by about ETB 2,533. Consistent with the findings of Angula (2010), increase in cultivated land size may have boosted production of horticultural crops and also consistent with the government's massive push to promote and deliver technology packages to smallholders.

Livestock possession was also found to be positively influence the level of horticultural crops commercialization and statistically significant at 1% level.

The positive coefficient of livestock possession implies that an increase in livestock possession by one TLU would increase the value of horticultural outputs the household sold by about ETB 759. One reason could be that, livestock provides manures as manure is the main nutrient used by farmers for crop production in study area and livestock are the main source for this nutrient, the increase in the number of livestock owned would improve the horticultural crops productivity and hence increases the marketable surpluses. This is consistent with the findings of Solomon et al. (2010) which suggest that farmers with more livestock tend to have higher market integration.

Distance to the nearest market was again found to be negatively and statistically significant influence on the value of horticultural output sold at 5% level. The shorter the time taken to reach the nearest market would result to a greater degree of commercialization of horticultural crops. Distance to market was negatively affecting the value of horticultural product sold possibly because of the increased transaction costs associated with marketing of the farmers' agricultural produce. This implies that the location of farmers in respect of potential markets is an important factor in encouraging farmers to increase their sales. This result is in conformity with the findings of Berhanu and Moti (2010) and Solomon et al. (2010), which found that being closer to market, enhance market participation.

CONCLUSIONS AND IMPLICATIONS

Transforming the subsistence-oriented production system into a market-oriented production system as a way to increase the smallholder farmer's income and reduce rural poverty has been in the policy spotlight of many developing countries, including Ethiopia. There is need to deliberately improve the smallholder commercialization decision as well as the level of commercialization in order to facilitate stable incomes and sustainable livelihoods. This study has identified household level determinants of the output side commercialization decision and the level of commercialization in horticultural crops in Gemechis district, West Hararghe zone, Oromia National Regional State, Ethiopia.

Some relevant policy implications can be drawn from the findings of this study that can help to design appropriate intervention mechanisms to improve the smallholder commercialization of horticultural crops in the study area. The fact that distance to the market places has become important determinants of farmers participation in the marketing of horticultural crops suggests the role of policies geared towards improving physical access to market places could yield positive results towards improving commercialization of smallholder farmers of horticultural crops. As a result, improving rural infrastructure in developing market infrastructure in the form of establishing produce collection points across rural areas would assist poor farmers for faster delivery of farm produces especially perishable commodities of horticultural crops.

Gender is significant factor in determining commercialization decision. Therefore, policies should aim at supporting the female headed households by way of proving inputs, knowledge about the horticultural crops. As a result increasing women access to assets, institutional services, and market access and market information is required to boost their production and productivity in horticultural crops and improve their market participation of horticultural crops. Household size is an important determinant of the level of horticultural crop commercialization. Therefore, interventions aimed at promoting family planning amongst farm communities are required to advance the commercialization process in agriculture through increased productivity of family labour. On the other hand, provision of rural employment opportunities is essential to reduce high dependence by households on farm output only. This is a critical step in generating more marketable surplus.

Farm size and irrigation was positive implication on households' market participation of horticultural crops. The size of land allocated for horticultural crops affected the smallholder commercialization of horticultural crops positively and significantly. However, increasing the size of landholding cannot be an option to increase horticultural crops supply since land is a finite resource. Therefore, intervention aims to increase productivity of horticultural crops per unit area of land through proper utilization of land resource in the district. Increasing the productivity of horticultural crops per unit area of land through promoting and delivering technology packages to smallholders that would increase productivity of smallholders and enables them to link up with crops output market would be a better alternative for smallholder commercialization. This intensification of agricultural production should be supported with small scale irrigation development to increase the cropping intensity as to enhance the comparative advantage of smallholders in the production of horticultural crops.

Livestock possession is also an important determinant of the sales value of horticultural crops which calls for enhancing the livestock assets of the household as it provides manures for the farm, means of transportation of their products to the market, and provide financial liquidity for the farmers. The education of the household head also plays a prominent role in the intensity of horticultural crop sales, thus, the policies should aim in upgrading the knowledge of the household head through training.

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Appendix

Appendix Table 1. VIF for multicollinearity test.

Variable	VIF	1/VIF
Droad	2.17	0.460
Dmarket	2.04	0.490
Age	1.49	0.669
Hsize	1.49	0.670
CultInd	1.34	0.744
Marketinfo	1.19	0.842
Extension	1.18	0.847
Hheduc	1.18	0.850
Livestock	1.15	0.869
Credit	1.15	0.869
Irrig	1.11	0.903
Gender	1.08	0.922
Nfarmiacc	1.08	0.923
MEAN VIF	1.36	

Source: Own computational from survey data, 2012.

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Full Length Research Paper

Quantitative and qualitative analyses of weed seed banks of different agroecosystems

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One of the main survival mechanisms of weeds in constantly disturbed environments, specially the annual weeds, is their high production of seeds. In this study it was intended to evaluate the influence of different agroecosystems (vegetable garden, pasture, native field, soybean, dry bean and corn) on the strength of the seed bank, making quantitative and qualitative analyses. On each site, soil samples were collected, split to submit half to seed extraction by washing samples with water and counting the total number of seeds (quantitative analysis), and half to germination in trays placed in a greenhouse to evaluate weed emergence (qualitative analysis). The quantitative analysis of the agroecosystems showed that those cultivated with corn and vegetable garden presented best conditions for weed occurrence. The qualitative analysis resulted in the highest number of viable seeds for the vegetable garden (141,094,713 seeds, of which 74,965,862 were from monocotyledons plants and 66,128,851 dicotyledons). The weed seed concentration found for the vegetable garden is probably related to the management intensity in the area. The inverse is observed for the environments of less management intensity, as pasture and native field. Dry bean and soybean plots presented small seed bank and low emergence.

Key words: Vegetable garden, pasture, soybean, dry bean, corn, native field.

INTRODUCTION

The reserves of viable seeds in soil at the surface and in depth are known as seed bank (Gomes and Christoffoleti, 2008), other concepts or designations being also found. It is also known as seed reservoir, including the amount of non dormant seeds and other plant propagation structures present in the soil or in plant residues (Monquero and Christoffoleti, 2003). This reserve is the sum of all produced and introduced seeds along time that continue alive and dormant, with the seeds recently produced (Kuva et al., 2008). The variability and botanical density of a seed bank at a given time are the result of the balance between the input of new seeds

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Table 1. Treatments and sampling collection sites.

Treatments	Soil sampling location
1	Vegetable Garden
2	Soybean Field at harvest[1]
3	Dry bean Field at harvest[1]
4	Corn Field at harvest[1]
5	Native Field
6	Pasture

[1]area of Grass-legume rotation under no tillage.

(by rain and dispersion) and losses by germination, deterioration, parasitism, predation and transport out of the area (Machado et al., 2013).

An accurate measure of weed emergency is a subsidy to farmers for a more efficient weed control without the inappropriate use of herbicides (Kuva et al., 2008). The quantitative and qualitative evaluation of seed banks can practically be made only by direct germination in soil samples and by physical and chemical seed extraction followed by viability essays (Luschei et al., 1998). The size and the composition of the weed seed bank are very important for the decision of integrated weed management strategies. The *in situ* observation of seedling emergence in the field may give a general indication of the size and composition of the vegetative population, and of the seed bank. However, this is not a precise method because several seeds can stay viable for a long period without germination, and some of the germinated seeds may not emerge due to unfavorable conditions or to deep positioning in the soil (Lacerda et al., 2005). The simplification of the environment that characterizes the modern agricultural systems, as for example mono-cropping, accelerates the ecological succession patterns (Gasparino et al., 2006), generating specialized “habitats” within ecosystems.

The cultivation system exerts an influence on the size of the seed bank. Carmona (1995) estimated the seed banks of four distinct agroecosystems: crop rotation (soybean, fallow, dry bean); lowland; citrus orchard and pasture of *Brachiaria brizantha*. The average quantities of seed per square meter were 22,313 for lowland; 6,768 for rotation; 3,595 for the orchard crowns; and 529 for pasture. He also found out that similarities of seed bank sizes among agroecosystems is greater for the most disturbed areas, as it is the case of crop rotation, lowland and orchards. In agricultural areas seed banks are comparatively greater than in non agricultural areas of low environmental disturbance, because weeds have a strategy of producing large numbers of seeds in much disturbed situations (Monquero and Christoffoletti, 2005). Environmental and management factors influence the seed consumption rate by predator organisms (Balbinot et al., 2002). The consumption of these seeds is made by a large number of species (animals, insects, fungi, etc) that are naturally present in the environment.

In agroecosystems the weed population is related to their seed bank, so that the knowledge of the seed bank size and of its species composition can be used to predict future infestations, to construct population models along time, and consequently for the definition of management programs that lead to a better rationalization of the use of herbicides (Gardarin et al., 2011; Soltani et al., 2013). In general, the decision-making of weed management strategies is based on visual evaluations of the needed weed control intensity without much technical criteria. It is therefore important, for emerging technologies like precision agriculture, to develop control strategies based on estimations of the potential of the weeds in the soil. They should be supported by research and be based on economical viability (Voll et al., 2003).

One of the important factors in studies of seed banks is related to the techniques used for their evaluation (Caetano et al., 2001). The quantification of a cultivated soil seed bank includes the problem of the minimum number of soil samples to be collected in order to have a precise estimation of the number of seeds per unit area (Voll et al., 2003). The understanding of the dynamics of a weed seed bank and the simulation of the emergency flux are among the most recent strategies used for weed control (Vivian et al., 2008). In this context, this experiment was carried out with the aim of evaluating the influence of different types of soil use, that is, different agroecosystems on their seed banks, making qualitative and quantitative analyses.

MATERIALS AND METHODS

Experiments were carried out in Ponta Grossa, PR, Brazil, where the climate is sub-tropical humid, mesotherimic, of Cfb type (Koeppen, 1931), with mild summers and frequent frosts in winter. Average temperature of the hottest month is less than 22°C and of the coldest month is less than 14°C. Average yearly rainfall is 1,545 mm, with no defined dry season (IAPAR, 2008). The soil is a red latosol, typical distrophic, according to EMBRAPA (2006), and an Oxisol according to the Soil Survey (2010). Natural vegetation is dominated by C_4 plants represented by some grasses like *Andropogon* sp., *Aristida* sp., *Paspalnm* sp., *Panicum* sp., and gallery forests are found along the natural drainage canals. The relief is softly ondulated with slopes between 2 and 7%. Data were collected during two different phases, first collecting soil samples for the qualitative analysis, and second manipulating tray soil samples for the quantitative analysis of the seed banks. The sites for sample collection, which represent the treatments, belong to different environments as shown in Table 1.

The fields of dry bean, soybean and corn where soil samples were collected, were cultivated by a long duration minimum tillage system with a rotation schedule shown in Table 2. The experimental field design was completely randomized with six treatments and 16 replicates (plots of 3 × 6 m), carried out as described above. Soil samples were composed of 20 sub-samples of each agroecosystem from the surface layer (0 to 0.5 m) in a randomized way. One composite soil sample of 3 to 4 kg was prepared after homogenizing the sub-samples, which were divided into parts A and B.

Sample A: This was used for the quantitative analysis of the seed bank through the number of seeds per ha and per 0.05 m of soil

Table 2. Rotation schemes where dry bean, soybean and corn soil samples were collected.

Season-year	Rotation scheme			
Winter - 2000	AP + E[1]	AP	T	P
Summer - 2000/2001	M[2]	S/F	F/S	S
Winter - 2001	AP[3]	T	P	AP+E
Summer -2001/2002	S/F[4]	F/S	S	M
Winter - 2002	T[5]	P	AP+E	AP
Summer - 2002/2003	F/S[6]	S	M	S/F
Winter - 2003	P[7]	AP+E	AP	T
Summer - 2003/2004	S[8]	M	S/F	F/S
Winter - 2004	AP/E	AP	T	P
Summer - 2004/2005	M	S/F	F/S	S

[1]Black oat + pea, [2]Corn, [3]Black oat, [4]Soybean/dry bean, [5]Wheat, [6]Dry bean/soybean, [7]Fallow, [8]Soybean.

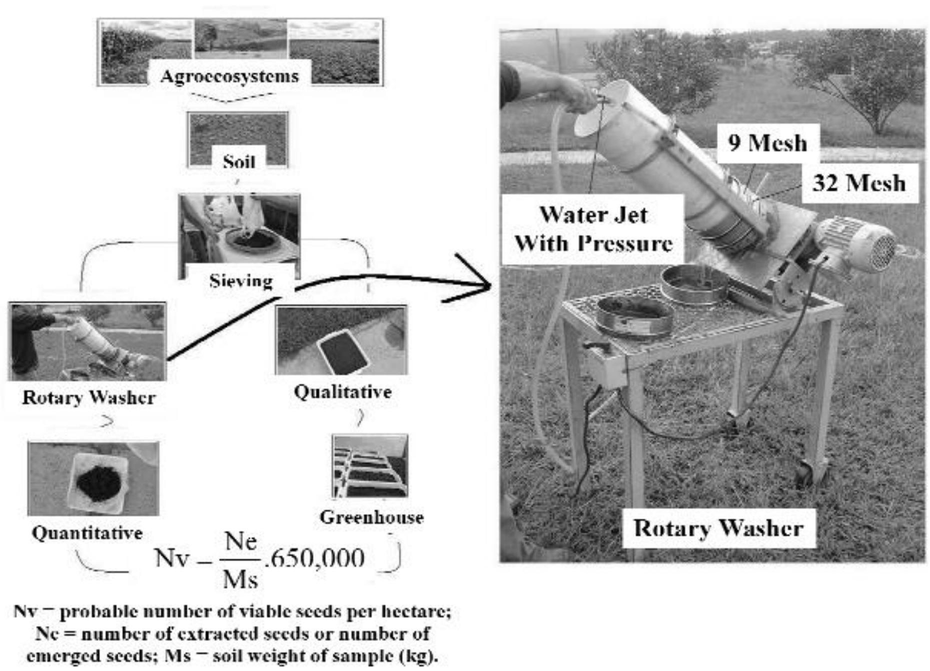

Figure 1. Visual description of the used methodology.

depth. Samples were passed through a rotary washer (Figure 1) with two sieves, one with larger openings (9 mesh) to retain coarser materials like plant residues, and one with smaller openings (32 mesh) to retain seeds, coarser soil particles and aggregates, and plant material that was not retained by the previous sieve. After washing samples were air dried for 20 days and, with aid of a magnifying glass the inert material was separated and seeds counted.

Sample B: This was used for the qualitative analysis evaluating the number of non dormant viable seeds (germinated and emerging later) per ha and 0.05 per m depth. For the qualitative analysis field soil samples were displayed on plastic trays to form a 0.04 – 0.05 cm soil layer, so that seed depth would not be a limiting factor for their germination. Trays were displayed in a greenhouse and irrigated periodically to allow the germination of non dormant seeds. At fixed time intervals emerged seedling were counted, making the distinction of the monocotyledons and dicotyledons. These seedlings were eliminated to give place to those germinating later. When the germination flux ended, soil was turned over to stimulate further germination, and counts continued for 53 days, a time admitted sufficient for this evaluation. The quantitative analysis was based on the estimative of the total number of probable seeds per hectare, per 0.05 m layer in depth, and the qualitative analysis on the estimative of the number of probable viable seeds in the same layer. For this layer of average soil bulk density of 1.3 g cm^{-3}, the soil mass totalized 650,000 kg of dry soil. The probable number of seeds per hectare in the 0.05 m soil layer was calculated through Equation (1) of Monqueiro and Christoffoleti (2003):

$$Nv = \frac{Ne}{Ms}.650{,}000 \quad (1)$$

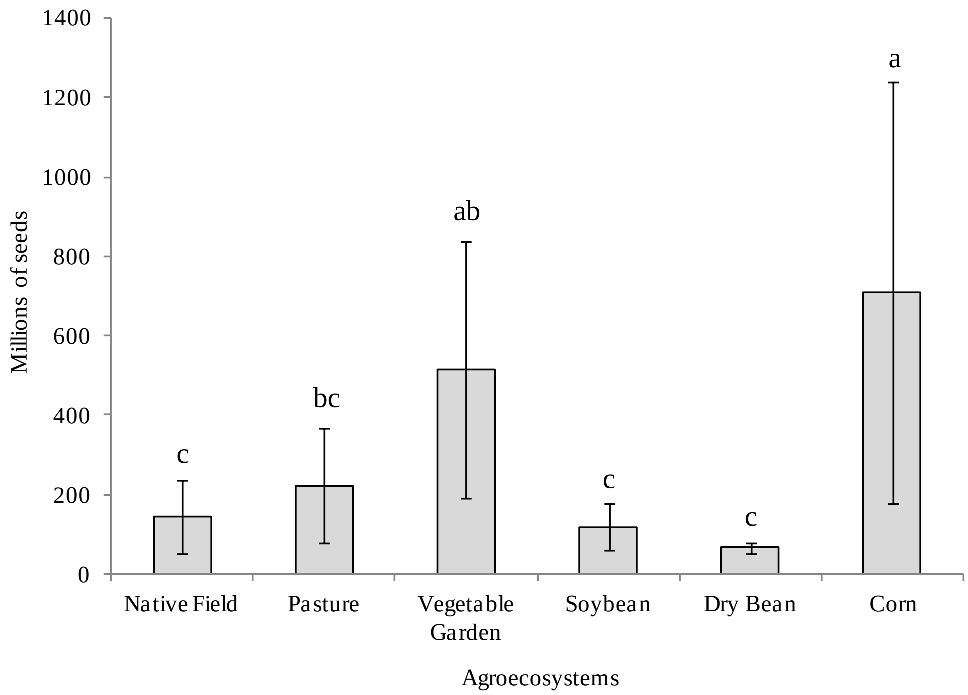

Figure 2. Seed bank size per hectare – quantitative analysis. Averages followed by the same letter do no differ among each other by the Duncan test at 5% significance level.

Where: Nv = probable number of viable seeds per hectare; Ne = number of extracted seeds or number of emerged seeds; Ms = soil weight of sample (kg).

Results were submitted to analysis of variance and means were compared by the Duncan test ($p< 0.05$), using the SASM - Agric (2001) program.

RESULTS AND DISCUSSION

In a general way, data show a great variability in both, the seed banks as well as the total germination of these banks in the different ecosystems. According to Carmona (1995), such variability is normal in these types of studies. The largest weed seed bank was found in the agroecosystem of corn (Figure 2), however not statistically different from the vegetable garden. The agroecosystem pasture presented the third largest seed bank, also not differing from the other, followed by native field, soybean and dry bean.

The history of the experimental fields (Table 2) points to a winter fallow interval that may have favored a renovation of the seed bank since weeds could complete their reproduction cycles. However, there was no difference between the agroecosystems corn and vegetable garden. This happened due to a better relation between the environment (soil and climate) and the weed species present in this environment that had a better ability to contribute to the establishment of a seed bank. In relation to the vegetable garden agroecosystem, soil revolvement stimulates an increase of seed viability. Practices that promote the inversion of soil layers as plowing, foment a better seed distribution within the soil profile, and also bury a significant amount of seeds so that the regeneration capacity of part of certain seed populations is derailed. On the other hand, practices that do not invert soil layers allow the majority of the seeds to remain at soil surface (Lacerda et al., 2005). According to Lacerda et al. (2005), higher values of weed viable seeds in the conventional management system is due to the frequent soil perturbations by mechanical implements during a corn field establishment in summer.

For the pasture agroecosystem, the lack of soil perturbation added to the low fertility, promoted a more stable environment that is propitious only for few species with less individuals, reducing the strength of the seed bank (Carmona, 1995). Marquezan et al. (2003) analyzing the dynamic of a red rice seed bank, concluded that during the fallow period rice seed was reduced on average by 85% per year because the soil surface seeds lost their viability more rapidly in relation to deeper seeds. Another explanation is in the way data obtained in small samples are transformed to hectares through the average relation of soil mass per unit volume. Ideally, soil bulk density should be measured along sampling points in order to have more representative data. Observing again the history of the area (Table 2), now in relation to the agroecosystems soybean and dry bean, we can see a much lower seed number in comparison to the vegetable

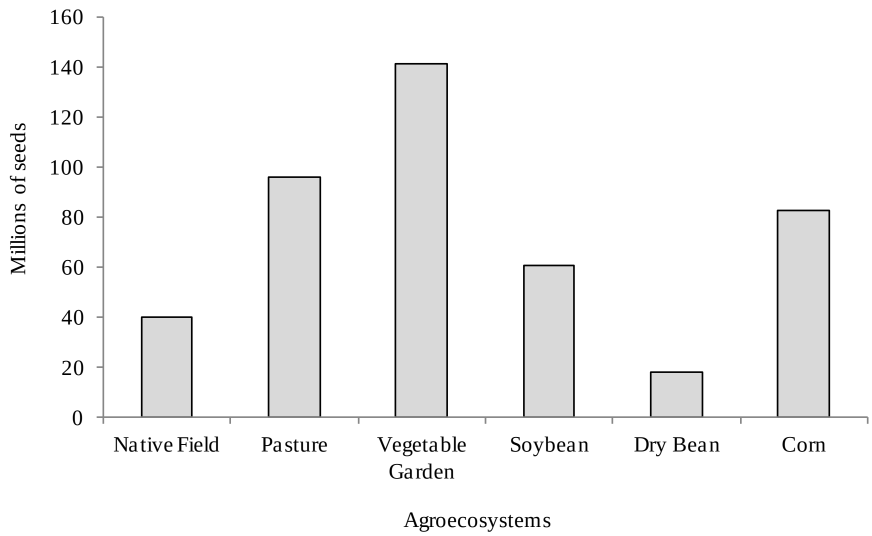

Figure 3. Probable total number of viable seeds (mono and dicotiledons) per hectare – qualitative analysis**.**

Table 3. Percentage of dormant seeds and emerged seeds, in relation to the total number of the seed bank.

Agroecosystem	Dormant seeds (%)	Emerged seeds (%)
Native field	72.19	27.81
Pasture	57.08	42.92
Vegetable garden	72.63	27.37
Soybean	48.54	51.46
Dry bean	73.40	26.60
Corn	88.30	11.70

garden and corn (Figure 3). This is probably due to the rapid and good covering of the soil surface by the crop and use of herbicides, which do not favor weed germination. This is the case of pastures and native fields because according to Caetano et al. (2001) the application of herbicides for weed control influences the distribution of the seed bank in the soil profile.

The variability of the data obtained in this type of study is normally high due to the relatively great non uniformity of seed distribution in the soil (Carmona, 1995). Observing the number of viable seeds (Figure 3) obtained from seeds germinated in soil trays, we can see little differences between treatments. However, observing the vegetable garden environment in relation to the other, it can be noted that the viable seed bank of this environment is much larger. This is mainly due to the fact that this environment involves manual control of weeds, little use of herbicides, constant soil revolvement, in this way favoring the renovation of the seed bank. This is confirmed when looking at the dry bean environment that due to soil surface shading and use of herbicides, diminishes drastically the renovation of the soil seed bank.

Despite the obtained data, it can be seen in Table 3 that most of the seeds remain dormant for variable periods. To analyze a dormant seed bank there is need of longer evaluations. However, observing the total seed number together with the number of viable seeds, it can be noted that the viability potential of the seeds is only manifested when stimulated and submitted to ideal conditions of development. Dormancy and its seasonal changes are related to the persistence of seeds in the soil and, consequently, to the problems faced during the infestation of the crops. Weed seeds pass through annual cycles of more or less intensity of dormancy. These changes are attributed to variations in temperature, light, rainfall, agricultural practices and seed depth (Vivian et al., 2008). For the vegetable garden environment (Table 3), 72.63% of the seeds are dormant. This is due to soil mixing that lead to a more uniform seed distribution in the profile, and in a burying of a greater amount of seeds making them unviable (Lacerda et al., 2005). For the

Table 4. Qualitative analysis of mono and dicotyledon weeds in the surface layer (0.05 m of deep).

Agroecosystems	Probable number of viable seeds	
	Monocotyledons	dicotyledons
Native field	22360435[ab]*	17903565[b]*
Pasture	75402000[a]	20353111[b]
Vegetable Garden	74965862[a]	66128851[a]
Soybean	40002667[ab]	20958000[b]
Dry bean	11017804[b]	6859021[b]
Corn	58793967[ab]	24020134[b]

*Averages followed by the same letter do no differ among each other by the Duncan test at 5% significance level.

other agroecosystems the percent of dormant seeds was also high since seeds can remain viable in the soil for long periods without germination (Caetano et al., 2001). In this respect, Lacerda et al. (2005) states that in fallow areas the number of species and viable seeds in the soil are smaller. For all agroecosystems the majority of the weeds were monocotyledons (Table 4). For the corn environment the development of monocotyledons was favored because corn itself is a monocotyledon and herbicides used in this situation did not control weeds from the family Poaceae. For the agroecosystem vegetable garden, a large number of monocotyledons were observed, which can be explained by the intense cultivation of this area, with several stimulations of the seed bank. Blanco and Blanco (1991) observed that the weed management through soil movement with rotary hoes stimulated weed seed emergence.

For the dry bean environment the development of monocotyledons was also favored, despite being a dicotyledon plant. In this environment, however, there was an equilibrium of viable mono and dicotyledons seeds because besides soil chemical and physical effects, there were biological effects due to the interference of plant residues on the survival of seeds from the bank (Gomes and Christoffoleti, 2008) taking into account that the crop was managed under minimum tillage. For the natural ecosystem of native fields, an even greater equilibrium between viable mono- and dicotyledon seeds would be expected. This is however explained by the fact that the monocotyledon seed population was larger than that of the dicotyledons.

Cultivation systems favored the renovation of seed banks, with different intensities, and promoted a better development of monocotyledons in relation to dicotyledons. The size and composition of the soil seed banks are extremely variable among different habitats (Kuva et al., 2008). This is a response of the strategy of invasive plants producing a large number of seeds and having good dissemination mechanisms, longevity and dormancy to survive in hostile environments. The evaluation of the need for control of weeds is a function of the emergence rate of the species present in the soil seed bank and has to be established for each management system of the implanted crop (Voll et al., 2003).

In general, seed banks are composed of many species, few of them dominant, corresponding to 70 to 90% of the total seed number in the soil. These species are considered harmful because they resist control measures and are more adaptable to different climatic conditions.

Conclusions

The emergence of monocotyledon plant seeds was greater in all agroecosystems, especially in corn and pasture. The agroecosystem vegetable garden favored the increase of the soil seed bank because of its more intense soil revolvement and less use of chemical weed control. The agroecosystems dry bean and soybean presented low emergency and a smaller seed bank.

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Full Length Research Paper

Participatory varietal selection of bread wheat (*Triticum aestivum* L.) genotypes at Marwold Kebele, Womberma Woreda, West Gojam, Ethiopia

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Participatory variety selection was conducted at Marwoled Kebele, Womberma Woreda, to select superior bread wheat varieties on farmers' fields with their participations. Bread wheat variety called Kubsa (HAR1685) is the sole variety grown by farmers. Twelve alternative bread wheat varieties were evaluated under rainfed conditions using a randomized complete block design with three replications as grandmother trial and three farmers' fields with one replication each as mother trial. In both trials, highly significant differences among the genotypes were observed in terms of plant height, spikelets per spike, hectoliter weight, thousand grain weights, leaf rust, yellow rust and days to maturity. HAR3730 (5.4 t ha^{-1}), ETBW5518 (5.3 t ha^{-1}), Plcafeor (4.8 t ha^{-1}), ETBW5521 (4.7 t ha^{-1}), ETBW5520 (4.4 t ha^{-1}) and HAR1685 (4 t ha^{-1}) were highest yielding over the check variety Kubsa (HAR1685) and selected by farmers and researcher. Developed participatory bread wheat varietal selections have solved many constraints related to farmers' participations, set parameters, select superior varieties, evaluating the performance of better varieties, and identify better varieties and accelerating the dissemination of farmers' selected varieties at Marwoled Kebele. Therefore, promotion of higher yielding selected cultivars is necessary at Marwoled Kebele to diversify wheat varieties to cope up with evolving disease pathogens and epidemic occurring in wheat system in the region.

Key words: Participatory selection, bread wheat, varietal selection.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the second most important cereal crop after rice (Ekboir, 2000) followed by maize *(Zea mays)* and barley (FAO, 1999). To meet the food needs of the ever growing world population, the forecast demand for the year 2020 varies between 840 (Rosegrant et al., 1995) and 1050 million tons (Kronstad, 1998).

Ethiopia is the first largest wheat producer in sub-Saharan Africa, except South Africa (Aquino et al., 1996). The major wheat producing areas in Ethiopia are located in Arsi, Bale, Shewa, Ilubabor, Western Hareghe, Sidamo, Tigray, Northern Gonder and Gojam Zones (Beke1e et al., 2000).

Ethiopia is one of the centers of diversity and origin for various agricultural crops. The importance of adaptation to variable and risky low-input rain-fed conditions,

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secondary crop uses, and cultural preferences has received little or no attention (Sperling et al., 1993).

Participatory Variety Selections (PVS) can thus effectively be used to identify farmer's acceptable varieties that are better than old and obsolete varieties with which farmers stick for long period (Joshi and Witcombe, 1996). Participatory varietal selections are farmer-centered varietal selections limited to testing of the finished varieties. Farmers evaluate multiple traits that are important to them and help to increase on-farm varietal diversity, faster varietal replacement and rapid scaling up. Moreover, quality traits like milling percentage, cooking and keeping quality, taste, and market price can be assessed in PVS that are difficult or expensive to evaluate in conventional trials. All PVS use some form of mother and baby trials where the former are fewer in number than the latter has to compare all of the test entries (Witcombe et al., 2005). Similarly, participation of farmers during varietal selection in the Marwoled Kebele is uncommon. This on-farm management and informal plant breeding increasingly becomes crucial in many areas of the developing world, while it ensures the conservation of genetic diversity and continuous evolution of crop species to meet local needs and environmental constraints (Smith et al., 2001). Marwoled Kebele has high potential for the production of bread wheat. Almost all farmers of the Kebele grow only one bread wheat variety called Kubsa (HAR 1685) which is a risky practice while an outbreak of disease can devastate the whole bread wheat grown in the area. Although the area has high potential for increasing wheat productivity and quality, little is known about the existing bread wheat production, productivity and grain quality as well as, the adequacy of current participatory variety selection to improve yield and quality and to develop alternative cultivars adaptable to the area through participatory varietal selection approach. Therefore, it is of paramount importance to identify high yielding and good quality bread wheat genotypes for the area.

Thus, this study was carried out with the objective of selecting bread wheat varieties with the participation of farmers at Marwoled Kebele in Womberma Woreda.

MATERIALS AND METHODS

Participatory varietal selection of bread wheat trial was conducted in Marwoled Kebele at Womberma Woreda in Western Gojjam Zone, in Ethiopia, in 2010/11 main cropping season. The trial site is located at 10° 05.7'N latitude and 37° 02.6'E longitude with an altitude of 1,970 meters above sea level. Marwoled Kebele is one of the 19 peasant associations (rural Kebeles) of the Womberma Woreda. The altitude of Marwoled Kebele varies from 1038 to 2,067 masl and the average annual rainfall is about 1,260 mm. The soil coverage of the Kebele is Vertisol (20.63%) and leptosol (79.37%). The pH is 6.05. The average N content is 0.11%, and organic matter content is 2.41% at the depth of ≥ 0.2 m.

The general agro ecological condition of the experimental site is suitable for growing different crops. According to Marwoled Kebele Agriculture and Rural Development Office, the total population of the Kebele is estimated at about 4,214 which is 3.52% of the total population of the district. The Kebele shares 3.13% (4,139 ha) of the total area of the district. This area is dominated by bread wheat production in addition to other major crops under rain fed condition.

Experimental design

Five released bread wheat varieties namely Paven-76, kubsa (HAR1685), Millenium, Plcafeor, and Gasay (HAR3730) and seven promising varieties namely ETBW5518, ETBW5519, ETBW5520, ETBW5521, ETBW5522, ETBW5525 and ETBW5526 were assessed on-farm at Marwoled Kebele peasant association in Womberma Woreda. Randomized complete block design with three replications on one host farmer's field was used for this research. This was named grandmother trial. Three other host farmers planted one replication each as mother trial. The grandmother trial was used to generate breeder's data while the three mother trials were used for participatory varietal selection and to value farmers' preferences during evaluation.

Farmers' data collection

Four different groups of farmers having eight members each were selected to rate different traits from emergence to maturity and post-harvest evaluation. Farmers and the breeder jointly evaluated the genotypes, but the farmers alone made the final decision. Traits considered and criteria used for participatory varietal selection by farmers were: Plant stands (PS), Number of tillers (NT), Spike length (SL), Number of Kernels (NK), Disease Resistance (DR), Seed Coat color (SCC) and Seed Size (SS).

Breeders' data collection

Plant height (PH), Tiller number per plant (NT), Stand Percent at Emergence (SPG, %) and at harvest (SPH, %), Days to maturity (MA), Days to heading (HD), Spike length (SL), Number of spikelets per spike (NSKPS), Kernel number per spike (KSP), Grain filling period (GFP), Biological yield (BM),Thousand grain weight (TGW), Grain yield (YD), Hectoliter weight (HLW) (Kg/hl), Harvest index (HI) and Disease score.

Data analysis

To reveal the total variability present within the genotypes in randomized complete block design, analysis of variance (Table 1) was computed for all the characters as per Gomez and Gomez (1984) using "SAS" software window version 8 (1999). Statistical Package for Social Science (SPSS) Version 16 was used to analyze the participatory varietal selection data collected through farmer participation.

RESULTS AND DISCUSSION

Farmers employed seven different parameters to select their preferred varieties including plant stand, number of tillers, seed coat color, seed size, spike length, number of kernels and disease resistance.

The use of PVS proved to be a useful selection method. Farmer participation creates a feeling of ownership (Weltzien et al., 2003). Variety selection by farmers at the same low input farming conditions

Table 1. Analysis of variance.

Source of variation	Df	Mean squares	Expected mean squares	F-ratio
Replication	(r-1)	MS_r	$\sigma^2_e + g\sigma^2_r$	
Genotype	(g-1)	MS_g	$\sigma^2_e + r\sigma^2_g$	MS_g/MS_e
Error	(r-1) (g-1)	MS_e	σ^2_e	
Total	rg-1			

r = number of replications, g = number of genotypes, DF = degree of freedom, MS_r = mean Square due to replications, MS_g = mean square due to genotypes, and MS_e = mean square due to environment, σ^2_e = Environmental variance and σ^2_g = Genotypic variance.

Table 2. Farmers' preference scores and ranking on grandmother trial.

Varieties	Parameters and scores								
	Plant stand	Number of tillering	Seed coat color	Seed size	Spike length	Number of kernel	Disease resistance	Total scores	Rank
Paven-76	3.6	2.3	2	2.3	2.6	2	1.3	16	8
HAR1685	4.3	5	3.3	4	4.3	4.3	3.3	28	2
Millennium	4	2.6	2	2	2	2	2	17	7
Plcafeor	3.3	3	2	2	2	2	2	16	8
HAR3730	5	3.6	4.6	4.6	5	4.4	4.6	31	1
ETBW5518	4.3	3	2.3	2.3	4.3	3.6	4.3	24	4
ETBW5519	2.6	3	2	2	2	2	4.3	18	6
ETBW5520	3.6	3.6	2	2	3	2.6	3	20	5
ETBW5521	5	3.3	3	3	4.6	3.3	5	27	3
ETBW5522	3.6	3.6	2	2.3	2.6	3.3	3	20	5
ETBW5525	5	4	2.6	3.3	4.3	4	4	27	3
ETBW5526	4.6	3.6	3	3	5	4	4.6	27	3

N.B: Farmers preference ranking, key for scaling (1-5); 1=least 5=best.

addresses also the needs of more marginalized farmers (Dawson et al., 2007). It is a rapid and cost effective way to assess and select potential varieties (Abidin, 2004). Joshi and Witcombe (1996) reported that adoption rates of cultivars would be improved through increased farmers' participation. Poor farmers can adopt new varieties as rapidly as wealthier ones through participatory varietal selection.

In the grandmother trial, HAR3730 and ETBW5526 were selected by farmers and the latter was selected due to its good plant stand, white seed coat color, large seed size, better spike length, many kernels and better resistance to disease (rust) over kubsa (HAR1685) though it had less tillers than kubsa (HAR1685). Other varieties were not selected by farmers and not rated over the check variety kubsa (HAR1685) (Table 2). Farmers ranked HAR3730 variety first from grandmother trial.

In the mother trials, HAR3730, ETBW5526 and ETBW5521 were selected in descending order with overall ranking of seven parameters. HAR3730 was ranked highest in terms of tillers, white seed coat color, larger seed size, larger spike length, number of kernels and better disease resistance.

ETBW5526 ranking 2nd was selected by farmers due to its good plant stand, large spike length, more kernels and better disease resistance. ETBW5521 ranking 3rd was selected owing to its high tillering, large spike length, more kernels and better disease resistance (Table 3).

Comparison of varieties for yield and yield related traits

Yield and grain quality of produced grain play an important part in the successful production and marketing of wheat. Traditionally, high yielding ability alone was the most important factor to the producer. Grain quality becomes also more important as it is produced for commercial purposes (Berhanu, 2010).

Grain yield is the final result of its components. In the Grandmother trial, HAR3730 (5.4 t ha^{-1}), ETBW5518 (5.3 t ha^{-1}), Plcafeor (4.8 t ha^{-1}), ETBW5521 (4.7 t ha^{-1}), ETBW5520 (4.4 t ha^{-1}) and HAR1685 (4 t ha^{-1}) gave more yield than the check variety Kubsa (HAR1685).

Table 3. Farmers' preference scores and ranking on mother trial.

Varieties	Parameters and scores							Total score	Rank
	Plant stand	Number of tillering	Seed coat color	Seed size	Spike length	Number of kernel	Disease resistance		
Paven-76	2.6	2.3	2.3	2.6	2	1.6	1.6	15	9
HAR1685	4.3	3.6	3	3.6	3	2.6	3	23	4
Millennium	4.6	2	2	2	2	2.3	3.3	18	8
Plcafeor	2	2	2.3	2	2	2	1.6	14	10
HAR3730	4.3	4.6	4.6	4.6	5	4.3	4.3	32	1
ETBW5518	4	3.3	2.3	2.6	3	3	3	21	6
ETBW5519	3.6	2.6	2.3	2	2	2.6	2.6	18	8
ETBW5520	3.3	3	2.6	3	3.3	2	2.6	20	7
ETBW5521	3.6	4.3	3	3.6	4	3	4	25	3
ETBW5522	4.3	4	3	2.6	3.6	3.3	2.3	23	4
ETBW5525	3.3	3.3	3	3	4	3	3.6	22	5
ETBW5526	4.6	3.3	2.6	3.6	4	4.6	3.6	26	2

Farmers preference ranking,key for scaling (1-5): 1=least 5=best.

ETBW5519 (3.5 t ha^{-1}) and Paven-76 (3.4 t ha^{-1}) were the lowest yielding varieties. In the Mother trial ETBW5518 (4.64 t ha^{-1}), ETBW5521 (4.61 t ha^{-1}), HAR3730 (4.59 t ha^{-1}), HAR1685 (4.03 t ha^{-1}) produced better yield over the check variety. Based on the two trial types HAR3730, ETBW5518 and ETBW5521 were higher yielding bread wheat varieties.

Plant height

In the grandmother trial, HAR3730 (97.4 cm), ETBW5525 (96.6 cm), ETBW5526 (95.3 cm), ETBW5522 (94.8 cm) and ETBW5521 (94.9 cm) were the tallest varieties while HAR1685 (85.0 cm) and ETBW5519 (88.8 cm) were the shortest varieties (Table 4). In the mother trial, ETBW5525 (101.4 cm) and ETBW5522 (100.8 cm) were the tallest varieties while HAR1685 (88.6 cm) was the shortest one (Table 5). Based on the findings of combining the two trials, ETBW5525 (101.4 cm) and ETBW5522 (100.8 cm) observed the tallest varieties and HAR1685 (88.6 cm) showed on the contrary the shortest variety.

Days to maturity

Paven-76, Plcafeor, HAR3730 and ETBW5520 observed early maturing bread wheat varieties whereas ETBW5519 and ETBW5526 showed late maturing in the grandmother trial (Table 4). In the mother trial Paven-76, Plcafeor, HAR3730, ETBW5520 and ETBW5522 appeared early maturing. ETBW5526 and ETBW5519 were recorded as late maturing (Table 5). ETBW5519 was recorded as late maturing as compared to other varieties in both trials. In this finding, delayed maturity was observed due to the difference between maturities from genetic effect.

Days to heading

Paven-76 and plcafeor headed early while ETBW5526 headed late in both trials. In the mother trial, ETBW5519 headed late (Tables 4 and 5).

Biomass yield

ETBW5518 (13.4 t ha^{-1}) and ETBW5521 (12.3 t ha^{-1}) in the grandmother trial and ETBW 5518 (121.63 t ha^{-1}) in the mother trial produced the highest biomass yield (Tables 4 and 5).

Harvest Index

Varieties such as HAR3730 (45%) and Plcafeor (41%) had the highest harvest index in the grandmother trial. Similarly, ETBW5521 and HAR3730 showed the highest harvest index in the mother trial (Tables 4 and 5).

Tillering capacity

In the grandmother trial, HAR1685 and ETBW5525 had more tillers while ETBW5518 and ETBW5521 had few tillers (Table 4). In the mother trial, Paven-76 and ETBW5522 had high number of tillers than the rest varieties (Table 5). Generally, HAR1685, Paven-76 and ETBW5522 had better tillering capacity.

Table 4. Mean separation of different agronomic traits for 11 treatments in grandmother trial.

Treatments	PH	SL	SKPSP	YD	HLW	TGW	LR	GFP	MA	HD	HI
Paven-76	92.2^{abc}	8.2^{dc}	16.4^{bcd}	3.4^{d}	75^{cde}	27^{ef}	21.6^{cd}	43.6^{f}	103.3^{e}	59.6^{f}	34.2^{cde}
HAR1685	85^{d}	8.2^{dc}	15.8^{cd}	4^{bcd}	72.2^{e}	25^{f}	23.3^{cd}	47^{bc}	111^{ab}	64^{abc}	32.7^{cd}
Millennium	93^{abc}	7.8^{d}	16.6^{bcd}	3.7^{cd}	77.2^{abc}	30.3^{cde}	33.3^{ab}	46.6^{bcd}	110.3^{b}	63.6^{bcd}	35.5^{bcde}
Plcafeor	90.1^{bcd}	8.4^{dc}	16.6^{bcd}	4.8^{ab}	77.3^{abc}	35^{ab}	18.3^{d}	49^{a}	105^{de}	56g	41.2^{ab}
HAR3730	97.4^{a}	9.2^{ab}	17.2^{b}	5.4^{a}	80.8^{a}	35.3^{a}	33.3^{ab}	45.6^{de}	107.6^{c}	62^{de}	45.6^{a}
ETBW5518	93.6^{abc}	8.4^{dc}	17^{bc}	5.3^{a}	79.8^{ab}	33.6^{abc}	28.3^{bc}	46.6^{bcd}	110.3^{b}	63.6^{bcd}	40.7^{abc}
ETBW5519	88.8^{cd}	8.4^{dc}	17.2^{b}	3.5^{d}	74.5^{cde}	26^{f}	21.6^{cd}	47.6^{b}	113.3^{a}	65.6^{a}	31^{e}
ETBW5520	92.5^{abc}	8.2^{dc}	15.3^{d}	4.4^{abcd}	75.7^{cde}	31^{bcde}	28.3^{bc}	46^{cde}	107^{cd}	61^{ef}	37.1^{bcde}
ETBW5521	94.9^{ab}	8^{d}	16.8^{bc}	4.7^{abc}	77.6^{abc}	33^{abcd}	23.3^{cd}	47.3^{b}	111.6^{ab}	64.3^{ab}	37.6^{bcd}
ETBW5522	94.8^{ab}	9.73^{a}	15.7^{cd}	4.1^{bcd}	74.8^{cde}	31.6^{abcd}	16.6^{d}	45.3^{e}	107.6^{c}	62.3^{cde}	37.3^{bcde}
ETBW5525	96.6^{a}	8.7^{bc}	19.1^{a}	4^{bcd}	73^{de}	29^{def}	21.6^{cd}	47^{bc}	111^{ab}	64^{abc}	34.4^{cde}
ETBW5526	95.3^{ab}	9.8^{a}	16.2^{bcd}	4.6^{abc}	76.2^{bcd}	30.6^{cde}	36.6^{a}	47^{bc}	112.3^{ab}	65.3^{ab}	37.2^{bcde}
Mean	92.88	8.61	16.68	4.36	76.2	30.63	25.55	46.58	109.22	62.63	37.07
CV (%)	3.55	4.32	4.88	14.05	3.05	7.8	19.09	1.44	1.33	1.72	10.48
LSD	5.58	0.63	1.38	1.03	3.94	4.05	8.26	1.14	2.46	1.83	6.58
SE	1.9	0.21	0.46	0.35	1.34	1.37	2.81	0.38	0.83	0.62	2.24

PH=Plant height (cm), SL= spike length (cm), SKPSP= spikeletes per spike, YD= grain yield (t/ha), HLW= hectoliter weight (kg/hl), TGW= thousand grain weight (g), LR= leaf rust (%), YR= yellow rust (%), GFP= grain filling period, MA=days to maturity, HD= days to heading, HI= harvest index, CV(%)= coefficient of variation, LSD= least significant difference, SE= standard error, α = 0.5.

Table 5. Mean separation of different agronomic traits for 7 treatments in mother trial.

Treatments	PH	SKPSP	KPS	HLW	TGW	MA	HD
Paven-76	94.53^{bc}	16^{e}	40.2^{d}	72.13^{c}	27^{d}	105.33^{f}g	60.66^{f}
HAR1685	88.6^{c}	16.86^{cde}	47^{bcd}	72.13^{c}	27.33^{cd}	108.33^{cde}	64^{bcd}
Millennium	98.2^{ab}	17^{cde}	43.13^{cd}	78.46^{a}	29.66^{bcd}	108.333^{cde}	63.33^{cde}
Plcafeor	97.33^{ab}	16.8^{de}	46.66^{bcd}	72.53^{bc}	33.33^{ab}	104^{g}	59^{g}
HAR3730	93.53^{bc}	18.06^{cb}	47.13^{bcd}	75.93^{abc}	31.33^{bcd}	108.33^{cde}	62.66^{de}
ETBW5518	98.73^{ab}	17.13^{cde}	49.13^{bc}	77.2^{a}	31^{bcd}	110^{abc}	64.66^{bc}
ETBW5519	94^{bc}	18.46^{b}	52.93^{ab}	76.93^{ab}	27^{d}	111.66^{a}	66.33^{a}
ETBW5520	98.73^{ab}	17.13^{cde}	48.6^{bc}	79.06^{a}	33.66^{ab}	107^{ef}	62^{ef}
ETBW5521	95.6^{ab}	17.53^{bcd}	49.2^{bc}	79.2^{a}	37.33^{a}	110.33^{abc}	65^{ab}
ETBW5522	100.86^{a}	15.93^{e}	47.2^{bcd}	71.7^{c}	27.66^{cd}	107.33^{def}	62.33^{e}
ETBW5525	101.46^{a}	19.8^{a}	60.06^{a}	76.2^{abc}	32^{bc}	109.33^{bcd}	64.33^{bc}
ETBW5526	98.46^{ab}	18^{bcd}	57.13^{a}	75.26^{abc}	30.66^{bcd}	111.33^{ab}	65.33^{ab}
Mean	96.67	17.39	49.03	75.56	30.66	108.44	63.3
CV (%)	3.67	4.25	9.24	3.59	9.06	1.14	1.52
LSD	6.01	1.25	7.67	4.59	4.7	2.1	1.63
SE	3.6	1.07	5.49	2.8	3.17	2.3	2.09

PH=Plant height (cm), SKPSP= spikeletes per spike, KPS=kernels per spike, HLW= hectoliter weight (kg/hl), TGW= thousand grain weight (g), MA=days to maturity, HD= days to heading, CV (%) =coefficient of variation, LSD=least significant difference, SE=standard error, α = 0.5.

Spike length

ETBW5526 (9.8 cm), ETBW5522 (9.73 cm) and HAR3730 (9.2 cm) had longer spike length while Millennium and ETBW5521 had the shortest spike length in the grandmother trial (Table 4). Similarly, ETBW5521 (9 cm), ETBW5525 (9.26 cm) and ETBW5522 (9.33 cm) had the longest spike length whereas HAR1685 and Millennium had the shortest spike length in the mother trial (Table 5). In both trials, ETBW5522 showed the

Table 6. Analysis of variance for 19 traits of bread wheat varieties in grandmother trial.

Traits	MSr	MSt	Mse	CV (%)
PH	11.42	37.07**	10.87	3.55
SL	0.023	1.22**	0.14	4.32
NT	11.67	1.80^{ns}	1.02	15.55
SKPSP	7.21	2.86**	0.66	4.88
KPS	377.42	36.76^{ns}	21.89	11.61
BM	1.83	2.03^{ns}	1.2	9.34
YD	0.98	1.26**	0.38	14.06
MO	0.58	0.11^{ns}	0.45	8.98
HLW	28.81	19.45**	5.45	3.05
TGW	39.69	34.45**	5.72	7.81
LR	63.19	121.72**	23.8	19.09
YR	158.33	406.25**	117.4	32.92
SR	46.53	42.92^{ns}	45.01	48.3
GFP	0.33	5.28**	0.45	1.45
MA	1.44	28.26**	2.11	1.33
HD	0.44	22.15**	1.17	1.73
SPG	6.25	19.88*	8.52	3.17
SPH	2.08	9.28^{ns}	7.38	2.92
HI	91.05	48.41**	15.1	10.48

MSr=Mean square due to replication, MSt= Mean square due to treatment, MSe= mean square due to error,DF= degree of freedom, PH=plant height, SL= spike length, NT= number of tillering, SKPSP= spikeletes per spike, KSP=kernels per spike, BM= biomass yield, YD= grain yield, MO=moisture contents, HLW= hectoliter weight, TGW= thousand grain weight, LR= leaf rust, YR=yellow rust, SR=stem rust, GFP= grain filling period, MA=days to maturity, HD= days to heading, SPG=stand percentage at growth, SPH= stand percentage at harvesting, HI= harvest index, CV (%) =coefficient of variation, ** indicates significance at 0.01probability level, ns indicates non significance.

Table 7. Analysis of variance for 19 traits of bread wheat varieties in mother trial.

Traits	MSr	MSt	MSe	CV (%)
PH	233.56	38.98**	12.59	3.67
SL	1.77	0.49^{ns}	0.27	6.02
NT	6.94	2.28^{ns}	2.8	19.15
SKPSP	4.55	3.48**	0.54	4.25
KPS	130.92	90.63**	20.56	9.24
BM	578.66	63.23^{ns}	62.57	7.16
YD	1.6	0.58^{ns}	0.48	16.38
MO	1.4	0.73^{ns}	0.43	9.03
HLW	26.31	23.65**	7.36	3.59
TGW	50.58	30.24**	7.73	9.06
LR	63.19	57.32**	17.74	16.66
YR	214.58	285.04**	68.37	29.62
SR	29.86	69.44^{ns}	25.31	36.96
GFP	25.19	0.57^{ns}	0.89	2.09
MA	43.02	15.89**	1.54	1.15
HD	13.36	13.11*	0.93	1.52
SPG	43.75	15.90^{ns}	18.75	4.76
SPH	56.2	8.33^{ns}	12.31	3.79
HI	43.56	39.84^{ns}	38.4	16.21

MSr= Mean square due to replication, MSt= Mean square due to treatment, MSe= mean square due to error, DF= degree of freedom, PH=plant height, SL= spike length, NT= number of tillering, SKPSP= spikeletsper spike, KSP=kernels per spike, BM= biomass yield , YD= grain yield, MO=moisture contents, HLW= hectoliter weight, TGW= thousand grain weight, LR= leaf rust, YR=yellow rust, SR=stem rust, GFP= grain filling period, MA=days to maturity, HD= days to heading, SPG=stand percentage at growth, SPH= stand percentage at harvesting, HI= harvest index, CV (%) =coefficient of variation, ** indicates significance at 0.01 probability level, ns indicates non significance.

longest while Millennium the shortest spike length.

Thousand grain weight

HAR3730 (35.3 g) had the highest thousand seed weight. Similar result was reported by Berhanu (2010). HAR1685 (25 g) had the lowest thousand seed weight (Table 4). In the Mother trial, ETBW5521 had the highest thousand seed weight (Table 5).

Hectoliter weight

Test weight provided a rough estimate of flour yield potential in wheat. It is important to millers just as grain yield is important to wheat producer. HAR3730 (80.8 kg/hl) and ETBW5518 (79.8 kg/hl) scored the highest weight whereas HAR1685 scored the lowest (72.2 kg/hl) hectoliter weight in grandmother trial (Table 4). In the mother trial, ETBW5520 (79.06 kg/hl) and ETBW5521 (79.2 kg/hl) scored the highest weight and Paven-76 and HAR1685 both scored the lowest weight of (72.13 kg/hl) (Table 5).

Analysis of variance

There was significant difference (p<0.01) among the treatments with respect to yield and yield related traits. Genotypes in the grandmother trial exhibited highly significant difference for plant height, spike length, spikelets per spike, grain yield, hectoliter weight, thousand grain weights, leaf rust, yellow rust, grain filling period, days to maturity, days to heading, harvest index and stand percentage (Table 6).

Genotypes in the mother trial significantly varied (p<0.01) in plant height, spikelets per spike, kernels per spike, hectoliter weight, thousand grain weight, leaf rust, yellow rust, days to maturity and days to heading in mother trial (Table 7).

In the grandmother and mother trials highly significant height, spikelets per spike, hectoliter weight, thousand differences among genotypes were observed in plant grain weights, leaf rust, yellow rust and days to maturity in both trial types.

Conclusions

Developed participatory bread wheat varietal selections solves many constraints related to farmers' participations, set parameters, select superior varieties, evaluating the performance of better varieties, and identify better varieties and accelerating the dissemination of farmers' selected varieties in the Kebele. Farmers' participation in the PVS enabled them to increase their knowledge to select superior varieties that fit in their own agro-economic and management condition. Those varieties selected by farmers showed a yield advantage over the local variety kubsa (HAR1685). Bread Wheat varieties diversification in the Kebele may increase remarkably if the PVS approach would be widely used in the Kebele. In general, it can be concluded that the participatory varietal selection of bread wheat could be improved based on the existing potential of the study area. Farmers must have an opportunity to participate with varietal selection to get more yield of bread wheat based their indigenous knowledge. Farmers should diversify their cultivars along with Kubsa which is the only bread wheat variety grown by farmers in Marwoled Kebele. Cultivars such as HAR3730 and ETBW5526 gave high yield compared to other varieties.

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Full Length Research Paper

Effect of transpiration suppressants and nutrients under rainfed conditions: An integral view on crop productivity and biological indices in millet/pulses intercropping system

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Under rainfed condition (650 mm/annum) of India drought of unpredictable intensity and duration is a prevailing feature. Appropriate intercropping combinations and management practices for sustaining crop productivity in such situations needs to be worked out, where monoculture is prevailing. Objectives were to examine the effect of transpiration suppressants and nutrients on sustaining productivity, profitability of pearlmillet/pigeonpea intercropping for realizing maximum nutrients and moisture use efficiency in moisture scarce conditions. Though there was a reduction in yield of component crops under intercropping greatly so for pigeon pea, higher Pearlmillet Equivalent Yield (PEY), land equivalent ratio (LER) value, economics (net returns and B:C ratio) was achieved higher in pearlmillet/pigeonpea intercropping system as compared to their sole cropping. Nutrients and apparent rain water use efficiency (ARUE) was also higher in same cropping system. The yield response of the transpiration suppressants was observed only in limited soil moisture conditions (2009). However, with respect to yield advantage indices, the effect of transpiration suppressants was comparable to control. Over the period of time, 50 kg N + 17.2 kg P ha^{-1} recorded higher crop performance ratio, ARUE, agronomic and physiological efficiency of N and P over other fertility treatments.

Key words: Apparent rainfall use efficiency, *Cajanus cajan*, biological indices, nutrients use efficiency, *Pennisetum glaucum*, transpiration suppressants.

INTRODUCTION

Pearlmillet [*Pennisetum glaucum* (L.)] is a major cereal crop in the arid and semi-arid regions of India. Today, it is getting more attention due to increasing evidence of less seasonal rainfall, terminal heat, frequent occurrence of

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extreme weather events coupled with scanty water resources (Singh et al., 2010). Annual rainfall and its monthly distribution are highly variable in this zone (Painuli et al., 2002). Studies in rainfed sub tropical agro climatic zones of India indicated depleted soil fertility, poor microbial activity and low organic matter content resulting in the reduced soil volume exploited by the plant for essential nutrients and water (Jakhar et al., 2006). Therefore, efficient soil management and profitable production systems are needed for this non irrigated region to improve the economic condition of the farmers. In grey areas of the country, the best alternative to increase the production of cereals, millets and pulses is the adoption of location-specific intercropping systems. Pearlmillet and pigeonpea intercropping has been the most important for dryland areas with limited water availability on marginal and sub-marginal lands in north-west, west and central parts of India (Singh et al., 2010). Careful selection of crops having different growth habit can reduce the mutual competition to a considerable extent (Moriri et al., 2010). Pigeonpea [*Cajanus cajan* (L.) Millsp.] is deep rooted and slow growing in early growth, more rapidly growing crops like pearlmillet may be conveniently intercropped in the hope of utilizing the natural resources more efficiently (Ghosh et al., 2006). To stabilize crop production and to provide insurance against aberrant weather situations in rainfed agriculture, intercropping of millets with pulses such as pigeonpea could be a viable risk minimizing agronomic means of sustainable venture. Use of transpiration suppressants like cycocel (growth retardant) and phenyl mercuric acetate (PMA, stomata closing type); reduce transpiration losses from plants and effectively increases productivity and water use by crops under rainfed conditions (Gaballah and Moursy, 2004). It is necessary to consider nutrient competition in an intercropping system that involves crops of different maturity, such as a pearlmillet with pigeonpea, whose peak demand for resources do not coincide (Tobita et al., 1996).

Understanding is needed of when and which component crop is suffering from which nutrient deficiency to establish strategies for fertilizer use. The cereal components is usually taller and has a faster growing or more extensive root system (Lehmann et al., 1998), and has a high demand for soil N (Carr et al., 2004). However, an effectively nodulated legume component is able to fix N_2 from the atmosphere (Jensen, 1996), leading to a potentially non-competitive association with respect to N nutrition at least. However, with the changing scenario of crop improvement in pearlmillet and pigeonpea intercropping, there is a need to relook and investigate low cost technology. In this paper, we have attempted to examine the effect of transpiration suppressants and nutrients on sustaining productivity of pearlmillet/pigeonpea intercropping for realizing maximum yield and profit in moisture scarce conditions.

MATERIALS AND METHODS

Experimental site

The field experiment was conducted at the Indian Agricultural Research Institute (IARI), New Delhi, situated at latitude of 28° 4" N longitude of 77° 12" E and altitude of 228.6 m for two consecutive years (2009 to 2010). The soil of the experimental site was sandy loam in texture having pH 7.8, organic carbon 0.3% and EC 0.38 dS m^{-1}. Soils at 0 to 15 cm depth are low in alkaline permanganate N (61.72 mg/kg of soil) (Subbiah and Asija, 1956), available P (4.72 mg/kg of soil) (Olsen et al., 1954) and medium in available K (ammonium acetate K 85.4 mg/kg of soil) [Flame photometer method (Hanway and Heidel, 1952)]. The moisture at 0.03 and 0.15 M pa tensions were 18.8 and 6.5% [pressure plate apparatus (Richards and Weaver, 1943)] and bulk density was 1.50 Mg m^{-3} (0 to 15 cm). The region has a semi-arid tropical climate and receives an annual rainfall of 850 mm, (>90% from July to September).

Experimental and crop culture

The experiment was laid out in split plot design with nine combinations including three cropping system (C1- pearlmillet sole, C2- pigeonpea sole, C3- paired row of pearlmillet + one row of pigeonpea) and three transpiration suppressants [T0- control, T1- cycocel (200 ppm), T2-PMA (320 ppm)] in the main plots, that were each split for four fertility levels (F0- Control, F1- 25 kg N + 8.6 kg P ha^{-1}, F2- 50 kg N + 17.2 kg P ha^{-1}, F3- 25 kg N + 8.6 kg P ha^{-1} + *Azotobacter* + PSB) in sub plot and replicated thrice. Pearlmillet (variety Pusa-383) and short duration pigeonpea (variety Pusa-991), both as sole and intercrops were sown in the third week of July. Two to three seeds of pigeonpea were sown $hill^{-1}$ at a row spacing of 50 cm and the seedlings were thinned to one plant $hill^{-1}$ one week after emergence for achieving a plant density of 100 × 10^3 ha^{-1} and plant-to-plant spacing of 20 cm. For pearlmillet, row-to row spacing of 50 cm and plant-to-plant spacing of 10 cm were maintained to get a plant density of 200 × 10^3 ha^{-1}. In intercropping, one row of pigeonpea was sown after every two rows of pearlmillet (1:2) at a distance of 30 cm. This way, pigeonpea to pigeonpea row distance in intercropping was 100 cm. A plant population of 200 × 10^3 ha^{-1} for intercropped pearlmillet and 50 × 10^3 ha^{-1} for intercropped pigeonpea was maintained. Transpiration suppressants was applied at 55 days after sowing (DAS) in 2009 and at 70 DAS in 2010. PMA (320 ppm) and cycocel (200 ppm) were applied at 256 and 160 g ha^{-1}, respectively, and total volume of solution was maintained at 800 L/ha.

Fertilizer was drilled in bands 8 to 10 cm below the surface. Pearlmillet seeds were inoculated with biofertilizers [*Azotobacter* and phosphate solubilizing-bacteria (PSB)]; while, pigeonpea seeds were inoculated with PSB and Rhizobium culture 2 h before sowing at 20 g/kg seed. Pearlmillet was harvested manually at 88 and 91 DAS while pigeonpea was harvested at 145 and 147 DAS in 2009 and 2010, respectively. The crop was harvested manually by sickle at ground level and threshed with an electrically operated multi crop thresher.

Yield advantage indices

The yields of sole and intercrop pigeonpea was converted to pearlmillet equivalent yield (PEY) on financial basis and expressed as PEY = yield of pigeonpea × unit price of pigeonpea/unit price of pearlmillet. However, PEY does not indicate the net gain obtained from a cropping system and also does not explain the land use pattern of the cropping systems. Land equivalent ratio (LER) is the relative land area under sole crops that is required to produce the yields achieved in intercropping. LER value greater than unity reflects the extra advantage of intercropping system over sole cropping system; It was calculated by using following formula:

LER = Yab/Yaa + Yba/Ybb

Where, Yaa is yield of component a as sole crop, Ybb is yield of component b as sole crop, Yab is yield of component a as intercrop grown in combination with component b and Yba is yield of component b as intercrop grown in combination with component a. Crop performance ratio (CPR) was calculated by using the formula:

CPR = Qia/Pia × Qsa + Qib/Pib × Qsb

Where Q ia and ib is productivity per unit area in the intercrop of a and b, Qsa and Qsb is productivity per unit area in the sole crops of a and b, Pia and Pib is proportion of the intercrop area sown with the species a and b.

Apparent rain water use efficiency

Apparent rain water use efficiency (ARUE) of crop was worked out from the seasonal rainfall of water as illustrated by using the following formula:

WUE (kgha^{-1}mm^{-1}) = Grain yield (kg ha^{-1})/Rainfall (mm)

Nutrients use efficiency

The estimated values of agronomic efficiency (AE), physiological efficiency (PE) and harvest index (HI) of applied N and P were computed using the following expressions as suggested by Fageria and Baligar (2003) and Dobermann (2005):

AE = (YN - YAc)/Na
PE = (YN - YAc)/(UN - UAc)
HI = GUN/UN

Where YN is grain yield (kg ha^{-1}) in N applied plots, YAc is grain yield (kg ha^{-1}) in absolute control, Na is nutrient (N/P) applied (kg ha^{-1}), UN is total nutrient (N/P) uptake (kg ha^{-1}), UAc is total nutrient (N/P) uptake (kg ha^{-1}) in absolute control and GUN is total nutrient (N/P) uptake (kg ha^{-1}) in grain.

Production efficiency

Farmers are concerned mostly with total profit and the marginal benefit: cost ratio from investment in labour and inputs (Ghosh et al., 2006). The yield and economic performance of intercropping was assessed to determine whether pearlmillet yield and additional pigeonpea yield were sufficient for practising intercropping system. For comparing the economical value of systems, the grain yields were converted into gross return and/or net return.

Economics

Economics of different treatment was worked out by taking into account the cost of inputs and income obtained from output (grain and stover yield). Net returns (Rs ha^{-1}) calculated by using formula = gross returns - cost of cultivation. Benefit: cost ratio was calculated by used formula = gross returns/cost of cultivation. Minimum support price (fixed by government of India) of pearlmillet in 2009 and 2010 = Rs 8400 and Rs 8800 t^{-1}, respectively, minimum support price of pigeonpea in 2009 and 2010 = Rs 23000 and Rs 28000 t^{-1}, respectively. The cost of cycocel = Rs 5,122 L^{-1} and cost of PMA = Rs 10,588 kg^{-1}, `140/man-day, price of stalk/stover = `1500 t^{-1}, cost of nitrogen = `11.54 kg$^{-1}$ N, cost of phosphorus (P) = `49.35 kg^{-1}, cost of biofertilizers = `10 packet$^{-1}$, cost of cycocel = `5122 L^{-1}, cost of PMA = `9588 kg^{-1} was used for economic analysis.

Rainfall

The total rainfall received during rainy seasons (June to December) was 493 mm in 2009 and 776 mm in 2010 (Figure 1a and b). The year 2009 received low rainfall during a part of the pearlmillet and pigeonpea growing seasons. In comparison to the long term average, the rainfall received during growing season was not only low but also erratic. Most of the precipitation occurred during July to August.

Data analysis

Data obtained from pearlmillet and pigeonpea crops for consecutive two years were pooled and statistically analyzed using the F-test as per the procedure given by Gomez and Gomez (1984). LSD at P = 0.05 were used to determine the significance between treatment means.

RESULTS

Yield

There was 8.3% reduction in grain yields of intercrop pearlmillet and 149% of intercrop pigeonpea over the corresponding sole crops (Table 1). Transpiration suppressants compared with no suppressants significantly (*$P < 0.05$) increased grain yield of sole and intercrop pearlmillet and pigeonpea in 2009 but not 2010. Application of 50 kg N + 17.2 kg P ha^{-1} on an average gave significantly higher pearlmillet and pigeonpea grain yield by 31, 25 and 16 and 38, 31 and 19% over control, 25 kg N + 8.6 kg P ha^{-1}, 25 kg N + 8.6 kg P ha^{-1} + BF, respectively.

Biological indices

The yield advantage in terms of pearlmillet equivalent yield (PEY) was greater in pearlmillet/pigeonpea intercropping system than their respective sole cropping (Table 1). The yield response to transpiration suppressants was higher in 2009. PMA spray recorded the highest PEY and control showed the lowest. On an average, 45 and 10% more yield advantages in terms of PEY was received from intercropping over sole pearlmillet and sole pigeonpea, respectively. Transpiration suppressants also gave 6% more PEY over control. Higher LER values in intercropping system that is, 1.31 and 1.35 in respective years of 2009 and 2010 clearly indicated 31 and 35% advantage over sole cropping. Transpiration suppressants increased the LER values on an average of 3% over control (Table 1). The

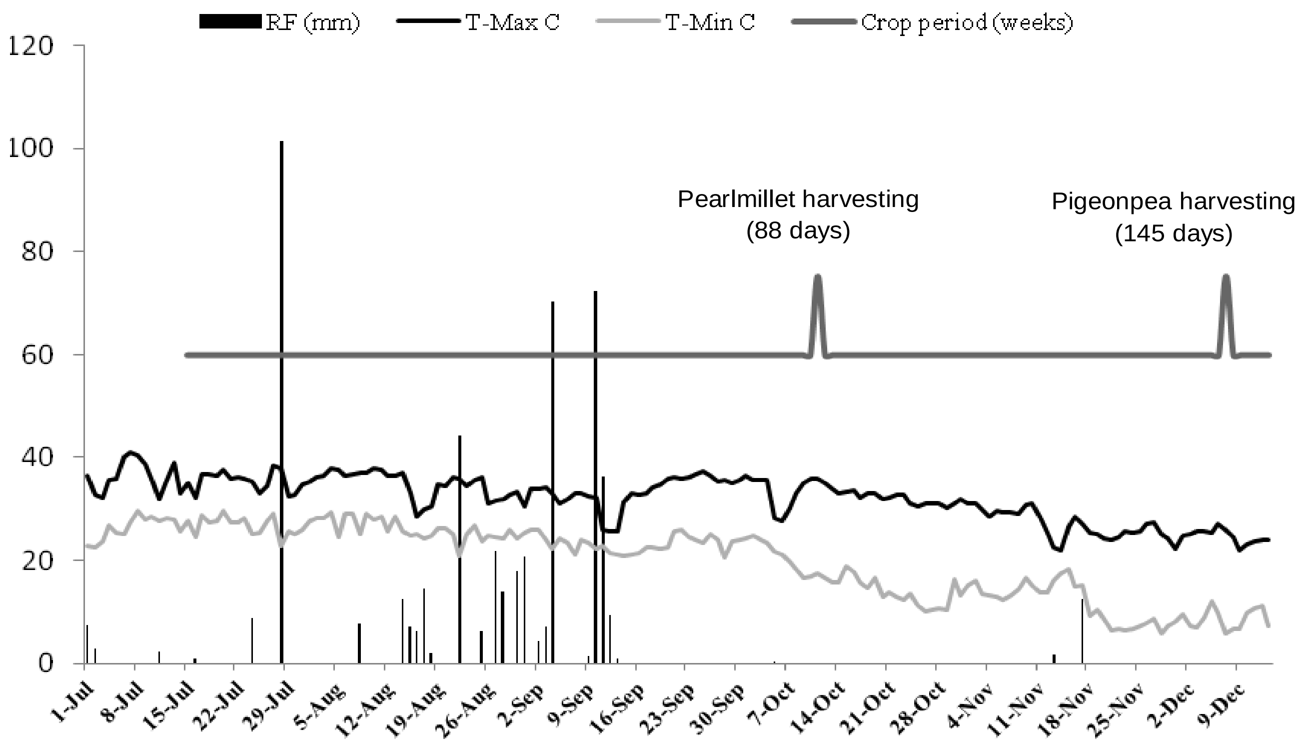

Figure 1a. Meteorological parameters and crop duration during cropping season of 2009.

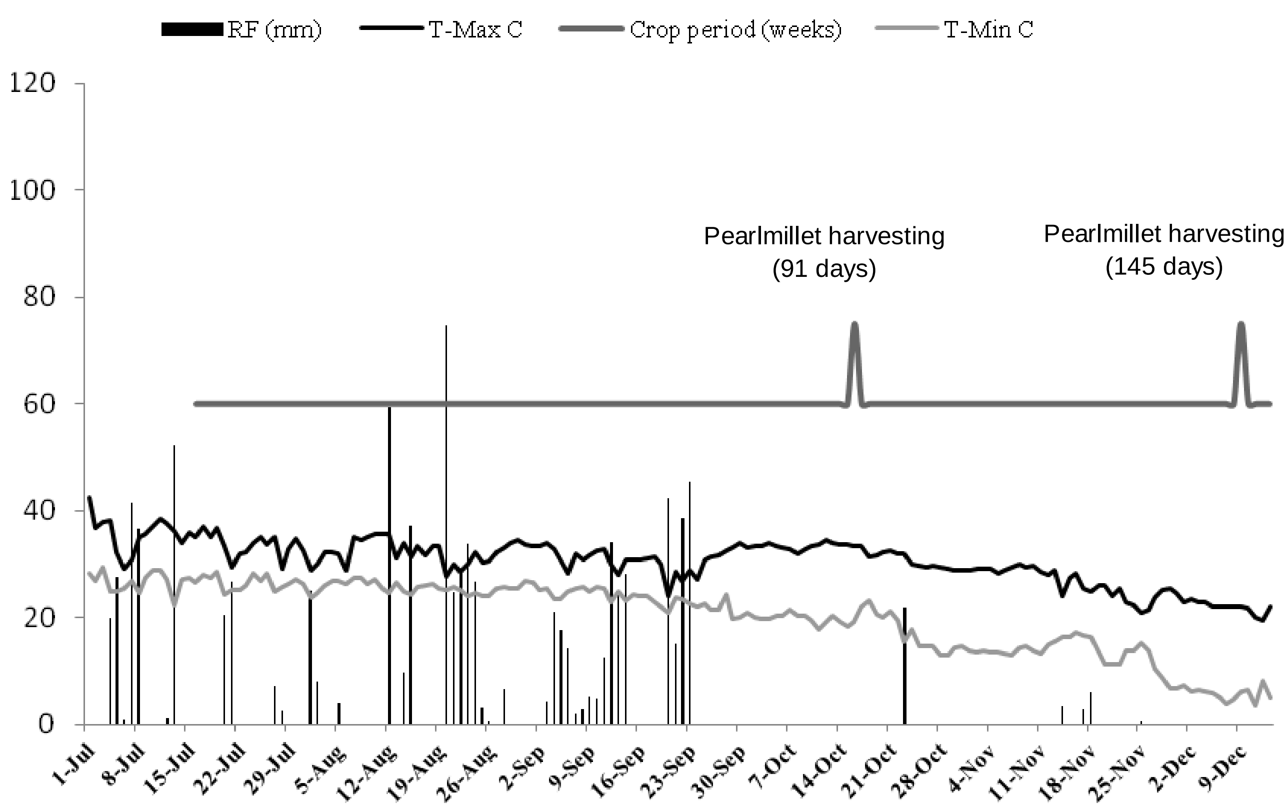

Figure 1b. Meteorological parameters and crop duration during cropping season of 2010.

Table 1. Effect of cropping systems transpiration suppressants and fertility levels on yields, PEY and LER of sole pearlmillet, sole pigeonpea and intercropping system.

Treatments	Grain yield of pearlmillet (t/ha)		Grain yield of pigeonpea (t/ha)		Pearlmillet equivalent yield (PEY) (t/ha)		Land equivalent ratio (LER)	
	2009	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**
Cropping systems								
Sole pearlmillet	2.93	3.34	-	-	2.93	3.34	1.00	1.00
Sole pigeonpea	-	-	1.50	1.54	4.09	4.20	1.00	1.00
Pearlmillet + pigeonpea	2.74	3.04	0.57	0.65	4.31	4.82	1.31	1.35
L.S.D. (P = 0.05)	0.15	0.11	0.03	0.06	0.16	0.54	0.11	0.32
Transpiration suppressants								
Control	2.69	3.14	1.01	1.07	3.62	3.99	1.09	1.10
Cycocel	2.89	3.19	1.04	1.09	3.81	4.15	1.10	1.11
PMA	2.93	3.24	1.05	1.12	3.89	4.19	1.12	1.14
L.S.D. (P = 0.05)	0.19	NS	0.03	NS	0.16	NS	NS	NS
Fertility levels								
Control	2.37	2.73	0.85	0.90	3.16	3.39	1.07	1.10
25 kg N + 8.6 kg P/ha	2.86	3.05	1.00	1.08	3.63	3.96	1.11	1.11
50 kg N + 17.2 kg P/ha	3.13	3.57	1.17	1.24	4.22	4.68	1.12	1.15
25 kg N + 8.6 kg P/ha + BF	2.96	3.41	1.12	1.16	4.10	4.41	1.12	1.12
L.S.D. (P = 0.05)	0.17	0.09	0.04	0.10	0.15	0.28	NS	NS

* NS, BF and PMA represent non significant, biofertilizers (Azotobacter and phosphate solubilizing bacteria) and phenyl mercuric acetate, respectively. Yields of sole and intercrop pigeonpea were converted to pearlmillet equivalent yield (yield of pigeonpea × unit price of pigeonpea/unit price of pearlmillet). Thus, PEY in intercropping is yield of intercrop pearlmillet + PEY of intercrop pigeonpea.

higher value of CPR in cropping system was recorded in PMA spray (1.76) over control (1.66) (Figure 2a). While in 2010, the effect of transpiration suppressants did not show any significant variation. 50 kg N + 17.2 kg P ha^{-1} significantly increased the PEY being on par with 25 kg N + 8.6 kg P ha^{-1} + *Azotobacter* + PSB as compared with other fertility levels (Table 1). The significantly higher LER and CPR were recorded under same treatment during both the year of experimentation.

Apparent rain water use-efficiency

Over the period of time, intercropping system was recorded significantly at 18 and 127% higher apparent rain water use-efficiency (ARUE) over sole pearlmillet and sole pigeonpea (Figure 3a). The minimum ARUE was recorded under sole cropping of pigeonpea (4.64 kg ha^{-1} - mm). Among transpiration suppressants, higher ARUE was recorded in PMA spray (8.23 kg ha^{-1} - mm) over control (7.94 kg ha^{-1} - mm) (Figure 3b). The maximum ARUE was observed with the application of 50 kg N + 17.2 kg P ha^{-1}, followed by 25 kg N + 8.6 kg Pha^{-1} + *Azotobacter* + PSB (Figure 3c). The minimum ARUE was recorded with control during both the year of experimentation.

Nutrients use indices

The pearlmillet/pigeonpea intercropping system significantly increased AEN and AEP than either of the sole cropping. Significantly, higher PEN (18.38 kg $grainkg^{-1}$ N uptake) and PEP (1.09 kg grain kg^{-1} P uptake) was recorded with pearlmillet/pigeonpea intercropping system as compared to sole cropping of pearlmillet and pigeonpea (Table 2). Sole pearlmillet recorded significantly higher NHI as compared to sole cropping of pigeonpea and pearlmillet and pigeonpea intercropping system. The effect of transpiration suppressants on agronomic efficiency, physiological efficiency and harvest index of N and P was found to be non significant (Table 2). The highest AE and PE of N and P was recorded with the application of 25 kg N + 8.6 kg P ha^{-1} + *Azotobacter* + PSB over other fertility levels (Table 2). There was no significant effect of N and P fertilization on NHI of pearlmillet and pigeonpea crops.

Economics

On an average, intercropping system gave maximum net returns of 38.62 × 10^3 ` ha^{-1}, which was about 54% higher than sole pearlmillet and 22% higher than sole pigeonpea

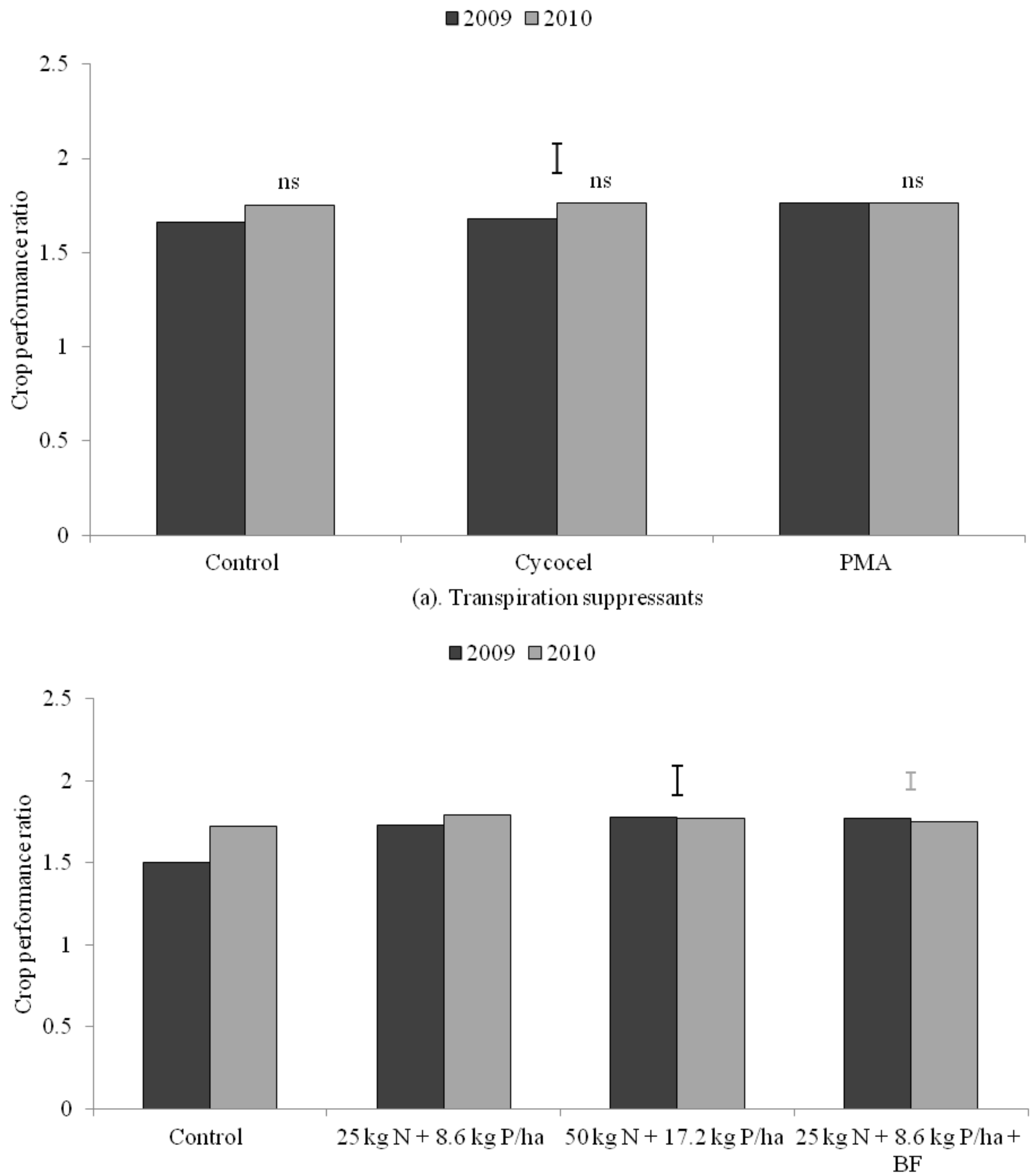

Figure 2. Crop performance ratio under different transpiration suppressants (a) and fertility levels in pearlmillet/pigeonpea intercropping system (b). Vertical bar and ns represents L.S.D. (P = 0.05) and non significant, respectively.

(Table 3). This system also provided significantly higher ` per ` invested (3.23) than that of the other two systems (Table 3). Higher crop profitability was recorded under intercropping system over sole pearlmillet and sole pigeonpea. The effect of transpiration suppressants was not significant on net return and benefit: cost ratio. Cycocel gave the highest crop profitability of other treatments. Application of 50 kg N + 17.2 kg P ha^{-1} through fertilizer enhanced mean net returns by `11.32 × 10^3 ha^{-1} over control. Further, application of 25 kg N + 8.6 kg P ha^{-1} + BF enhanced net returns by Rs 9.63 × 10^3 ha^{-1} over control (Table 3). Inclusion of biofertilizers

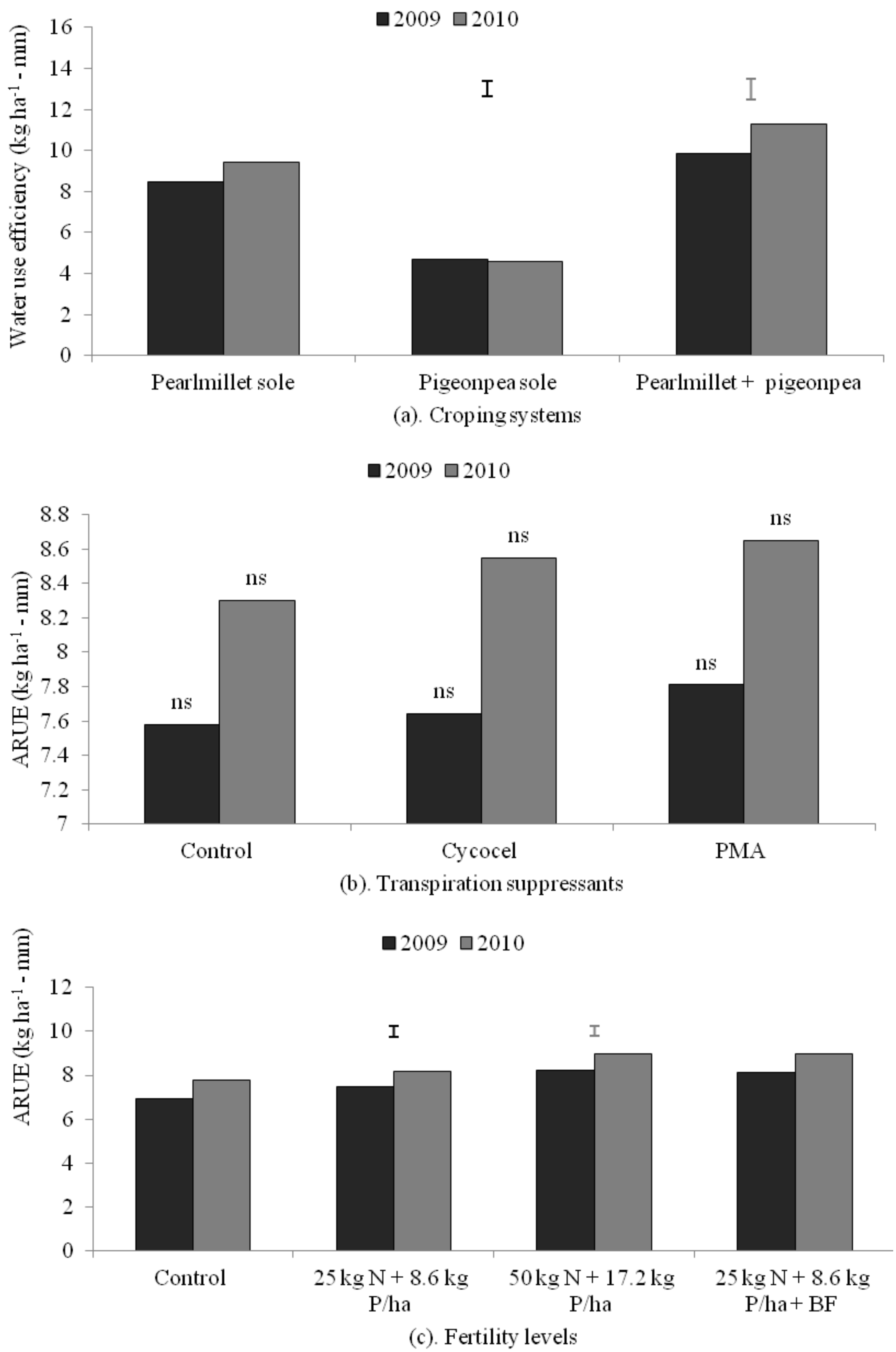

Figure 3. The apparent rain -use-efficiency (kg ha^{-1}-mm) of pearlmillet and pigeonpea crops under different cropping systems (a) and transpiration suppressants (b) and fertility levels in 2009 and 2010 (c). The ns and vertical bar represents non significant and L. S. D. (P = 0.05), respectively.

Table 2. Effect of cropping systems, transpiration suppressants and fertility levels on agronomic efficiency, physiological efficiency and harvest index of N and P (pooled data of two years).

Treatment	Nitrogen			Phosphorus		
	AEN (kg grain /kg N applied)	PEN (kg grain /kg N uptake)	NHI (%)	AEP (kg grain /kg P applied)	PEP (kg grain /kg P uptake)	PHI (%)
Cropping systems						
Pearlmillet sole	14.86	15.15	54.93	0.58	0.64	37.57
Pigeonpea sole	7.165	7.66	38.61	0.21	0.47	45.61
Pearlmillet + pigeonpea	27.73	18.38	50.87	1.03	1.09	46.41
L.S.D. (P = 0.05)	3.88	3.66	2.57	0.20	0.75	2.86
Transpiration suppressants						
Control	16.72	14.27	47.94	0.63	0.80	43.40
Cycocel	16.42	12.93	48.10	0.57	0.68	43.20
PMA	16.61	13.81	48.37	0.62	0.71	43.01
L.S.D. (P = 0.05)	NS	NS	NS	NS	NS	NS
Fertility levels						
Control	0.00	0.00	48.93	0.00	0.00	45.62
25 kg N + 8.6 kg P/ha	16.89	15.12	48.66	0.64	0.98	42.55
50 kg N + 17.2 kg P/ha	18.21	19.18	47.12	0.66	0.96	42.18
25 kg N + 8.6 kg P/ha + BF	31.25	20.61	47.84	1.13	0.99	42.44
L.S.D. (P = 0.05)	2.96	2.47	NS	0.14	0.21	1.95

* NS, BF and PMA represent non significant, biofertilizers (*Azotobacter* and phosphate solubilizing bacteria) and phenyl mercuric acetate, respectively. AEN and AEP; PEN and PEP and NHI and PHI representing agronomic efficiency of N and P, physiological efficiency of N and P and harvest index of N and P, respectively.

Table 3. Effect of cropping systems, transpiration suppressants and fertility levels on economics and crop profitability (pooled data of two years).

Treatment	Economics				Crop profitability (Rs/ha/day)
	Cost of cultivation ($\times 10^3$ Rs/ha)	Gross returns ($\times 10^3$ Rs/ha)	Net returns ($\times 10^3$ Rs/ha)	B:C ratio	
Cropping systems					
Pearlmillet sole	13.99	39.08	25.09	1.79	269.74
Pigeonpea sole	15.42	47.09	31.67	2.06	221.46
Pearlmillet + pigeonpea	16.18	54.80	38.62	2.39	270.09
Transpiration suppressants					
Control	13.76	45.49	31.73	2.31	253.24
Cycocel	14.43	47.33	32.30	2.15	257.82
PMA	16.30	48.16	31.36	1.87	250.23
Fertility levels					
Control	14.32	39.51	25.19	1.76	201.16
25 kg N + 8.6 kg P/ha	15.22	45.53	30.31	1.99	241.62
50 kg N + 17.2 kg P/ha	15.98	52.62	36.64	2.29	292.38
25 kg N + 8.6 kg P/ha +BF	15.27	50.32	35.05	2.30	279.90

(*Azotobacter* + PSB) with 25 kg N + 8.6 kg P/ha enhanced the net returns by `4.41 × 10^3 ha^{-1} over only 25 kg N + 8.6 kg P ha^{-1}. Application of 50 kg N + 17.2 kg P ha^{-1} increased the mean net returns and B:C ratio by 49.34 and 36.58, 21.66 and 17.15 and 5.18 and 2.18% over control, 25 kg N + 8.6 kg P ha^{-1} and 25 kg N + 8.6 kg

P ha^{-1} + BF, respectively.

The highest and 45% more crop profitability was also found in same treatments over control. These findings are in line with those of Ghosh et al. (2006).

DISCUSSION

Soil water deficits that frequently occur during crop growth because of erratic monsoon and non-uniform distribution of rain reduce yield in traditional production systems (Gupta and Rajput, 2001). In 2009, the crops faced initial water stress due to delayed onset of monsoon and at later stages, frequency and severity of water deficit increased from September to December. Though, adequate precipitation occurred in July to September (Figure 1a and b). The rainfall during growing season (July to December) in 2009 was 493 mm against 776 mm in 2010 (Figure 1a and b). Therefore, yield of crops in 2009 was generally low compared to 2010. The higher profile soil water content in 2009 was related to less extraction of soil water owing to low biomass production. Our results clearly indicated that under uneven and deficit rainfall situation, pearlmillet/pigeonpea intercropping is superior to conventional pearlmillet or pigeonpea monoculture production in the semi-arid region of India, and minimizes the risk of failure of monoculture (pearlmillet/pigeonpea) and provides maximum profit. The pearlmillet/pigeonpea intercropping system maintained comparatively lower water storage than sole cropping suggesting higher soil water extraction. Thus, higher profit in the intercropping system may be attributed to more extraction of soil water, high yield and high market price of pigeonpea as a bonus in intercropping system.

The duration of a crop in an intercropping system plays a useful role in achieving yield advantage. Higher yield advantage can be expected when the maturity period of the component crops are different (Nambiar et al., 1983). In pearlmillet/pigeonpea intercropping system, associated crops had different maturity periods and hence competition was less. Figure 2 show that pearlmillet was harvested when the associated pigeonpea attained its grand growth period (85-90 DAS) and competition with associated pigeonpea was not considerable. Pearlmillet being a fast growing crop, utilized resources, particularly the soil water due to rainfall received during June to August (Figure 1) early in the season. Pigeonpea utilized resources later in the season and being a deep-rooted crop; it continued to grow by extracting residual soil moisture from deeper soil layers. Crop complementarities or supplementarities determine the magnitude of competition.

In the present study, though there was a reduction in yield of intercrops, but, higher PEY and LER value in intercropping system indicated a definite advantage compared to monoculture yields apparently because of crop complementarities. Our results indicated that use of transpiration suppressants was advantageous in rainfed India during drought situations to increase yield significantly. Myaka et al. (2006) also emphasised the significantly higher yield in intercropping under non-irrigated environment than sole cropping. Tetarwal and Rana (2006) reported that yield from transpiration suppressants spray in pearlmillet were greater than control in limited moisture condition. CPR is defined as the productivity of an intercrop per unit area of ground area compared with that expected from sole crops sown in the same proportions. A value of CPR greater than unity implies an intercrop advantage and a value less than unity implies the intercrop disadvantages.

In our study, there were significant differences among the treatments. The higher value of CPR was recorded in PMA over other transpiration suppressants treatment. In all treatments, it was higher than unity in pearlmillet/pigeonpea intercropping system, showing intercrop advantage. This indicates that in order to improve the mixture productivity of the intercropping system, efforts should be geared towards improving the productivity of the dominated components as sole cropping. These findings are in line with those of Ghosh et al. (2006). Among N and P fertilization, highest value of PEY, LER and CPR was recorded in pearlmillet/pigeonpea intercropping system with the application of 50 kg N + 17.2 kg P/ha followed by 25 kg N + 8.6 kg P/ha + *Azotobacter* + PSB than other fertility levels. In all fertility treatments, CPR were higher than unity in pearlmillet/pigeonpea intercropping system than sole cropping, showings intercrop advantage. This indicates that in order to improve the mixture productivity of the intercropping system, efforts should be geared towards improving the productivity of the dominated components as sole cropping. These findings are in line with those of Padhi et al. (2010).

The ARUE of intercropping system was higher over sole pearlmillet and pigeonpea. The grain yields of both crops were proportionately higher under intercropping than the amount of water used for biomass production. Pearlmillet intercropped with pigeonpea utilized more water for evapotranspiration and metabolic activities. But, in intercropping system, both the intercrops drew more moisture for dry matter production than sole pigeonpea which resulted in higher rate of moisture use in intercropping system than sole pigeonpea. These findings are in accordance with Kachhadiya et al. (2009) and Yi et al. (2010). The maximum and minimum AE and PE of N and P were recorded with pearlmillet/pigeonpea intercropping system than that of their sole cropping. It was due to more uptake of N in intercropping system and lesser uptake in either of sole crop that is, pearlmillet or pigeonpea, which resulted into more yield per unit of N uptake. Transpiration suppressants did not significantly affect the AE and PE of N and P. It might be due to almost same amount of N uptake among all the transpiration suppressant treatments. N and P fertilization had significant effect on AE and PE of N and P of pearlmillet and pigeonpea crops. Application of 25 kg N + 8.6 kg P ha^{-1} + BF (*Azotobacter* + PSB) recorded significantly higher AE and PE of N and P in pearlmillet and pigeonpea crops over other fertility levels. This was due to additional N_2 fixation by biofertilizers which ultimately made more N available to the plant for uptake and thus there were more AEN and PEN. These findings are in accordance with Myaka et al. (2006) and Singh et al. (2010).

Pearlmillet sole cropping significantly recorded higher NHI followed by intercropping system and the minimum under sole cropping of pigeonpea, while higher PHI was recorded under intercropping system. It might be due to the maximum N and P content and their uptake under pearlmillet sole cropping as compared to sole cropping of pigeonpea. Transpiration suppressants and N and P fertilizations had no-significant effect on NHI of pearlmillet and pigeonpea crops. Pearlmillet/pigeonpea intercropping system gave higher net returns and B:C ratio as compared to either of sole cropping due to more combined yield with nearly similar cost of cultivation (Kachhadiya et al., 2009). Cycocel spray gave higher net returns and net returns per rupee invested than other treatment in limited moisture conditions. This was due to the increased yield with low cost in these treatments. These findings are in accordance with Rana et al. (2009). The maximum net returns was recorded with application of 50 kg N + 17.2 kg P ha^{-1} followed by 25 kg N + 8.6 kg P ha^{-1} + *Azotobacter* + PSB, while B:C ratio was more under 25 kg N + 8.6 kg P ha^{-1} + *Azotobacter* + PSB than other treatment. Higher net returns with combined N and P fertilization were due to higher grain yield. These findings are in accordance with Ghosh et al. (2006).

Conclusion

Based on two year results, it is concluded that consistently higher productivity and profitability from pearlmillet/pigeonpea intercropping could be obtained. The risk of low yields or crop failure associated with the prevailing traditional monoculture production system, under drought of unpredictable intensity and duration could be reduced, especially when transpiration suppressants is used under moisture stress conditions. Use of transpiration suppressants (PMA and cycocel) was found useful in year of low rainfall and dry spells; while, there is no need of transpiration suppressant spray in good rainfall condition to realize optimum yield of pearlmillet/pigeonpea intercropping system. Application of 50 kg N + 17.2 kg P ha^{-1} was found to be more productive over other fertilizer doses.

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Assessment of factors and factors affecting milk value chain in smallholder dairy farmers: A case study of Ada'a District, East Shawa Zone of Oromia regional State, Ethiopia

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Analysis of factors affecting milk value chain in smallholder dairy farmers was conducted in Ada'a district to strength the position of smallholder dairy farmers in milk value chain. Purposive and simple random sampling was employed as sampling techniques to select 100 smallholder dairy farmers 50 from urban area and 50 farmers from rural area to collect the required information. The data was collected through semi-structured questionnaire survey and analysed by using appropriate Statistical Package for the Social Sciences (SPSS) statistical software. Value chain mapping was used to show both qualitative and quality data collected during the filed study period. Different factors affecting milk value chain in smallholder dairy farmers were identified. Among these factors reduction in volume of milk produced, high cost of different inputs (animal feeds, improved breeds), high barging power of trader, weak relationship of dairy cooperative with its members, long fasting period of Ethiopia Orthodox Church are identified as the major factors affecting milk value chain in smallholder dairy farmers. Out of the total interviewed farmers in the urban area about 50% of the respondents produced 10.5 L of milk per day per cow from cross breed cow. On the other hand, smallholder dairy farmers live in the rural area only produce 2.6 L of milk per day per cow from local cow. Hence, to improve the position of small holder dairy farmers in milk value chain there should be strong relationship between dairy cooperative and smallholder farmers inorder to get economic benefit and to secure market access from dairy cooperative.

Key words: Factors affecting milk value chain, smallholder dairy farmers, animal feeds, dairy cooperative.

INTRODUCTION

In Ethiopia, agriculture is the most important economic sector contributing by 43% to the gross domestic product (GDP), providing 85% of the foreign earnings and employing 85% of the labour force (Deresa, 2010). Hence, the capacity of the nation to address food insecurity, poverty, and to bring sustainable national

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economic growth and development is highly dependent on the improvement of agriculture. The livestock sub sector also plays a vital role as sources of food, income and foreign currency to Ethiopian economy and contributes about 12 and 33% of the total and agricultural GDP, respectively.

Ethiopia holds the largest livestock population in Africa estimated to about 52.13 million cattle, 24.2 million sheep and 22.6 million goats (CSA, 2012). The total annual national milk production in Ethiopia comes from about 10 million milking cows and is estimated by 3.2 billion litres that is, 1.54 L/cow on average (CSA, 2012). The dairy value chain comprise about 500,000 smallholder rural farmers who produce about 1,130 million litres of milk of which 370 million litres of raw milk, 280 million litres of butter and cheese and 165 million litres is consumed by the calves (Mohammed, 2009). The remaining 315 million litres was marketed through both informal and formal retailers through farmers' organizations.

Ada'a District is one of the 12 districts of East Shawa Zone of oromia regional state which is well known in dairy production and produce huge amount of milk per annual which is estimated about 10, 678,045 L of milk. In the study area, this milk is marketed through different channels, formal through dairy cooperative and informal via private milk processing company.However, the concept of milk value chain development approach is not well known in Ethiopia and the underlying factors affecting the milk supply are not well addressed. As a result of this, most small holder dairy farmers' could not get fair share from milk value through sustainable milk and milk products marketing.

Moreover, this share is exploiting by middle man (traders) who collectedhuge volume of raw milk from smallholder dairy farmers in rural areas with low price. Therefore the research designed to cover the following objectives farmers with the following objectives: To identify different factors and actors affecting milk value chain in smallholder dairy farmers; to strengthen the position of small holder dairy farmers in milk value chain in the study areas; to examine the performance of smallholder dairy farmers and other actors in milk value chain in the study area; to assess milk quality measures exist along milk value chain in the study area.

Research questions

(1) What are the different factors and actors that affect milk value chain in small holder dairy farmers in the study area?
(2) What is the current potential of milk production in the study area?
(3) What are the different factors that determine farmers to choose different marketing channels in the study area?
(4) What quality control measures are applied by actor in the chain?

MATERIALS AND METHODS

Description of the study areas

The study was conducted in Ada'a district located at 38 km South East of Addis Ababa, the capital city of Ethiopia at 8°44N and 39°2E, and an altitude of 1880 m above sea level. The area receive a mean annually rain fall of 865 mm with mean minimum and maximum annual temperature of 15 and 28°C, respectively. This district covers an area of 1750 km^2, stretching East of the Bole international airport to the North of the Koka dam. The population in Adama, Addis Ababa, Mojo and Bushoftu create a large market opportunities for most dairy products produced in this district . Simple random sampling methods was employed to select a total of 100 smallholder dairy from urban and rural areas to generate the required information. Then 50 smallholder dairy farmers both from urban and rural areas were purposively selected. Finally 25 members and 25 non-members of dairy cooperative were again purposively selected to collect the required information through semi structure questionnaire survey.

Method of data collection

Semi-structured questionnaire survey (with check lists) is/are the main tool(s) of data collection to extract the required information both from urban and rural in the study areas. Value chain mapping of was implemented to show both qualitative and quantitative data collected during the field study period.

Method of data analysis

To process and analysis the collected data, value chain mapping and Statistical Package for Social Sciences (SPSS) statistical software of 19 version was used. Data collected through semi-structured questionnaire survey was processed by using SPSS statistical software version of 19.Chi-Square tests and descriptive statistics were used to analysis the survey data collected from smallholder dairy farmers through semi- structured questionnaire survey in the study areas.

RESULTS AND DISCUSSION

Different actors involved in milk value chain were interviewed to illustrate their position and roles in milk value chain in the study area. Smallholder dairy farmers live in urban and rural areas were interviewed during the field study time and its results were summarized and presented in the Figure 1.

Demographic characteristics of dairy producers

Demographic characteristics of dairy producers interviewed with semi-structured questionnaire survey during the field study period are presented in the following sections.

Age

Dairy farmers live in Urban area had an average age of 43 while rural dairy farmers who do not involved in formal

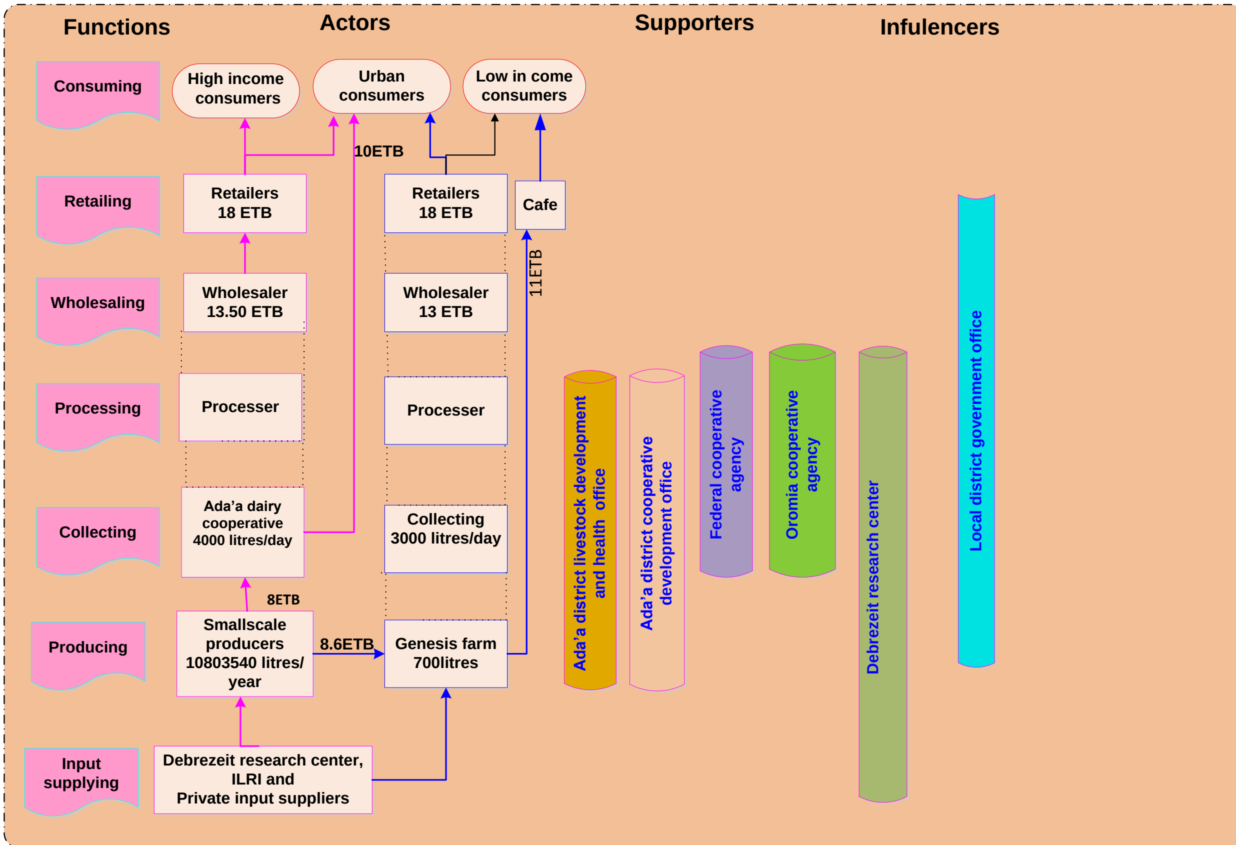

Figure 1. Milk chain map of the study areas.

milk marketing channel had 41 years old.

Religion

Due to long fasting period of Ethiopia Orthodox religion church, most of the consumers in the study area do not consume animal origin during this time. The survey result revealed that Orthodox religion is the most dominate type of religion in the study area and has great influence on milk marketing system in the study area.

Sex

Out of the total respondents about 58% of the interviewed small scale dairy farmers involved in formal milk value chain are male whereas 42% involved in informal milk marketing channel are female.

Educational background

Out of the total interviewed about 64 and 20% of the respondent farmers have reached primary and secondary education, respectively whereas about 14% of the respondents have never been in school. The survey results showed that 6% of the interviewed farmers who have not been in school did not deliver their milk to the dairy cooperative and they sell their raw milk to private milk collectors and direct to local consumers. Only 10% of the interviewed farmers who live in urban and rural area and who completed secondary school level have delivered their milk to dairy cooperative. From the total interviewed farmers both in rural and urban areas, about 35% of the respondents dairy farmers have reached primary education level and sell their milk to directly to the local consumers and private milk collectors.

Quantity of milk produced, consumed and sold by smallholder farmers

The interviewed made with small scale dairy farmers indicated that milk yield is highest during the first five months of lactation and declines then up to the end of the lactation period. However its production depends on the month of calving and availability of feed during the summer season of the year when there is an excess amount of animal feeds. Milk production is high during

May to September since feed supply is adequate. The mean milk yield produced per day by smallholder farmers during the rainy season was 24 l, of which 10.41 and 89.59% was home consumed and sold respectively while during the dry season of the year the mean milk yield in the study area was 21 l, of which 7.6 and 92.4% was home consumed and sold, respectively. Milk sold during dry season is relatively higher than milk sold during summer season because of high demand of milk during dry season than rainy season.

On average 75% of the interviewed small scale dairy farmers in the study area had 3 milking cows. Out of the total 50% of the interviewed farmers in the urban area were produced 10.5 l of milk per day per cow from cross breed cow. On the other hand, smallholder dairy farmers live in the rural area only produce 2.6 l of milk per day per cow from local cow. Because of this, most of the interviewed farmers in the rural area do not want to have local cows. Most of the interviewed small scale farmers in study area indicated that, the average laction length of cross breed and local cow were 240 and 255 days, respectively.

Approximately 10, 803,540 volume of milk is produced per year in this district's. In the study area, most of smallholder farmers in urban area use zero grazing to feed their cows. The interviewed made with rural dairy farmers indicated that large portion of milk produced in this area was directly sold to local consumers where the producers can earn high price per litre of milk. About 63% of the interviewed farmers in the study district reported that the trend of their milk production was decreased because of the herd size is reduced as a result of shortage of animal feeds. Out of the total interviewed farmers 61% of the respondents farmers indicated that their average herd size decreased as compare to the previous year. Out of the total interviewed, 68% of the respondents indicated that dairy derived income was decreased due to reduction in volume of milk produced as a result of limited number of herd size and shortage of availability of animal feeds.

Utilization of milk

In the study, district the interviewed farmers indicate that milk produced in rural area under go different process after the milk was produced. The dairy farmers 'also used the milk produced for different purposes. Some farmers directly sell their milk to the neighbouring consumers without processing of the milk whereas other farmers locally process their milk into different products such as butter and cheese to sell to local market.

Dairy activities and source of animals feeds

Dairy activities

The survey result revealed that about 67% of the resopndents in the study district were used family labour for dairy production and dairy related activities. Whereas only 33% of the intereviewed farmers were used hired labour for their dairy business. Out of the total interviewed farmers 55 and 12% of respondents live in rural and urban area used family labour to carry out their dairy activities respectively. But only 27 and 6% of the respondends found in urban and rural area did not use family labour for dairy production.

Source of animals feeds

The survey result revealed that all of the interviewed dairy farmers live in urban area do not have any grazing land where as smallholder dairy farmers found in rural area have on average 1.3 ha of crop land and they use crop residues for feeding of milking cow especially during the dry season of the year at critical shortage of animal feeds (Figure 2).

The survey result indicated that most of the respondants in the study district were used purchased feeds such as nough cake, wheat bran, mixed feeds, grass hay and crop residues for feeding of their animals and they provide on average 2.5 kg of concentrate feeds per day per milking cow. However, if they want to get high volume of milk from their cow they slightly increase the amount of cencentrate given for their cow.

Factors and actors affecting milk value chain in the study area

During the field study period there is reduction in volme of milk produced by smallholder farmers due to low availability of animals feeds, high cost of animal feeds,high barging power of private milk collectors, weak relationship of dairy cooperative and its members were identified as the major factors and actors affecting milk value chain in the study areas. Some of the major problems/constraints that faced different actors involved in milk value chain of the study area were assessed and it resuluts was summaried in Figure 3.

Actors' shares in formal and informal milk value chain

Based on the collected information during the filed study period the value share of each actors involved in formal and informal milk value chain of the study area were calculated and shown in Figure 4.

DISCUSSION

Inputs providers

During the field study period some of the governmental

Figure 2. Indicate marketing of crop residues for animal feeds.

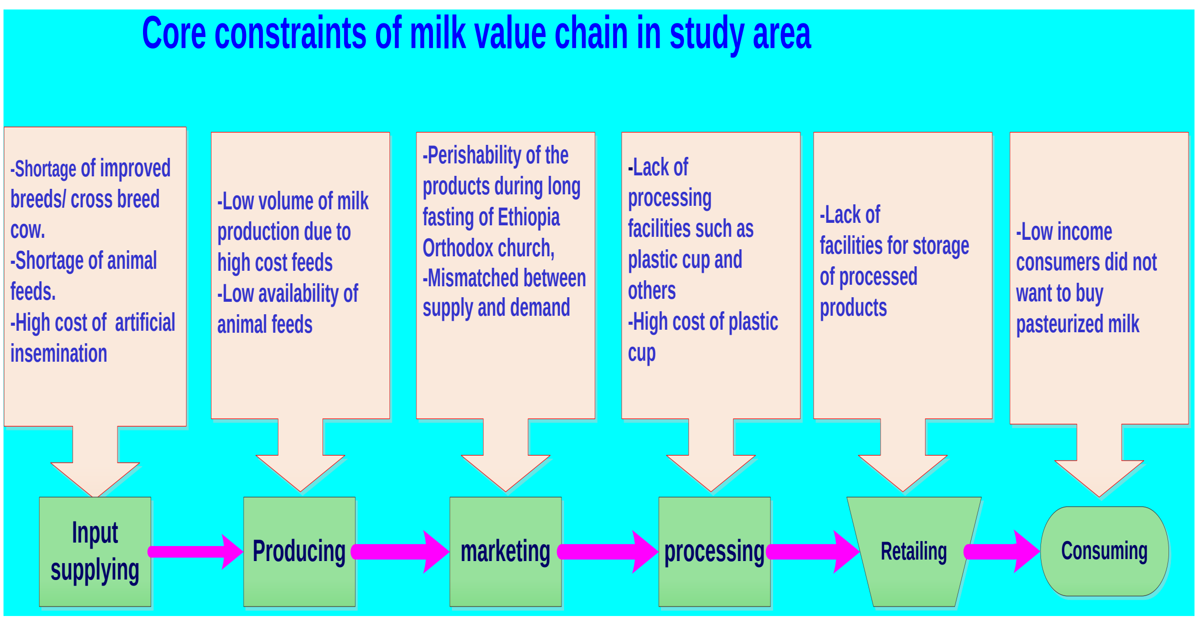

Figure 3. Factors affecting milk value chain in the study areas.

and non-governmental organization involved in provision of AI service, veterinary service, improved forage varieties and value addition technologies were identified. Among these actors Debrezeit agricultural research center, Addis Ababa university faculty of Veterinary medicine, National artificial insemination center, Ada'a dairy cooperative and private sectors are some of the major actors who closely support smallholder dairy farmers in provision of different inputs to improve production and productivity of livestock in the study area.

This field study result and the finding of Anteneh (2008) have similarity who reported that governmental organiaztion and private sector play a vital role in provision of different inputs. Anteneh (2008) also categorized the service delivery system of the study area into four main types such as animal feed suppliers, animal health providers, AI and improved bull service providers and financial service providers.

Non-governmental organizations also provided improved forage and pasture seeds, trainings and

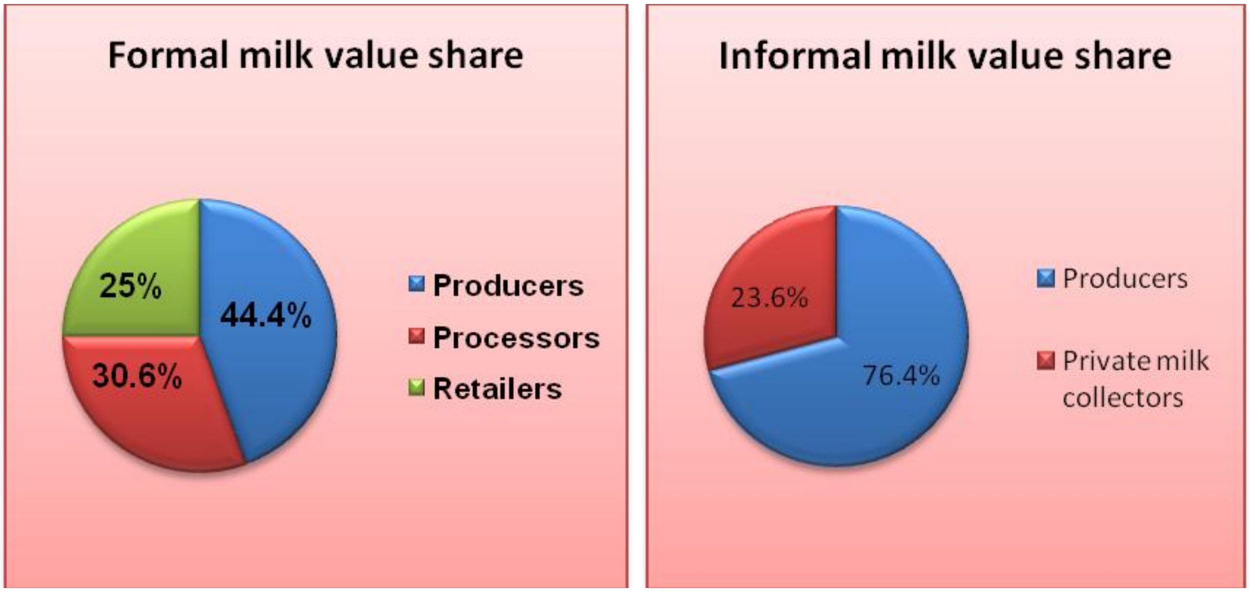

Figure 4. Indicate formal and Informal milk value shares.

demonstrate dairy technologies for the target farmers in the study area. However there is limited capacity of value chain actors in supplying inputs and there is high demand for cross breed dairy cow and other inputs from regional government. Some farmers indicated that AI service provided by private sector is very expensive (50 to 70ETB per cow) as compare to AI service provided by Ada'a dairy cooperative which cost 30ETB per cow. SNV(2006) reported that the cost of bull service is 15 ETB and the cost of AI service is 12ETB. This variation in cost of AI service is because of the cost of crossed breed heifer/cow is very expensive now a day. Hence farmer prefer to have crossbreed heifer by inseminating his loca cow with exotic semen rather than buying cross breed heifer with high cost.

Milk production

Most of the interviewed small scale dairy producers in the study area produce on average 10.5 and 2.6 l of milk/ day/ cow from crossbreed and local cow, respectively. This finding is aligned with the finding of Anteneh (2008) who reported that average milk yield per cow per day from cross breed and local cow were 9.63 and 2.10 L, respectively. This variation in the average milk yield per cow between cross breed and local cow is attributed due to the difference in breed, management and feed systems. On average, farmers in the study area produces 2520 and 535.5 L of milk per cow per year from cross breed and local cow, respectively. The current average milk produced from local breed cow is comparable with the study conducted by Alemu et al. (2000) who report that the milk yield of local cow was 400-680 kg of milk per cow per lactation period. Holloway et al. (2000) reported that cross breed cow produced 1120-2500 L over a 279 day lactation period.

The survey result revealed that average lactaion length of cross breed and local cows in the study area was found to be 240 and 255 days, respectively. This is because of the fact that some of dairy farmers reported that they have milked their cow even during the whole pregancy period. This finding have similarity with the finding Solomon (2008) who reported that the average lactation lengeth of cross breed daiy cow is 249.9 days. According to Holloway et al. (2002) the average lactation length of cross bred was 279 days. This difference in lactaion lengeth of cross breed dairy cow is because of the effect of the availability of animal feeds during rainy and dry season which prolonged or shorted the heat period. Smallscale dairy farmers in the study area have 3 crossbreed and 1 to 2 local milking cows and they produced 23.95 and 21 L of milk per day during rainy and dry season, respectively.

Milk marketing channels

Out of the total interviewed smallholder dairy farmers, 59% of the respondents sold their raw milk through informal milk marketing channels. Whereas 41% of the respondents farmers were sold their milk through formal channels. There are many milk marketing channels through which smallholder dairy farmers sell their dairy products. However, most of the dairy farmers in the study area preferred to sell their milk through informal chain where they get high price per litre of milk. This finding have similarity with the finding of Van der Valk and

Tessema (2010) who reported that 98% of milk produced in rural area were sold through informal chain whereas only 2% of the milk produced reached the final consumers through formal chain.

The proportion of total production being marketed through the formal markets still remains small. Formal markets are particularly limited to peri-urban areas and to Addis Ababa. Van der Valk and Tessema (2010) reported that informal milk marketing channel is characherized by no licensing requirement to operate, low cost of operations, high producer price compared to formal milk marketing channel and no regulation of operations. Because of this, most of smallholder farmers in study area want to sell their dairy products where they get high price.This system of milk marketing channel still remained dominant in the study area.

The interviewed made with the General manager of Ada'a dairy cooperative indicated that Ada'a cooperative flow both formal and informal milk marketing channels to sell their raw milk and processed dairy products. On average, this organization sell 134 L of raw milk per day to low income urban consumers at each milk collection centres soon after collection of milk. The reason why this cooperative is involved in direct selling of raw milk to low income urban consumer is the high demand of milk in the study area. In this area, supply is very far below demand as a result of this, the dairy cooperative sell one litre of milk by 10 ETB to low income urban consumers. Some time when the demand is very high during dry season and before long fasting of Ethiopia Orthodox church, the dairy cooperative sell one litre of milk by 12 ETB. However, during long fasting period of Ethiopian Orthodox church almost for about two month started from mid-February to mid-April most of the people in the study district abstain eating of animal origin. During this time the demand of milk and milk product is very low and the cooperative and dairy farmers in the study area faced big challenge to sell their dairy products.

Van der Valk and Tessema (2010) indicate that the calendar of orthodox Christian church involves three prolong fasting period per year (before Easter, in August, in December) and two fasting period every two weeks (Wednesday and Friday) for a total of more than 200 days per year. During fasting period, most Orthodox Christians abstain from consuming products of animal origin. The survey result showed that about 57.5% of the interviewed farmers are Orthodox religion follower and they do not consume animal origin during this time. The study conducted by SNV (2006) also indicated that orthodox Christian comprises about 60% of population of the study areas. This indicates that many people of Ethiopia are Orthodox religion believers and they have great role in milk marketing during the long fasting period.

There is also mismatching in the supply and demand of dairy products during long fasting and after fasting period. After fasting most of the members of the dairy cooperative start to sell their milk to private milk collectors and directly to local consumers. As a result of this, Ada'a dairy cooperative did not get enough amount of milk. But during the long fasting period all the members of the dairy cooperative return back to the dairy cooperative to sell their raw milk. Even though the dairy cooperative decrease the purchasing price of milk, the members accept what the cooperative paid for them due to they do not have any option. There is price difference during long fasting period and after long fasting periods. During long fasting period Ada'a dairy cooperative purchase one litre of milk by 7.25 ETB from its members and other private milk collectors did not change the purchasing price of milk from the farmers.

Reduction in volume of milk production

Out of the total interviewed farmers, 62.5% of the respondents indicated that the trend of their milk production decreased. Especially, respondents in the rural area mentioned that there is a shrinkage of grazing land in the study area because an expansion of cereal production due to an ever increasing of human population. As a result of shrinkage of grazing land, some of the interviewed farmers reduced their herd size and has changed large number of local cow to few number of crossbreed cows due to the problem of animal feeds. From the field study result, it was observed that 55% of the respondents were mentioned as the trend of their herd size is steadily decreased as compare to the previous year. This reduction in herd size in the study district lead to an overall reduction in volume milk produced in the study areas. As a result of reduction in volume milk produced by small scale dairy farmers, the members could not deliver the same volume of milk as they have been delivered. On top of this, availability of the required amount of feeds also create a big problem to produce and deliver the volume of milk needed by the processing plant.

Production cost

From the total interviewed farmers, 67.5% of the respondents farmers rank high cost of animal feeds as the main problem of milk production in the study area. UNIDO (2009) reported that due to severe shortages of animal feed supplies, the cost of running a dairy farm is becoming more expensive. He also indicate that ever increasing cost of feed was the primary reason that one of company assessed closed its dairy farm and continuning processing by outsourcing the milk. Similarly, some small holders in regional towns also closed their farms because of the scarcity of feed supply or excessive cost of feed. Similar to this finding, SNV(2006) reported that in cmmercial dairy production system, feed costs constitute 74% of the total on farm production costs while labour cost accounts for only 6% of farm costs.

SNV(2006) also stated that Ethiopia has high cost of production because of about 70% of the farmers produce less than half of their fodder requriment and rely on bought commericial cut and carry fodder, brewer's waste and oilseed cakes.

The current field study also indicated on average smallholder dairy farmers in urban area cost 29 ETB to feed one milking cow per day to produce 10.5 L of milk per day per cow from crossbreed cow. Most of the interviewed farmers indicated that the cost of animal feeds increase from time to time but the price of milk is very cheap as compare to the cost of animal feeds. The study district is well known by cereal production especially white teff and other cereal crops. As a result of this there is no free grazing land, this make the price of animal feed very high relative to other places. There is a big problem in availability of animal feeds both in quantity and in quality which affect the volume of milk produced by the farmers consequently which influence the volume of milk collected by the Ada'a dairy cooperative. Out of the total interviewed farmers, 87.5% of the interviewed farmers indicate that the trend of availability of animal feeds is decreased. Not only cost of animal feeds but also the availability of animal feed is also very challenge for small-scale dairy farmers to feed their animals. This is because of an ever increase of human population which leads to expansion of cropping land and construction house for human dwelling. This leads to shrinkage of grazing land which is consequently affects milk production.

Conclusion

From the field study conducted, it was conculded that many factors affect milk value chain value of the study area. Among these factors, shortage of animal feeds which leads to reduction of volume of milk produced by small holder dairy farmers is identifed as one of the major factors which affect milk value chain of the study area. High cost of inputs especially feed cost negatively affects expansion of dairy farming activities as rural farmers do not use concetrate feeds to improve their milk production. This conesuqently affects overall reduction of volume of milk produced by smallholder dairy farmers to deliver enough volume of milk to milk processing companies and to local market. Trader play a vital role to expoilt smallholder dairy farmer's share of milk value by provided low price per liter of milk as compare to private milk processing comapany. In addition to this long fasting period of Ethiopian Orthodox religion church create a problem on milk marketing of smallholder dairy farmers during this time bacuase majority of Orthodox believers abstain from eating of animal origin food.

RECOMMENDATION

(1) To strengthen the position of smallholder dairy farmers in milk value chain adequate inputs should be provided for small holder dairy farmers in the study areas.
(2) Members must be delivered all volume of milk they produced to dairy cooperative in order to get equal economic benefit from the organization.
(3) For better marketing of milk and milk products, dairy farmers should be organized into dairy cooperative to sell huge volume of milk to dairy processing company/ plant in order to earn high price from their dairy products.

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Full Length Research Paper

Supermarket chains and small farmers in Africa: A new look from the perspective of New Institutional Economics

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Supermarket chains have expanded and internationalized to become large buyers and distributors in the global agri-food sector. Meanwhile, in Eastern and Southern Africa which is the focus area of this study, collecting data on rural poverty related to small farmers remains daunting. This study investigates the differences between large and small farmers, the transaction costs involved in supplying agricultural products to supermarket chains in Africa and the opportunities and challenges that small farmers face in accessing this market. This study begins with a qualitative exploratory survey and employs a theoretical review of the topic that is informed by New Institutional Economics and Transaction Costs Economic Theory. The study concludes that there are more reasons to believe in the opportunities than in the limitations for small farmers in accessing markets nurtured by supermarket chains after accounting for transaction costs and the organizational challenges involved.

Key words: Supermarket chains, small farmers; transaction costs.

INTRODUCTION

The global agri-food industry is subject to constant change that is related to new patterns of consumption and new forms of production and processing. These forms involve restructuring new supply channels to meet new sources of demand, which includes guaranteeing the safety and quality of food as an increasingly universal commitment. Thus, the world has witnessed the continuing transformation of the agri-food industry with the rise of supermarket chains, which have moved toward consolidation and transnationalization and are responsible for large areas of food distribution on many continents; simultaneously, the agri-food wholesale sector is internationalizing and moving toward increasingly specialized supply patters (Reardon et al., 2009).

This is the reality of Eastern and Southern Africa; since the late 1990s, the number of supermarkets has increased and feature more efficient management systems that benefit from economies of scale and sell food to the population at a relatively low price (D’haese and Huylenbroeck, 2005; Timmer, 2009).

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Driven by the growth in consumption and consumer demand for safe, uniform and high-quality products, the increase in the number of supermarkets has occurred throughout all of Africa; in particular, South Africa has experienced the greatest expansion, and supermarkets have expanded into small cities and poorer areas, which represent between 50% and 60% of the estimated retail market for food (D'haese and Huylenbroeck, 2005).

These supermarket chains have shown their economic strength and their business preparation by seamlessly integrating their organizations into the liberalized economy to maintain their competitiveness, whether by exploiting previously existing domains or through mergers and acquisitions to keep pace with the international expansion of the sector. The agri-food market has proven to be rapidly moving and dynamic. For example, the industry has initiated new evolutionary trends of exporting out-of-season fruit; thus, vegetables from Zambia, a southern African country, are exported almost exclusively to the United Kingdom (Dehnen-Schmutz et al., 2010).

A rapid dissemination of private policies about food safety has accompanied the rise of supermarket chains, which has delimited the industrial transformation in the agri-food network. This process has shown that public policies are not necessarily the fastest or most effective way of bringing about changes in food marketing (Timmer, 2009). Supermarket chains have thus created distinctive standards that involve environmental, social and economic responsibilities associated with strategies of profit maximization (Schwartz and Lyson, 2007; Konefal et al., 2005).

While these changes are occurring, Eastern and Southern Africa are still considered to have the highest concentration of poverty in the world, according to the International Fund for Agricultural Development (IFAD), specifically in the Rural Poverty Report 2011. According to the IFAD, the biggest concern for the near future is to overcome generalized food insecurity and the persistence of poverty in rural sub-Saharan Africa and in South Asia, in addition to locations on other continents.

Worldwide, approximately 450 million small farmers live on an average of two hectares of land; however, in Southern Africa alone, there are three million small farmers, many of them living in common areas that together represent approximately 13% of the agricultural land in the region (IFAD, 2011). Concomitantly, the price of food staples have been increasingly volatile with lingering uncertainties for low-income consumers; these uncertainties are in addition to the effects of climate change and the limitations of the region's natural resources and jeopardize efforts to reduce rural poverty.

One way to overcome some of the problems that occur in Africa may be related to the profitable production of fruit and vegetables that are in high demand by supermarket chains and in the traditional market. Such production might make it possible to increase the commercialization of the rural sector because the value of all fruit and vegetables sold on the global market is more than double the value of all cereal products sold (Weinberger and Lumpkin, 2007).

Thus, following Weinberger and Lumpkin (2007), although it is necessary to consider that small farmers and supermarket chains occupy the opposite extremes of the agri-food productive chain-and that small farmers experience great difficulties in producing and delivering products in accordance with the private standards established by these corporations-the question must be posed: What are the main differences related to the costs of transactions between large-scale agriculture and small farmers with respect to supplying supermarket chains? Additionally, what are the opportunities and challenges for small African farmers to access these growing supermarket chain markets?

METHODS

To answer these questions, this study begins with descriptive research on the expansion of supermarket chains and the conditions of small farmers in Africa; it focuses mostly on Eastern and Southern Africa and the issues associated with horticulture. The aim of this article is to understand the differences in the costs of transactions between large and small farmers as suppliers to supermarket chains and the opportunities and challenges of small farmers in accessing this growing market.

This topic is discussed in light of Transaction Cost Economics Theory (TCE), which is one of the axes of investigation of New Institutional Economics (NIE). Therefore, this study conducts a theoretical review with respect to this axis of investigation and later presents the results, which are then discussed and analyzed in accordance with data from the current literature on the subject and the theory proposed. This research relies on a theoretical referential searched from major databases and journals addressing this topic and secondary data accessed in the portals and reports from the Department of Agriculture, Forestry and Fisheries (DAFF) of South Africa, from the International Fund for Agricultural Development (IFAD), from the Organization of the United Nations (ONU), of the World Trade Organization (OMC), and from the United Nations Food and Agriculture Organization (FAO, 2010).

Theoretical review

Transaction cost economics and associated concepts

Until the middle of the 20th century, neoclassical economic theory considered a firm only as an agent of profit maximization and greater possible surplus, which underestimated the role and importance of various institutions that are capable of regulating the economic environment and therefore intervening in markets. The term "New Institutional Economics" that was coined by Williamson in 1985, recognizes in its initial approach that the market itself is an institution with complex rules, and the people who interact in this environment come to rely less on cognition and more on customs, norms, and language-with the latter also considered an institution (Hodgson, 2009).

The analysis involving the concepts related to transaction costs has different approaches and fundamentals, and Table 1 seeks to contextualize the main contributions of the theory and the respective authors that are most relevant to the analysis of TCE. Initially, Coase (1937) indicated that transaction costs are related to

Table 1. Authors and relevant conceptual bases of TCE.

Author	Conceptual basis
Coase (1937)	Transaction costs are the costs of performing a transaction by means of an exchange in the market.
Coase (1991)	Transaction costs are the costs of seeking information, negotiating and establishing contracts.
Arrow (1969)	Transaction costs are the costs of administrating the economic system and maintaining its operations.
Williamson (1985)	Transaction costs are different when they are *ex-ante* and *ex-post*. *Ex-ante* transaction costs describe relational costs, negotiation costs and the costs of safeguards established in contracts. *Ex-post* transaction costs are related to adjustments made to poorly functioning transactions or deals.
North (1994)	Transaction costs are costs that are subject to a set of operations involved in an economic system.
Hodgson (2002)	TCE is an exercise of comparative institutional analysis.

Source: Elaborated by the authors (2012).

market costs. Later, he associated transaction costs with the results of obtaining information related to market operations and the negotiation and establishment of contracts (Coase, 1991). Transaction costs are also understood as the costs associated with the administration and functioning of the economic system (Arrow, 1969). For Williamson (1985), this concept was interdisciplinary in nature and integrated law, economic principles and organizations under a microanalytical focus for the study of economic organizations.

Williamson (1985) didactically subdivided transaction costs into *ex-ante* and *ex-post* costs. *Ex-ante* costs describe the relational and negotiation costs and safeguards created through formal or informal contracts, such as the costs of formalizing transactions, locations of clients and suppliers, the costs to arrive at deals, and/or of instruction related to producing deals. *Ex-post* costs are costs related to adjustments made to transaction agreements and involve the costs of negotiation that are incurred when there are efforts to correct settlements, such as costs associated with establishing and maintaining governance structures and costs to maintain commitments established formally or informally.

These transactions present three fundamental characteristics, namely asset specificity, frequency, and uncertainty (Williamson, 1985). The specificity of assets matters most when it relates to specialized assets, whose costs in terms of productive value may change when they must be re-employed, such as in the interruption of a particular supply contract. For Williamson (1985), the frequency of transactions indicates the regularity of operations that influence the contractual relationship. Thus, according to Williamson, when transactions occur at a certain frequency, the emergence of opportunistic behavior is less common, and more robust institutions must be developed. Alternatively, the risk of opportunism increases when a specific interaction occurs only once. Finally, the uncertainty of transactions is related to a higher or lower level of trust in the agents and their ability to anticipate future events, considering that the higher that the cost of uncertainty is, the higher the cost of the transaction.

Corroborating this analysis, TCE for Hodgson (2002) is an exercise of comparative institutional analysis in which institutional environments comprehend the institutions of governance as the contracts between companies, corporations, departments, and nonprofit organizations; thus, institutions eventually emerge to regulate individual behavior.

Related to the foregoing subject, which involves supermarket chains and farmers comprehending the conditions of order and disorder to understand the changing economic processes that occur in the market, this study focuses on the agri-food sector and the policies, competitiveness and efficiencies involved therein. Order is achieved when uncertainties are reduced because institutions offer greater predictability in human interaction; disorder, on the contrary, produces unstable political and economical relationships in relation to markets, in addition to increasing uncertainties (North, 2005). Therefore, network organization claims to be superior to integration by the market to the extent that it reduces transaction costs, and it claims to be superior to integration by hierarchy once it is free from (dis)economies of scale, which is typical of large organizations (Ebers, 1999).

However, TCE promotes study and understanding in the framework of organizational decisions, such as vertical integration, purchases instead of internal production, entry into international markets, and the strategies used in managing distribution channels. This is justified by the wide use of the concepts developed by NIE in general, and TCE in particular, both “intra” and “inter” organizationally (Williamson, 1985).

TCE aims to understand how organizations protect themselves from the uncertainties and risks inherent in trade relationships in market transactions. Supported by such assumptions, organizations seek to create hiring and governance structures with this purpose and that result in the reduction of “limited rationality,”[1] while defending transactions from the dangers of opportunism (Williamson, 1985).

In addition to limited rationality, opportunism is also an assumption of behavioral change and arises from the possibility of the absence of cooperation in a particular game (market) and might be the result of information asymmetry in the environment (Williamson, 1985). This behavior distances itself from the ethical

[1] Limited rationality observes that decision makers frequently decide based upon an asymmetry of information or incomplete information and do not perceive the different factors that influence the nature of the problem and its possible solutions (SIMON, 1970).

principles expected in a formal or even informal contractual relationship.

The counterpoint of opportunism, trust, may be understood as the expectation of behavior that serves as a basis upon which to establish reliable relationships between people and organizations (Hardin, 2001). Trust boosts economic exchanges and the governance of transactions and continues to be considered as a belief in the credibility of a person or system without having to surrender to the power of another (Arrow, 1974; Giddens, 1991; Luhmann, 1988). Trust eases work relationships and economic exchanges, helps activities flow better, and ensures that goals are achieved faster and with lower costs, which enables more effective management of individuals and organizations (Williamson, 1985).

RESULTS

Supermarket chains in the new economic context

The expansion of international trade in the agri-food sector represents a transformation of the industrial standard. Liberalization in the food processing and retail sectors encourage large and competitive investments, which has been called a revolution of supermarkets by Reardon et al. (2009). These new paradigms are marked by the consolidation and transnationalization of the retail market by means of the specialization and differentiation of wholesale markets; they are also distinguished by the organizational and institutional changes symbolized by increased vertical coordination and the use of private standards for food production (Reardon et al, 2009). It is important to note, however, that these changes are generally considered positive regarding market demand and are caused by both the urbanization and the liberalization of trade (Timmer, 2009).

The accelerated growth of the supermarket sector, which involves Africa and many other continents, includes the emergence of an international market of horticulture in addition to the traditional trade in fruit, vegetables, cereals and animal and vegetable products which has been increasingly fast and dynamic; for example, fruit and vegetables produced out of season in Zambia are exported almost exclusively to supermarkets in the United Kingdom, and European consumers have regular access to green beans from Kenya (Dehnen-Schmutz et al., 2010; Timmer, 2009). These structural changes in international horticulture have taken into account aspects of production, healthcare of workers and the safety of the food produced, which has led to a distance between traditional wholesalers and a concentration of retail routes (dehnen-schmutz et al., 2010).

Thus, purchasing power in the agri-food sector is increasingly concentrated in the hands of a few. Supermarkets have plied a supremacy and governance in supermarket chains, adopting the so-called “private standards” of highly strict requirements for the quality of assets produced by farmers, such as consistency and supply opportunity (Hazell and Poulton, 2010). These standards may also condition supply on the traceability of the source and on the conditions under which the products were produced, such as the application of pesticides, organic farming, the use of child labor, and animal welfare. These requirements generate credibility in consumption, but are conditions that impair the production of small farmers and increase transaction costs because there are audits and certification costs whose impact is smaller for production in the scale economy (Hazell and Poulton, 2010). Undeniably, however, supermarkets are increasing the means by which to bring diversity to consumers who are clearly supporting this trend with their purchasing power (Timmer, 2009).

Private voluntary standards: challenging requirements

Private voluntary standards consist of sets of rules elaborated by the private sector that are steadily becoming more common around the world and are associated with consumption and marketing strategies that have implications for market access by farmers in exporting countries. Debated by the United Nations (UN) in terms of trade and development, voluntary standards translate into a de facto power in the market given to companies and networks on a global scale, such as in the case of the supermarket chains listed in Table 2. These standards, once required, are incorporated into the supply chains of the agri-food sector and combine food safety and environmental health, worker health and many other safety requirements (ONU, 2010).

These standards imply costs for suppliers and, according to Timmer (2009), may take effect with greater speed and rigor than public standards and cause changes in the patterns of food trade. In the meantime, they provide benefits by reducing environmental impacts, by considering the health of the producers and by conserving materials; after all, one reason for this trend is to conciliate food safety purposes with environmentally sustainable methods of production. To access these sophisticated supply chains and maintain their livelihoods within them, farmers must comply with these standards, which increase in strictness in international markets (Markelova and Mwangi, 2010).

Private standards are established by representative codes in the international food market and are divided into specific and collective norms. Some collective norms guide agricultural production (inside the gate), generally have more localized or regionalized coverage and are used by more than one company, such as the EuropeGAP and the Freshcare Code of Practice.

Nevertheless, there are other standards set for food

Table 2. Companies, types of assets and specificities.

Company/Norm	Type of asset	Specificities required in the agricultural production of assets
Tesco (Nature's Choice)	Fruit, vegetables and salads.	Rational use of agricultural inputs such as fertilizers and plant protection products; Prevention of pollution; Conservation of fauna and landscape; Recycling, reuse and energy conservation; Protection of human health.
Marks and Spencer (Fieldto - Fork)	Fruit, vegetables and salads.	Reduction in pesticide levels; Obtaining raw materials from sustainable sources.
Auchan (Filière Agriculture Raisonnée)	Coffee, cereals and dried fruit.	Ecological production (cooperation agreement with Ecocert); Respect for the environment; Animal welfare; Elimination of packaging or creation of recyclable packaging.
Carrefour (Filière Qualité)	Meat, eggs, and fruit, (e.g., free-range chicken).	Production of safe and healthy food with authentic flavor; Environmentally correct production; Socially correct production.

Source: Elaborated with data from the OMC (2010).

processing (outside the gate), such as the BRC Global Standard, the Dutch HACCP, the International Food Standard and the GlobalGAP, which may serve the interests and international scope of transnational and multinational companies (ONU, 2010).

Specific standards are the individual property of the companies; in this case, supermarket chains guide production with specific requirements for the production of assets at the farm level (inside the gate). Thus, Table 2 presents the main points that comprise the requirements for each type of asset, according to data from the World Trade Organization (OMC, 2010).

Audits and inspection processes with respect to the specificities of the assets consist of analyzing the components of production such as fertilizer, irrigation, crop protection, waste and pollution management, and the health and well-being of workers, among others (OMC, 2010).

When mandatory, the standards can result in implications that are beyond the reach of production on a small scale that might lead to the exclusion of small farmers from global supply chains, which is the main concern of "developing" countries, according to the World Trade Organization, particularly because these countries might benefit from trade for development, as in the case of Africa. Strategies might be adopted such that small exporting farmers in these countries could strengthen their management skills and thereby promote their competitiveness (OMC, 2010).

For Konefal et al. (2005), aided by the set of private standards, chains of transnational supermarkets have increasing control over what food to produce, where, how and by whom it is grown.

Attributes such as quality, safety, working conditions and the environment are used to differentiate the food market to consumers; such attributes work as measures of corporate responsibility and as strategies for profit maximization.

In businesses between Africa and Europe, British supermarkets have adopted a definition of codes and norms of food safety and agricultural practices with a traceability of the production of African suppliers, the requirements for hygiene in agricultural holdings, environmental protection measures and measures protecting the welfare of workers, which gives products elements of quality and ensures a functionalist conception of institutions (Freidberg, 2003).

However, there is a concern that such rules might reproduce and deepen social and ecological inequalities-although they result in improvements in food safety and quality-which might leave small farmers to absorb many of the additional costs of production (Konefal et al., 2005).

Among the examples in which these two effects have occurred include the production and consumption of milk in Brazil, the production of fruit and vegetables in Africa for export to Europe, and the production of fruit and vegetables in Argentina, Brazil, Chile, Costa Rica and Mexico (Konefal et al., 2005).

Small farmers: The situation in Eastern and Southern Africa

The rural areas of the African continent possess one of the highest rates of poverty in the world, according to a report on rural poverty produced by the International Fund for Agricultural Development (IFAD, 2011), a UN-specialized agency. The vast majority of the rural poor in Eastern and Southern Africa are small farmers who work in conditions of static or declining productivity. Although, the rate of extreme poverty in rural areas of sub-Saharan Africa fell from 65 to 62% in the last decade, this rate remains by far the highest on the continent.

In Eastern and Southern Africa, poverty is a predominantly rural phenomenon, and, according to the report, these rural areas continue to be marked by stagnation, low productivity, low income and growing vulnerability. Meanwhile, rural poverty is concentrated in five countries, in particular: Ethiopia, Kenya, Madagascar, Tanzania and Uganda. Thus, there is a need for the UN to work with small-scale farmers to help them in relationships with urban and domestic markets, in addition to large markets.

Most small farmers in the region live and farm on lands that might be much more productive if they were associated with irrigation schemes in potentially lucrative sites, such as the Great Lakes areas of Burundi, Rwanda and Uganda that are predominantly inhabited by small farmers who earn a living without access to new technologies (IFAD, 2011).

IFAD initiatives, in combination with private sector initiatives, seek to support small farmers in accessing these markets in which new systems of commercialization emerge from the private sector. One such project in Zimbabwe has witnessed farmers form an organization to produce fruit and vegetables to supply supermarket chains, in addition to buying production inputs collectively for the group.

With respect to the economic policies and institutions in this region, they have generally failed to help small farmers to bring their agricultural production into the economic reality of the world market. Such a task requires public investment to support agricultural growth, to ensure production safety with respect to the negative effects of climate change, and financing for the agricultural sector, which are all crucial to guarantee continuous production and which has so far been insignificant (IFAD, 2011).

Promising new opportunities have emerged for small farmers mostly because it will be necessary to increase global productivity to ensure enough food for an increasingly urban population that is estimated to reach 9 billion by 2050 (IFAD, 2011). IFAD has indicated that it will be necessary to establish sustainable approaches that are focused on the market, in addition to providing investment for small farming organizations and for small farms.

According to data from DAFF (2010), the gross income of farmers fell 0.4% in the period between 2008/2009 to 2009/2010 because of lower income from major field crops (-18.0%) such as corn, soybeans, coffee, and beans, among others, and increased income from horticultural products (6.6%) and products of animal origin (5.6%). Thus, the generally low income obtained over the period may be attributed primarily to prices of major crops. There was a reduction of 1.9% in the prices of agricultural products compared with an increase of 9.6% in the prices paid for production inputs over the same period, which resulted in a 10.9% reduction in terms of national trade.

However, according to Daff (2010), gross agricultural income from large-scale agriculture in South Africa can be broken down as follows: 31% of the income comes from horticulture, 35% from animal production, 21% from agricultural crops (cereals and oilseeds), 12% from products of animal origin and 1% from other products. Thus, the strong participation and presence of large vegetable producers directed toward supermarket chains for domestic supply can be understood, and much of this production is destined for export.

DISCUSSION

This section presents a discussion of the issues, first following the logic of an approach based on transaction costs and subsequently analyzing the opportunities and challenges faced by African small farmers in accessing markets.

The transaction costs involved and the institutionalized market

Initially, the data presented indicate that private standards in the agri-food sector have been expanding across the African continent, except in Eastern and Southern Africa. At the global level, they cause changes in the ‘order and conditions of the game’ in the market among suppliers and supermarket chains. Thus, the transaction costs that occur as a result of changing distribution channels are transferred to individual farmers; as Timmer (2009) indicates, these costs are generally ‘pushed out of the system’, which North (2005) explains as a way to reduce market uncertainty. Therefore, the order stipulated by supermarket chains (through private standards) is embodied in strategic decisions that allow a greater degree of trust in agents and extends from suppliers to final consumers (Williamson, 1985).

It is possible to consider that private standards are the ‘new order’ in this market and the ‘conditions of the game’ are set by the specificities of the assets produced, requiring from suppliers what Coase (1937) stipulated as the ‘condition of exchange in the market’. Thus, recognition of concept of the market as an institution from

Williamson (1985) is essential because both the private standards and the rise of supermarket chains-and consumers who are attached to the process of certification that is generated by the standards-are institutionalized processes.

However, while supermarket chains are expanding as transnational, multinational and increasingly consolidated with the adhesion of consumers, they may represent risks to small farmers due to the high transaction costs involved in the structural change that has been initiated by such market activities (Reardon et al., 2009; Dehnen-Schmutz et al., 2010; Timmer, 2009; Hazell and Poulton, 2010). After all, in Timmer's (2009) view of the retailer network, it is more expensive to work with a large number of small farmers than to have business dealings with a few large suppliers. This condition corroborates the view of Ebers (1999) that the organization in a network claims to be superior to market integration because it allows market costs to be reduced, and it is superior to integration by hierarchy once it is free from the (dis)economies of scale, which is typical of large organizations. This vision reflects the principles adopted by supermarkets when their organization is structured in chains (or networks) and in the choice of their partners.

It is possible to maintain that the main transaction cost in the relationship under study is caused by the specificities of the assets, as Table 2 shows; in this table, each supermarket chain represented (Tesco, Marks and Spencer; Auchan and Carrefour) has a set of specificities that are required for the production of assets, which makes access to these markets restricted to those minimum conditions of production, or to 'conditions of the game'. In this way, it is logical to think that every company features its conditions according to the strategy of quality and the commitment to responsibility that they have with their suppliers (upstream) and with consumers (downstream).

For this reason, Williamson (1985) identifies the three fundamental characteristics of the economy of transaction costs as the specificities of assets, their frequency and their uncertainty. For purposes of this study, the first characteristic conditions the others. Therefore, the frequency (regularity) and/or uncertainty of the transactions among small farmers and supermarkets depend on the behaviors that small farmers adopt toward the specialized assets. Thus, these three characteristics are of fundamental importance from the point of view of continuity by the supermarket chain.

Therefore, it is reasonable that scale producers accumulate greater advantages over transaction costs compared with small farmers (individualized). In a study developed in Africa, Hazell and Poulton (2010) posit that this phenomenon occurs for the following reasons: qualified work, market knowledge, technical knowledge, input purchases, financing and capital, land, the sales market, product traceability, guarantees of quality and risk management. In addition to providing advantages for postharvest operations, according to Weinberger and Lumpkin (2007), savings from these processes partially compensate the higher production costs of the large producer.

Weinberger and Lumpkin (2007) argue that small farmers have advantages, such as lower production costs, because they can generate high yields with less capital and a lower cost of activity coordination. Hazell and Poulton (2010) argue that small farmers have lower costs related to the supervision of non-qualified work and food acquisition, and they can exploit local knowledge.

In order for small farmers to participate in the modern supply channels offered by supermarket chains, they must have many attributes. Reardon (2009) indicates that the type of farmer is chosen by: i) the price of the product; ii) the reward paid by the modern channel; iii) the relative cost and the risk of exploration; iv) the capacity to make investments; v) the assets of the farm; vi) access to the company; and vii) governmental assistance with respect to credit, inputs and information. This author posits that this reasoning justifies why only 18% of the supply to supermarkets in Kenya was from small properties until the end of the 1990s.

Therefore, because of these and other factors observed in the literature, it is possible that supermarkets have preferred the supply from medium and large producers to that of small farmers in the vast majority of African countries because they can protect themselves from the uncertainties and risks inherent in trade relationships (Williamson, 1985), while simultaneously reducing reliance on limited rationality (Simon, 1970). Supermarkets seek to acquire product from small farmers only in areas in which small farmers dominate the agrarian structure, which is illustrated by a study in Kenya, where Reardon et al. (2009) indicate that the logic is to buy and sell on a large scale when the market is competitive and requires safe, uniform and high-quality products (Hazell and Poulton, 2010; Weinberger and Lumpkin, 2007). Thus, even in extremely poor communities such as the Transkei region (South Africa), supermarkets buy from large producers and sell cheap food to the poor population, which is an issue that concerns some governments (D'haeset and Huylenbroeck, 2005).

Most supermarkets do not have formal contracts with suppliers; furthermore, they do not offer any purchase guarantee outside of a verbal agreement. This phenomenon occurs in the production areas of fruit for export in South Africa (Kritzinger et al., 2004). However, although introducing small farmers into the market creates many uncertainties and much volatility, Table 3 presents the positive aspects of small farmer participation and illustrates examples of their access to supermarket chain.

Table 3. Examples of small farmer access to supermarket chains.

Country	Strategies to lower transaction costs for small farmers
Uganda	Production of potatoes for supermarkets in the country by organizing groups of farmers (Markelova and Mwangi, 2010).
Kenya, Ethiopia and Zambia	Production of green beans and corn for supermarkets in Kenya and for export through support of the government (ministries), contributors and private companies that is organized into groups or cooperatives (Markelova and Mwangi, 2010; Neven et al., 2009).
Kenya	Production of fresh green beans exported daily to supermarkets in Europe through farmer cooperatives (Timmer, 2009).
Zambia	Production and export of fruit and vegetables to supermarkets in the United Kingdom that are produced by associations of small farmers (Dehnen-Schmutz et al., 2010).
Zimbabwe	Production of fruit and vegetables in groups of small farmers to supply supermarket chains (IFAD, 2011).
Brazil	Production of organic vegetables for the Pão-de-açúcar and Carrefour supermarket chains in São Paulo (Brazil), through a production association (Blanc, 2009).

Source: Elaborated by the authors (2011).

Thus, there are reasons to believe that even when supermarkets face uncertainties when choosing small farmers as suppliers, there are institutional ways to make small farmer participation in supermarket supply channels feasible.

Challenges and opportunities of small farmers in accessing supermarket chains

On the one hand, although supermarket chains have shown a global trend of increased consolidation, rigorous private standards and adhering to the pressures of new consumption patterns (in addition to their own strategies), on the other hand, this growth has allowed the agri-food sector to offer broad opportunities to a ranger of suppliers (Hazell and Poulton, 2010). In this sense, the evidence presented in this study suggests that private standards themselves neither exclude, nor include, small farmer access to the market generated by supermarket chains. However, according to data from the UN and FAO, the productive and life conditions of most small farmers in Eastern and Southern Africa are a significant constraint to access to this market. Extreme poverty, on the one hand, and non-cooperation among small farmers, on the other, are factors that may result in the emergence of opportunistic behaviors, which, according to Williamson (1985), may result from information asymmetry.

Consumers are increasingly concerned about the quality and safety of food and the environmental and social conditions of its production. When increased global demand and production is added to this trend, it is reasonable to believe that supermarket chains represent an opportunity for small farmers, when supported by favorable institutional factors, such as access to credit, capital, and innovation, among others (Weinberger and Lumpkin, 2007). For example, in Kenya, small farmers who produce vegetables and fruit for export have an agricultural net income (per family member) five times higher than that of small landowners who do not produce vegetables, according to data from the authors referenced above.

To access these markets, small farmers must be organized into groups, associations and/or cooperatives (see the examples in Table 3). However, based on a study from Kenya, Neven et al. (2009) claim that cooperatives are easy to form but difficult to maintain. Therefore, it is considered fundamental for the producer to ensure access to information, training and encouragement to face the challenges of agri-food sector supply because the retail markets control prices in this sector.

According to Markelova and Mwangi (2010), it is important to adapt the skills, needs and management experience of farmers to different organizational forms. Therefore, among the challenges of cooperation and articulation for small farmers is the institutional role of governments that, according to D'Haese and Huylenbroeck

(2005) should help integrate small farmers into supermarket supply chains. Thus, new institutional arrangements are necessary. The progress of small farmers in this business depends on developing new coordination systems (Hazell and Poulton, 2010), which, in turn, may be undertaken in conjunction with civil society, governmental and non-governmental organizations, organizations of farmers and agri-business companies.

However, to ease widespread rural poverty in Africa, the importance of small farmers' access to domestic markets cannot be ignored because locally produced food has more opportunities to support the local economy (Ilbery and Maye, 2006).

Finally, private standards might represent a possible governance change; Konefal et al. (2005) posit that standardization may be transferred from the public to the private domain with a tendency to mitigate when agriculture is understood as the backbone of the economy, as in the case of South Africa. Thus, Hodgson (2002) explains that institutions arise to regulate individual behaviors, and the institutional domain may be the source of the changes necessary to enable a more reciprocal relationship between small farmers and supermarket chains, which is verified by Timmer (2009).

Public norms and activity related to government policies can affect the pace and nature of the transformation of the agri-food industry previously acknowledged by Reardon et al. (2009). In particular, policies can stimulate governance mechanisms for small farmers themselves, including reducing transaction costs in this market. In this way, the state would develop its institutional role in relation to the market (Williamson, 1985). Government may be essential to ensure that supermarkets reasonably protect consumers, and may also concomitantly promote the strengthening of small farmer access farmers to the large agri-food market.

Conclusions

As a result of this analysis, which developed in trying to answer the proposed research questions, there are more reasons to believe in the opportunities than in the limitations of small farmer access to supermarket chain markets in Eastern and Southern Africa because of the necessity to increase the production of agri-food products. This view may be applicable across other continents. However, it is necessary to comprehend that opportunities are restricted by the order of and 'conditions of the game' in the trade relations of this market, in which supply is more focused on economies of scale, and governance has been verticalized by supermarket chains.

The main differences between large and small farmers in their access to this market and the opportunity offered by supermarket chains in Africa are connected to farmers' capabilities of attending to the specificities of the assets (which are most often ruled by a group of private norms), the frequency/regularity of the operations and the uncertainty of the transactions. According to Williamson (1985), these three fundamental characteristics, in turn, are linked to the responsibilities and strategies of supermarkets and to the food safety demanded by consumers. Together, these characteristics constitute different attributes of competitiveness in supermarket chains.

Finally, it is considered that the greatest challenges to small farmer access to supermarket chain markets are found in the institutional organization. Cooperative, associative organizations and production groups tend to require more access to information, market knowledge and specialization (instead of diversification) to facilitate the participation of farmers in this market. These factors result in reduced transaction costs and limited rationality and increased trust in these relationships. It is also the responsibility of governmental or non-governmental institutions to instill motivation for this access and to provide private institutions with a more detailed view of the social attributes required in the new patterns of consumption.

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Rhizosphere microflora of noni (*Morinda citrifolia*) as influenced by organic manures and drip irrigation

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An experiment was conducted at Horticultural College and Research Institute, Tamil Nadu Agricultural University, Periyakulam to elucidate the effect of different irrigation regimes and organic manures on rhizosphere microbial population of noni (*Morinda citrifolia*). The trial was carried out in split plot design with irrigation regimes on main plot (four levels) and organic manures on sub plot (eight levels) with two replications. Among the different treatment combinations, M_2S_4 (100% WRc through drip irrigation + 50% farmyard manure + 50% vermicompost) registered the highest rhizosphere bacteria, fungi, actinomycetes, *Azotobacter*, *Azospirillum* and phosphobacteria population. The same treatment also recorded the highest score for organic matter decomposition. The rhizosphere microflora activity and organic matter decomposition was found to be the lowest in M_4S_7 (check basin method of irrigation + 100% recommended dose of NPK through inorganic fertilizers).

Key words: *Morinda citrifolia*, drip irrigation, farmyard manure, vermicompost, inorganic fertilizers, microbial population, organic matter decomposition.

INTRODUCTION

Over the past few years as natural products have become increasingly popular, the field of natural herbal remedies have flourished. The day to day demand for plant based natural raw materials for pharmaceuticals is increasing tremendously. Most of the world's population depends on traditional medicine to meet their daily health requirements, especially within the developing countries, where plants are the main source of medicine. One upcoming botanical name, the fruit of *Morinda citrifolia* very popularly known as NONI belongs to the Rubiaceae family. The roots, stems, bark, leaves, flowers and fruits of the noni plants are all involved in various combinations in almost 40 known and recorded herbal remedies. Noni is the biggest pharmaceutical unit in the universe because it has more than 160 nutraceuticals, vitamins, minerals, micro and macro nutrients that help the body in various ways from cellular level to organ level (Rethinam and Sivaraman, 2007). Noni fruit contains a number of enzymes and alkaloids that are believed to play a pivotal role in maintaining a good health. The fruit juice is in high demand in alternative medicine for different kinds of illnesses such as arthritis, diabetes, high blood pressure, muscle aches, pains, menstrual difficulties, headaches, heart disease, AIDS, cancers, gastric ulcers, sprains, mental depression, senility, poor digestion, atherosclerosis, blood vessel problems and drug addiction (Wang et al., 2002).

The purpose of this medicinal herb will be fulfilled only if it is free from toxic residual effects due to chemical farming. Otherwise these herbs will become harmful than of medicinal value. Moreover, the medicinal plants have several active biochemical ingredients, which may get altered and deteriorated quality wise, when grown with the use of inorganic fertilizers and toxic pesticides. Rhizosphere microflora plays an important role in the maintenance of soil fertility because of their ability to

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carry out biochemical transformations (Thampan, 1995). Repeated and excessive application of inorganic fertilizers affected microorganisms which were essential for maintaining biological health of soil. The fertility of soil depends not only on its chemical components but also on the qualitative and quantitative nature of microorganisms inhabiting it. Soil microorganisms in the rhizosphere influence the plant growth in so many ways. Most of them play a role in carbon, nitrogen, phosphorus and sulphur cycle and availability of trace elements as reported by Karuthamani (2010). Soil rhizosphere microbes with specific functions can have significant effects on plant growth. These effects may be exerted directly on the host plant or indirectly through some effect on other microorganisms in the rhizosphere. For example, some microorganisms are pathogen antagonists, auxin producers, nitrogen fixers or phosphate solubilizers (Linderman, 1986). Hence, it is apparent that drip irrigation and organic manure application may have the greatest potential for plant growth enhancement.

Organic manures greatly influence the available soil microbial populations which are capable of regulating the supply of nutrients to higher plants. Therefore, it can be considered for better maintenance of soil organic matter (Gill and Cole, 1981). Organically grown products are in demand at present due to the awareness on health consciousness. This is true particularly in medicinal plants, wherein whole plant product is used in ayurvedic preparations (Maheswarappa et al., 1999). Because of the growing concern over the ill effects of inorganic fertilizers alternate sources of nutrients have been sought for and biofertilizers are an effective alternative or a supplement especially in the recent context of organic farming. A judicious and continuous use of one or more organic sources like animal manures, green manures, industrial wastes, oil cakes, crop residues and biofertilizers such as *Azospirillum*, phosphobacteria, VAM etc., could improve the soil fertility levels on a long term basis. The availability of irrigation water is dwindling day-by-day. Adoption of conventional methods of irrigation to crops leads to an acute scarcity of water and results in reduced production and productivity of crops. Therefore, it becomes highly imperative to go for alternate water saving methods for more crop and income for every drop of water. Drip irrigation can be used to improve the irrigation efficiency of horticultural crops by reducing evaporation and drainage losses by creating and maintaining soil moisture conditions that are favourable to crop growth. Drip irrigation can be considered as an efficient irrigation system, since it causes wetting of the soil only and maintain optimum moisture content in the root zone. It also offers several water management advantages like timely application of water and water supply.

Micro irrigation provides many unique agronomic, water and energy conservation benefits that address many of the challenges facing irrigated agriculture, now and in the future (Selvarani, 2009).

MATERIALS AND METHODS

This study was conducted at Horticultural College and Research Institute, TNAU, Periyakulam, Tamil Nadu, India which is situated at 77°E longitude, 10°N latitude and at an altitude of 300 m above mean sea level. The nature of soil of the experimental plot is sandy loam. The details of the initial soil chemical and physico-chemical characteristics of the experimental field were furnished in Table 1. The methods used where as follows:

a. Statistical design: Split plot design
b. Factors: 2
c. Replications: 2
d. Spacing: 3.6 × 3.6 m
e. Number of plants per replication: 5

Treatment details

Main plot (irrigation)

M_1 - 75% WRc (Computed water requirement through drip irrigation)
M_2 - 100% WRc (Computed water requirement through drip irrigation)
M_3 - 125% WRc (Computed water requirement through drip irrigation)
M_4 - Check basin method of irrigation (5 cm depth)

Sub plot (organic manures)

S_1 - 100% farmyard manure (FYM)
S_2 - 100% vermicompost (VC)
S_3 - 100% Coir Pith Compost (CPC)
S_4 - 50% FYM + 50% VC
S_5 - 50% FYM + 50% CPC
S_6 - 50% VC + 50% CPC
S_7 - 100% recommended dose (RD) of NPK through inorganic fertilizers (60:30:30 g NPK plant^{-1})
S_8 - control (no manures and no fertilizers)

All organic manures were applied on equivalent weight of recommended dose of nitrogen (60 g plant^{-1}) on N equivalent basis. The treatments S_1 to S_6 are applied in addition with *Azospirillum* (10 g plant^{-1}) + phosphobacteria (10 g plant^{-1}) + VAM (20 g plant^{-1}). Nutrient content of organic manures were given in Table 2.

Computed water requirement

Computed water requirement of noni was calculated by using the following formula:

$$WRc = CPE \times K_p \times K_c \times A \times Wp \text{ lit plant}^{-1}$$

Where WRc is computed water requirement (lit plant^{-1}), CPE is cumulative pan evaporation for two days (mm), K_p is pan co-efficient (0.75), K_c is crop factor (0.90 for vegetative stage, 0.95 for flowering and harvesting stage) (Allen et al., 1998), A is area occupied by the noni tree (3.6 × 3.6 m), Wp is wetting percentage (40). The quantity of water applied during the study period (June 2011 to March 2013) is enclosed in Table 3.

Observations

Enumeration of rhizosphere soil microbial population

The rhizosphere soil sample from noni was analysed for bacteria,

Table 1. Initial soil chemical and physico-chemical characteristics of the experimental field.

Properties	Details
Chemical properties	
Available nitrogen	173 kg ha^{-1}
Available phosphorus	24 kg ha^{-1}
Available potassium	340 kg ha^{-1}
Physico-chemical properties	
EC	0.32 dSm^{-1}
pH	7.93

Table 2. Nutrient content of organic manures.

Organic manure	Nutrient content (%)		
	N	P	K
FYM	0.75	0.37	0.71
Vermicompost	1.67	1.51	0.80
Coir pith compost	1.06	0.87	1.20

Table 3. Total water used during the study period.

Treatments	Water applied (mm)	Effective rainfall (mm)	Total water used (mm)
M_1S_1	619.85	400.5	1020.35
M_1S_2	619.85	400.5	1020.35
M_1S_3	619.85	400.5	1020.35
M_1S_4	619.85	400.5	1020.35
M_1S_5	619.85	400.5	1020.35
M_1S_6	619.85	400.5	1020.35
M_1S_7	619.85	400.5	1020.35
M_1S_8	619.85	400.5	1020.35
M_2S_1	826.47	400.5	1226.97
M_2S_2	826.47	400.5	1226.97
M_2S_3	826.47	400.5	1226.97
M_2S_4	826.47	400.5	1226.97
M_2S_5	826.47	400.5	1226.97
M_2S_6	826.47	400.5	1226.97
M_2S_7	826.47	400.5	1226.97
M_2S_8	826.47	400.5	1226.97
M_3S_1	1033.09	400.5	1433.59
M_3S_2	1033.09	400.5	1433.59
M_3S_3	1033.09	400.5	1433.59
M_3S_4	1033.09	400.5	1433.59
M_3S_5	1033.09	400.5	1433.59
M_3S_6	1033.09	400.5	1433.59
M_3S_7	1033.09	400.5	1433.59
M_3S_8	1033.09	400.5	1433.59
M_4S_1	2450.0	565.4	3015.4
M_4S_2	2450.0	565.4	3015.4
M_4S_3	2450.0	565.4	3015.4
M_4S_4	2450.0	565.4	3015.4
M_4S_5	2450.0	565.4	3015.4
M_4S_6	2450.0	565.4	3015.4
M_4S_7	2450.0	565.4	3015.4
M_4S_8	2450.0	565.4	3015.4

fungi, actinomycetes, *Azotobacter*, phosphobacteria and *Azospirillum*.

Serial dilution of soil sample

Ten grams of rhizosphere soil sample was transferred to 90 ml of sterile distilled water to get 10^{-1} dilution. After thoroughly mixing it, 1 ml of this dilution was transferred to 9 ml water blank to get 10^{-2} dilution. Likewise, sample was diluted serially with 9 ml water blanks till appropriate dilution was obtained (Parkinson et al., 1971).

Bacteria

The total bacterial population was enumerated by plating 1 ml of 10^{-6} dilution in sterile petriplates using nutrient agar medium. The bacterial colonies appearing on the plates after 48 h of incubation at 30°C were counted and expressed per gram of dry weight of the soil.

Fungi

For the enumeration of fungal population, 1 ml of 10^{-3} dilution of the soil sample was plated in sterile plate with Rose Bengal agar medium. After 72 h of incubation, the fungal colonies were counted and expressed per gram of dry weight of soil.

Actinomycetes

The total actinomycetes population was enumerated by plating 1 ml of 10^{-4} dilution with Kenknights agar medium. The powdery colonies of actinomycetes appearing after 5 days were counted and expressed per gram of dry weight of soil.

Azotobacter

Azotobacter population was enumerated by plating 1 ml of 10^{-3} dilution of rhizosphere soil sample with Waksman medium No. 77. *Azotobacter* cells grow as raised and slimy colonies on agar surface. The colonies were counted and expressed per gram of dry weight of soil.

Azospirillum

Azospirillum population was enumerated by plating 1 ml of 10^{-5} dilution of rhizosphere soil sample with N-free semisolid malic acid medium. At the end of the incubation time, the media colour change from yellowish green to blue colour and white sub surface pellicle like colonies appear at 5 days of incubation period. The colonies were counted and expressed per gram of dry weight of soil.

Phosphobacteria

Phosphobacteria population was enumerated by plating 1 ml of 10^{-5} dilution of rhizosphere soil sample with Katznelson and Bose medium using soil extract from the rhizosphere region. After incubation formation of transparent and clear zones around the bacterial colonies indicates the extent of phosphate solubilization. The colonies were counted and expressed per gram of dry weight of soil.

Organic matter decomposition

The organic matter decomposition was estimated using the method described by Nagarajan and Ramalakshmi (2010). In a 500 ml conical flask, 100 g of respective treatment soils were taken and 10 ml of 1 N NaOH was taken in penicillin vial. The NaOH containing vial was hanged over in the conical flask with the help of thread. To make the flasks air tight, wax coating was given to the area of mouth of the conical flask and rubber cork with paraffin wax then incubated for 7 days. Then, penicillin vial was taken without disturbing NaOH and 1 ml of $BaCl_2$ was added then transferred to conical flask and titrated against 1 N HCl with phenolphthalein indicator. The end point is disappearance of pink colour. The organic matter decomposition is expressed in terms of mg CO_2 per 100 g of soil.

Statistical analysis

The statistical analysis of data was done by adopting the standard procedures of Panse and Sukhatme (1985). The AGRES software (version 3.01) was used for analysis of data.

RESULTS

Bacteria

Among the irrigation regimes, M_2 (100% WRc through drip irrigation) recorded the highest rhizosphere bacterial population of 108.55, 143.48 and 163.48 × 10^6 cfu g^{-1} of soil in vegetative, flowering and harvesting stages respectively (Table 4 and Figure 1). The rhizosphere bacterial population was found to be the lowest (72.62, 91.66 and 104.61 × 10^6 cfu g^{-1} of soil) in the check basin method of irrigation (M_4) during different crop growth stages. Among the sub plot treatments, S_4 (50% FYM + 50% VC) resulted in increased rhizosphere bacterial population in vegetative (118.94 × 10^6 cfu g^{-1} of soil), flowering (155.66 × 10^6 cfu g^{-1} of soil) and harvesting (178.87 ×10^6 cfu g^{-1} of soil) stages. The rhizosphere bacterial population was found to be the lowest (40.88, 49.79 and 58.79 × 10^6 cfu g^{-1} of soil) in the treatment plots receiving 100% RD of NPK through inorganic fertilizers (S_7) in various stages of crop growth. The treatment S_8 (no manure and no fertilizers) registered the rhizosphere bacterial population of 63.19, 79.59 and 92.86 × 10^6 cfu g^{-1} of soil in vegetative, flowering and harvesting stages, respectively. Between the interactions, the experimental plots receiving 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) recorded the highest rhizosphere bacterial population in vegetative (142.28 × 10^6 cfu g^{-1} of soil), flowering (188.26 × 10^6 cfu g^{-1} of soil) and harvesting (216.48 × 10^6 cfu g^{-1} of soil) stages.

The rhizosphere bacterial population was found to be the lowest in M_4S_7 (check basin method of irrigation + 100% RD of NPK through inorganic fertilizers) with 35.26, 41.25 and 48.96 × 10^6 cfu g^{-1} of soil in vegetative, flowering and harvesting stages, respectively. The rhizosphere bacterial population of 58.25, 72.27 and

Table 4. Effect of different water regimes and organic manures on rhizosphere bacterial population (× 10^6 cfu g^{-1} of soil).

Treatments	Vegetative stage					Flowering stage					Harvesting stage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	105.89	121.37	122.53	78.41	107.05	138.70	162.17	163.24	97.29	140.35	157.24	184.56	184.78	110.43	159.25
S_2	110.27	131.14	131.27	83.18	113.97	145.23	173.27	174.86	107.34	150.18	168.52	196.42	197.29	120.09	170.58
S_3	94.82	118.25	118.18	75.42	101.67	120.64	159.36	158.44	94.48	133.23	139.85	180.51	180.07	107.38	151.95
S_4	111.62	142.28	135.44	86.43	118.94	147.14	188.26	177.35	109.87	155.66	172.34	216.48	201.49	125.18	178.87
S_5	100.21	119.42	118.96	81.57	105.04	129.22	161.58	161.09	103.25	138.79	150.58	182.39	181.97	117.91	158.21
S_6	106.35	126.65	127.34	82.46	110.70	142.69	166.92	168.25	107.51	146.34	165.38	188.25	192.37	123.27	167.32
S_7	41.38	43.22	43.67	35.26	40.88	49.70	53.02	55.18	41.25	49.79	58.48	62.32	65.41	48.96	58.79
S_8	62.17	66.08	66.27	58.25	63.19	78.54	83.29	84.25	72.27	79.59	92.43	96.91	98.40	83.68	92.86
Mean	91.59	108.55	107.96	72.62	95.18	118.98	143.48	142.83	91.66	124.24	138.10	163.48	162.72	104.61	142.23
	M	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SE(d)	0.4561	0.7258	1.4324	1.4517		0.5852	0.9555	1.8810	1.9111		0.6738	1.0909	2.1493	2.1818	
CD at 5%	1.4514	1.4868	3.0989	2.9736		1.8625	1.9574	4.0597	3.9148		2.1443	2.2347	4.6422	4.4694	
CD at 1%	2.6641	2.0059	4.4057	4.0119		3.4188	2.6408	5.7590	5.2816		3.9361	3.0149	6.5900	6.0298	

83.68 × 10^6 cfu g^{-1} of soil was observed from M_4S_8 (check basin method of irrigation + no manure and no fertilizers).

Fungi

Concerning the main plot treatments, M_2 (100% WRc through drip irrigation) recorded the highest rhizosphere fungal population of 32.08, 35.89 and 39.51 × 10^3 cfu g^{-1} of soil in vegetative, flowering and harvesting stages, respectively (Table 5 and Figure 2). The rhizosphere fungal population was found to be the lowest (21.44, 22.87 and 24.41 × 10^3 cfu g^{-1} of soil) in the check basin method of irrigation (M_4) during three different crop growth stages. Among the manurial treatments, S_4 (50% FYM + 50% VC) revealed increased rhizosphere fungal population in vegetative (34.93 × 10^3 cfu g^{-1} of soil), flowering (39.55 × 10^3 cfu g^{-1} of soil) and harvesting (43.79 × 10^3 cfu g^{-1} of soil) stages. The rhizosphere fungal population was found to be the lowest (11.72, 11.99 and 12.32 × 10^3 cfu g^{-1} of soil) in the treatment plots receiving 100% RD of NPK through inorganic fertilizers (S_7) in various stages of crop growth. The treatment S_8 (no manure and no fertilizers) registered the rhizosphere fungal population of 18.12, 19.08 and 20.07 × 10^3 cfu g^{-1} of soil in vegetative, flowering and harvesting stages, respectively. In the combined effect of treatments, the treatment combination comprising 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) recorded the highest counts for rhizosphere fungal population in vegetative (43.50 × 10^3 cfu g^{-1} of soil), flowering (51.28 × 10^3 cfu g^{-1} of soil) and harvesting (58.65 × 10^3 cfu g^{-1} of soil) stages, respectively.

The fungal population was found to be the lowest in the treatment combination M_4S_7 (check basin method of irrigation + 100% RD of NPK through inorganic fertilizers) with 10.20, 10.48 and 10.66 × 10^3 cfu g^{-1} of soil during various stages of crop growth. The treatment combination M_4S_8 (check basin method of irrigation + no manure and no fertilizers) showed the rhizosphere fungal population of 17.01, 18.06 and 18.96 × 10^3 cfu g^{-1} of soil.

Actinomycetes

Among the main plots, application of 100% WRc through drip irrigation (M_2) registered the high actinomycetes population of 22.24, 25.26 and 27.24 × 10^4 cfu g^{-1} of soil in vegetative, flowering and harvesting stages respectively (Table 6).

In the main plot, the actinomycetes population was found to be the lowest in the treatment comprising check basin method of irrigation (M_4)

Table 5. Effect of different water regimes and organic manures on rhizosphere fungal population (× 10^3 cfu g^{-1} of soil).

Treatments	Vegetative stage					Flowering stage					Harvesting stage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	29.65	36.17	36.09	23.53	31.36	32.58	40.02	40.19	25.09	34.47	34.69	44.12	44.30	26.66	37.44
S_2	31.29	38.06	38.15	24.87	33.09	34.26	43.76	44.07	26.56	37.16	36.98	48.06	48.67	28.72	40.61
S_3	29.19	35.10	34.22	23.05	30.39	32.06	38.92	38.05	24.67	33.43	33.79	42.80	42.16	26.10	36.21
S_4	31.85	43.50	39.28	25.09	34.93	34.92	51.28	44.81	27.18	39.55	37.62	58.65	49.62	29.27	43.79
S_5	29.37	35.92	35.18	23.12	30.90	32.40	39.66	39.60	24.46	34.03	34.07	44.02	42.98	25.88	36.74
S_6	31.02	36.42	36.65	24.61	32.18	33.95	40.72	40.87	26.42	35.49	36.80	44.68	44.52	29.02	38.76
S_7	11.86	12.61	12.19	10.20	11.72	12.03	12.97	12.48	10.48	11.99	12.49	13.21	12.93	10.66	12.32
S_8	18.22	18.84	18.42	17.01	18.12	19.12	19.78	19.36	18.06	19.08	20.18	20.50	20.63	18.96	20.07
Mean	26.56	32.08	31.27	21.44	27.84	28.92	35.89	34.93	22.87	30.65	30.83	39.51	38.23	24.41	33.24
	M	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SE(d)	0.1321	0.2127	0.4193	0.4254		0.1457	0.2364	0.4656	0.4728		0.1588	0.2580	0.5082	0.5161	
CD at 5%	0.4205	0.4358	0.9062	0.8715		0.4638	0.4842	1.0056	0.9685		0.5054	0.5286	1.0973	1.0572	
CD at 1%	0.7719	0.5879	1.2871	1.1758		0.8514	0.6533	1.4273	1.3066		0.9278	0.7131	1.5573	1.4263	

Table 6. Effect of different water regimes and organic manures on rhizosphere actinomycetes population (× 10^4 cfu g^{-1} of soil).

Treatments	Vegetative stage					Flowering stage					Harvesting stage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	20.70	26.53	26.18	16.28	22.42	22.59	29.76	29.45	17.69	24.87	24.46	32.04	31.65	19.26	26.85
S_2	21.34	27.25	27.60	17.04	23.31	23.26	31.32	31.86	18.40	26.21	25.15	33.65	34.20	20.06	28.27
S_3	20.79	23.24	23.78	16.10	20.98	22.70	26.15	27.02	17.57	23.36	24.55	28.35	29.16	19.08	25.29
S_4	21.86	29.85	28.05	17.62	24.35	24.08	34.80	32.49	19.16	27.63	26.12	37.65	34.88	20.68	29.83
S_5	20.18	24.39	24.66	16.52	21.44	22.15	27.63	28.12	18.02	23.98	23.95	29.84	30.36	19.64	25.95
S_6	21.69	27.05	26.84	17.16	23.19	23.82	31.12	30.35	18.68	25.99	25.78	33.36	32.58	20.21	27.98
S_7	6.68	7.50	7.12	5.10	6.60	7.20	8.12	7.68	5.56	7.14	7.66	8.75	8.12	5.84	7.59
S_8	11.59	12.09	12.46	10.54	11.67	12.55	13.17	13.58	11.42	12.68	13.64	14.29	14.81	12.38	13.78
Mean	18.10	22.24	22.09	14.55	19.24	19.79	25.26	25.07	15.81	21.48	21.41	27.24	26.97	17.14	23.19
	M	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SE(d)	0.0919	0.1488	0.2932	0.2977		0.1035	0.1672	0.3294	0.3343		0.1115	0.1804	0.3554	0.3608	
CD at 5%	0.2925	0.3049	0.6333	0.6098		0.3295	0.3424	0.7117	0.6848		0.3549	0.3695	0.7678	0.7391	
CD at 1%	0.5368	0.4113	0.8990	0.8227		0.6048	0.4619	1.0105	0.9239		0.6514	0.4986	1.0900	0.9971	

Table 7. Effect of different water regimes and organic manures on rhizosphere *Azotobacter* population (× 10^3 cfu g^{-1} of soil).

Treatments	Vegetative stage					Flowering stage					Harvesting stage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	14.20	17.12	16.95	11.54	14.95	15.87	19.10	18.79	12.42	16.55	17.14	20.46	20.21	13.58	17.85
S_2	15.25	18.73	18.82	12.05	16.21	16.80	21.06	21.19	13.02	18.02	18.06	22.48	22.69	14.13	19.34
S_3	14.10	16.32	16.47	11.35	14.56	15.65	18.50	18.42	12.18	16.19	17.01	19.89	19.80	13.35	17.51
S_4	15.39	19.85	19.20	12.22	16.67	16.92	22.60	21.82	13.31	18.66	18.20	24.25	23.36	14.42	20.06
S_5	14.26	17.36	17.30	11.86	15.20	16.04	19.63	19.22	12.75	16.91	17.40	21.13	20.62	13.80	18.24
S_6	15.02	17.84	18.06	12.14	15.77	16.65	19.78	20.15	13.22	17.45	17.87	21.25	21.67	14.27	18.77
S_7	6.45	6.95	6.80	5.85	6.51	6.88	7.35	7.28	6.15	6.92	7.35	7.89	7.76	6.51	7.38
S_8	8.38	8.60	8.79	7.73	8.38	9.14	9.36	9.61	8.34	9.11	9.92	10.25	10.54	9.06	9.94
Mean	12.88	15.35	15.30	10.59	13.53	14.24	17.17	17.06	11.42	14.98	15.37	18.45	18.33	12.39	16.14

	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M
SE(d)	0.0648	0.1028	0.2030	0.2057	0.0720	0.1143	0.2257	0.2287	0.0777	0.1231	0.2430	0.2461
CD at 5%	0.2063	0.2106	0.4393	0.4213	0.2290	0.2342	0.4883	0.4684	0.2474	0.2521	0.5259	0.5041
CD at 1%	0.3787	0.2842	0.6248	0.5684	0.4204	0.3160	0.6944	0.6320	0.4541	0.3401	0.7480	0.6801

in vegetative (14.55 × 10^4 cfu g^{-1} of soil), flowering (15.81 × 10^4 cfu g^{-1} of soil) and harvesting (17.14 × 10^4 cfu g^{-1} of soil) stages, respectively. Pertaining to the sub plot, application of 50% FYM + 50% VC (S_4) recorded the highest actinomycetes population of 24.35, 27.63 and 29.83 × 10^4 cfu g^{-1} of soil in vegetative, flowering and harvesting stages, respectively. The actinomycetes population was found to be the lowest (6.60, 7.14 and 7.59 × 10^4 cfu g^{-1} of soil) in the treatment S_7 (100% RD of NPK through inorganic fertilizers). The treatment S_8 (no manure and no fertilizers) registered the rhizosphere actinomycetes population counts of 11.67, 12.68 and 13.78 × 10^4 cfu g^{-1} of soil in vegetative, flowering and harvesting stages, respectively. The treatment combination comprising 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) recorded the highest scores for rhizosphere actinomycetes population in vegetative (29.85 × 10^4 cfu g^{-1} of soil), flowering (34.80 × 10^4 cfu g^{-1} of soil) and harvesting (37.65 × 10^4 cfu g^{-1} of soil) stages, respectively.

The actinomycetes population was found to be the lowest in the treatment combination M_4S_7 (check basin method of irrigation + 100% RD of NPK through inorganic fertilizers) with 5.10, 5.56 and 5.84 × 10^4 cfu g^{-1} of soil during different stages of crop growth. The treatment combination M_4S_8 (check basin method of irrigation + no manure and no fertilizers) showed the rhizosphere actinomycetes population of 10.54, 11.42 and 12.38 × 10^4 cfu g^{-1} of soil.

Azotobacter

Among the irrigation regimes, M_2 (100% WRc through drip irrigation) recorded the highest rhizosphere *Azotobacter* population of 15.35, 17.17 and 18.45 × 10^3 cfu g^{-1} of soil in vegetative, flowering and harvesting stages, respectively (Table 7). The rhizosphere *Azotobacter* population was found to be the lowest (10.59, 11.42 and 12.39 × 10^3 cfu g^{-1} of soil) in the check basin method of irrigation (M_4) during all the three crop growth stages. With reference to the sub plot treatments, S_4 (50% FYM + 50% VC) resulted in increased rhizosphere *Azotobacter* population in vegetative (16.67 × 10^3 cfu g^{-1} of soil), flowering (18.66 × 10^3 cfu g^{-1} of soil) and harvesting (20.06 × 10^3 cfu g^{-1} of soil) stages. The rhizosphere *Azotobacter* population was found to be the lowest (6.51, 6.92 and 7.38 × 10^3 cfu g^{-1} of soil) in the treatment plots receiving 100% RD of NPK through inorganic fertilizers (S_7) in various growth stages of the crop. The treatment S_8 (no manure and no fertilizers) registered the rhizosphere *Azotobacter* population of 8.38, 9.11 and 9.94 × 10^3 cfu g^{-1} of soil in vegetative, flowering and

Table 8. Effect of different water regimes and organic manures on rhizosphere phosphobacteria population (× 10^5 cfu g^{-1} of soil).

Treatments	Vegetative stage					Flowering stage					Harvesting stage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	21.37	28.40	28.06	18.52	24.09	23.11	30.72	30.19	19.85	25.97	24.51	32.68	32.06	20.56	27.45
S_2	23.11	28.72	29.03	19.02	24.97	24.53	31.76	31.89	20.16	27.09	26.38	34.68	34.57	21.42	29.26
S_3	21.26	27.20	25.26	18.06	22.95	22.58	29.04	26.98	19.24	24.46	23.29	30.64	28.09	19.85	25.47
S_4	23.18	33.75	29.92	19.18	26.51	24.79	37.44	32.19	20.93	28.84	26.62	41.82	35.14	21.78	31.34
S_5	22.60	27.62	27.53	18.13	23.97	23.72	29.71	29.93	19.44	25.70	24.86	30.91	30.97	20.17	26.73
S_6	22.66	28.44	28.60	18.66	24.59	24.08	31.02	31.59	19.92	26.65	25.57	33.95	34.18	20.60	28.58
S_7	7.90	8.67	8.82	7.12	8.13	8.09	9.48	9.22	7.35	8.54	8.21	9.73	9.49	7.44	8.72
S_8	13.96	14.26	14.63	12.88	13.93	14.17	14.88	15.09	13.21	14.34	14.79	15.02	15.53	13.68	14.76
Mean	19.51	24.63	23.98	16.45	21.14	20.63	26.76	25.89	17.51	22.70	21.78	28.68	27.50	18.19	24.04
	M	S	M at S	S at M		M	S	M at S	S at M		M	S	M at S	S at M	
SE(d)	0.1003	0.1622	0.3196	0.3244		0.1072	0.1750	0.3445	0.3500		0.1154	0.1862	0.3670	0.3724	
CD at 5%	0.3191	0.3323	0.6903	0.6645		0.3412	0.3585	0.7435	0.7170		0.3673	0.3815	0.7930	0.7629	
CD at 1%	0.5857	0.4483	0.9801	0.8965		0.6264	0.4836	1.0548	0.9673		0.6742	0.5147	1.1260	1.0293	

harvesting stages, respectively. Among the interactions, the experimental plots receiving 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) registered the highest rhizosphere *Azotobacter* population in vegetative (19.85 × 10^3 cfu g^{-1} of soil), flowering (22.60 × 10^3 cfu g^{-1} of soil) and harvesting (24.25 × 10^3 cfu g^{-1} of soil) stages.

The rhizosphere *Azotobacter* population was found to be the lowest in M_4S_7 (check basin method of irrigation + 100% RD of NPK through inorganic fertilizers) with 5.85, 6.15 and 6.51 × 10^3 cfu g^{-1} of soil in vegetative, flowering and harvesting stages, respectively. The rhizosphere *Azotobacter* population of 7.73, 8.34 and 9.06 × 10^3 cfu g^{-1} of soil was observed from M_4S_8 (check basin method of irrigation + no manure and no fertilizers).

Phosphobacteria

The rhizosphere phosphobacteria population increased from vegetative to harvesting stage (Table 8). Concerning the main plot treatments, M_2 (100% WRc through drip irrigation) recorded the highest rhizosphere phosphobacteria population of 24.63, 26.76 and 28.68 × 10^5 cfu g^{-1} of soil in vegetative, flowering and harvesting stages, respectively. The rhizosphere phosphobacteria population was found to be the lowest (16.45, 17.51 and 18.19 × 10^5 cfu g^{-1} of soil) in the check basin method of irrigation (M_4) during three different crop growth stages. Pertaining to the sub plot, application of 50% FYM + 50% VC (S_4) registered the highest rhizosphere phosphobacteria population of 26.51, 28.84 and 31.34 × 10^5 cfu g^{-1} of soil in vegetative, flowering and harvesting stages, respectively. The rhizosphere phosphobacteria population was found to be the lowest (8.13, 8.54 and 8.72 × 10^5 cfu g^{-1} of soil) in the treatment S_7 (100% RD of NPK through inorganic fertilizers). The treatment S_8 (no manure and no fertilizers) registered the rhizosphere phosphobacteria population of 13.93, 14.34 and 14.76 × 10^5 cfu g^{-1} of soil in vegetative, flowering and harvesting stages, respectively.

The treatment combination comprising 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) recorded the highest scores for rhizosphere phosphobacteria population in vegetative (33.75 × 10^5 cfu g^{-1} of soil), flowering (37.44 × 10^5 cfu g^{-1} of soil) and harvesting (41.82 × 10^5 cfu g^{-1} of soil) stages, respectively. The rhizosphere phosphobacteria population was found to be the lowest in the treatment combination M_4S_7 (check basin method of irrigation + 100% RD of NPK through inorganic fertilizers) with 7.12, 7.35 and 7.44 × 10^5 cfu g^{-1} of soil during different stages of crop growth. The treatment combination M_4S_8 (check basin method of irrigation + no manure and no fertilizers) showed the rhizosphere phosphobacteria population of 12.88, 13.21 and 13.68 × 10^5 cfu g^{-1} of soil.

Table 9. Effect of different water regimes and organic manures on rhizosphere *Azospirillum* population (× 10^5 cfu g^{-1} of soil).

Treatments	Vegetative stage					Flowering stage					Harvesting stage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	17.82	20.69	20.57	14.80	18.47	21.18	24.58	24.39	17.54	21.92	22.85	26.73	26.51	18.85	23.74
S_2	19.10	21.80	21.87	15.57	19.59	22.44	25.83	25.94	18.40	23.15	24.16	27.89	28.12	19.79	24.99
S_3	17.21	20.35	20.27	14.71	18.14	20.54	24.21	24.09	17.48	21.58	22.07	26.25	26.14	18.81	23.32
S_4	19.20	23.65	22.09	15.62	20.14	22.64	27.86	26.18	18.47	23.79	24.37	30.28	28.41	19.92	25.75
S_5	17.63	20.50	20.46	15.32	18.48	20.98	24.33	24.28	18.09	21.92	22.59	26.44	26.29	19.42	23.69
S_6	19.14	21.44	21.56	15.39	19.38	22.49	25.44	25.62	18.25	22.95	24.30	27.60	27.81	19.71	24.86
S_7	8.30	8.71	8.79	7.12	8.23	9.70	10.13	10.24	8.32	9.60	10.23	10.65	10.80	8.74	10.11
S_8	12.03	12.58	12.66	11.24	12.13	13.87	14.60	14.73	13.02	14.06	14.68	15.52	15.67	13.78	14.91
Mean	16.30	18.72	18.53	13.72	16.82	19.23	22.12	21.93	16.20	19.87	20.66	23.92	23.72	17.38	21.42
	M	S	M at S	S at M		M	S	M at S	S at M		M	S	M at S	S at M	
SE(d)	0.0818	0.1262	0.2498	0.2524		0.0963	0.1493	0.2955	0.2986		0.1035	0.1613	0.3190	0.3226	
CD at 5%	0.2602	0.2585	0.5421	0.5169		0.3065	0.3059	0.6409	0.6117		0.3295	0.3304	0.6917	0.6609	
CD at 1%	0.4776	0.3487	0.7727	0.6974		0.5627	0.4126	0.9132	0.8253		0.6049	0.4458	0.9852	0.8916	

Azospirillum

Among the main plot treatments, M_2 (100% WRc through drip irrigation) recorded the highest rhizosphere *Azospirillum* population of 18.72, 22.12 and 23.92 × 10^5 cfu g^{-1} of soil in vegetative, flowering and harvesting stages respectively (Table 9). The rhizosphere *Azospirillum* population was found to be the lowest (13.72, 16.20 and 17.38 × 10^5 cfu g^{-1} of soil) in the check basin method of irrigation (M_4) during the three different crop growth stages. Between the manure treatments, S_4 (50% FYM + 50% VC) recorded an increased rhizosphere *Azospirillum* population in vegetative (20.14 × 10^5 cfu g^{-1} of soil), flowering (23.79 × 10^5 cfu g^{-1} of soil) and harvesting (25.75 × 10^5 cfu g^{-1} of soil) stages. The rhizosphere *Azospirillum* population was found to be the lowest (8.23, 9.60 and 10.11 × 10^5 cfu g^{-1} of soil) in the treatment plots receiving 100% RD of NPK through inorganic fertilizers (S_7) in various stages of crop growth. The treatment S_8 (no manure and no fertilizers) registered the rhizosphere *Azospirillum* population of 12.13, 14.06 and 14.91 × 10^5 cfu g^{-1} of soil in vegetative, flowering and harvesting stages, respectively. In the combined effect of treatments, the treatment combination comprising 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) recorded the highest scores for rhizosphere *Azospirillum* population in vegetative (23.65 × 10^5 cfu g^{-1} of soil), flowering (27.86 × 10^5 cfu g^{-1} of soil) and harvesting (30.28 × 10^5 cfu g^{-1} of soil) stages, respectively.

The *Azospirillum* population was found to be the lowest in the treatment combination M_4S_7 (check basin method of irrigation + 100% RD of NPK through inorganic fertilizers) with 7.12, 8.32 and 8.74 × 10^5 cfu g^{-1} of soil during various stages of crop growth. The treatment combination M_4S_8 (check basin method of irrigation + no manure and no fertilizers) showed the rhizosphere *Azospirillum* population of 11.24, 13.02 and 13.78 × 10^5 cfu g^{-1} of soil.

Organic matter decomposition

Among the main plots, application of 100% WRc through drip irrigation (M_2) registered the highest organic matter decomposition of 77.10, 91.42 and 103.56 mg CO_2 100 g^{-1} of soil in vegetative, flowering and harvesting stages, respectively (Table 10). The organic matter decomposition was found to be lowest in the treatment comprising check basin method of irrigation (M_4) in vegetative (50.24 mg CO_2 100 g^{-1} of soil), flowering (60.56 mg CO_2 100 g^{-1} of soil) and harvesting (69.15 mg CO_2 100 g^{-1} of soil) stages. Pertaining to the sub plot, application of 50% FYM + 50% VC (S_4) registered the highest organic matter decomposition

Table 10. Effect of different water regimes and organic manures on organic matter decomposition (mg CO_2 100 g^{-1} of soil).

Treatments	Vegetative stage					Flowering stage					Harvesting stage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	68.74	87.19	88.62	55.38	74.98	84.12	104.93	105.06	67.62	90.43	95.98	116.89	118.26	76.15	101.82
S_2	75.09	96.24	96.89	59.24	81.87	88.69	110.45	112.18	71.08	95.60	101.49	125.02	126.25	81.84	108.65
S_3	64.40	83.09	81.95	53.12	70.64	81.39	99.14	95.78	64.27	85.15	92.46	110.48	107.29	73.21	95.86
S_4	75.67	104.92	98.25	59.37	84.55	90.42	123.56	115.19	73.28	100.61	103.68	140.86	130.09	82.92	114.39
S_5	68.12	84.19	83.46	57.15	73.23	83.65	102.59	99.72	66.08	88.01	95.08	115.48	112.92	74.87	99.59
S_6	71.48	89.57	90.38	57.76	77.30	86.27	105.43	107.52	71.39	92.65	99.72	119.67	121.18	82.10	105.67
S_7	26.44	27.52	28.23	20.46	25.66	31.52	33.20	33.29	25.38	30.85	38.29	40.20	41.62	30.76	37.72
S_8	43.17	44.08	44.29	39.43	42.74	50.18	52.04	52.75	45.39	50.09	57.06	59.87	60.68	51.32	57.23
Mean	61.64	77.10	76.51	50.24	66.37	74.53	91.42	90.19	60.56	79.17	85.47	103.56	102.29	69.15	90.12

	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M
SE(d)	0.3226	0.5100	1.0072	1.0200	0.3794	0.6079	1.1988	1.2157	0.4338	0.6892	1.3603	1.3783
CD at 5%	1.0268	1.0447	2.1803	2.0893	1.2075	1.2452	2.5919	2.4903	1.3806	1.4117	2.9435	2.8234
CD at 1%	1.8848	1.4094	3.1016	2.8188	2.2164	1.6799	3.6827	3.3598	2.5343	1.9046	4.1853	3.8092

of 84.55, 100.61 and 114.39 mg CO_2 100 g^{-1} of soil in vegetative, flowering and harvesting stages, respectively. The organic matter decomposition was found to be the lowest (25.66, 30.85 and 37.72 mg CO_2 100 g^{-1} of soil) in the treatment S_7 (100% RD of NPK through inorganic fertilizers). The treatment S_8 (no manure and no fertilizers) registered the organic matter decomposition of 42.74, 50.09 and 57.23 mg CO_2 100 g^{-1} of soil in different stages, respectively. The treatment combination comprising of 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) recorded the highest scores for organic matter decomposition during vegetative (104.92 mg CO_2 100 g^{-1} of soil), flowering (123.56 mg CO_2 100 g^{-1} of soil) and harvesting (140.86 mg CO_2 100 g^{-1} of soil) stages.

The organic matter decomposition was found to be the lowest in the treatment combination M_4S_7 (check basin method of irrigation + 100% RD of NPK through inorganic fertilizers) with 20.46, 25.38 and 30.76 mg CO_2 100 g^{-1} of soil during various stages of crop growth. The treatment combination M_4S_8 (check basin method of irrigation + no manure and no fertilizers) showed the organic matter decomposition of 39.43, 45.39 and 51.32 mg CO_2 100 g^{-1} of soil.

DISCUSSION

The bacterial population in vegetative, flowering and harvesting stages was found to be higher in the treatment combination comprising 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4). The drip irrigation system provides continuous and uninterrupted supply of moisture for congenial microbial activity and proliferation. Similarly, under drip irrigation system, the soil moisture content did not too fluctuate between wet and dry extremes (Patil and Janawade, 1999) which favours the microbial growth and proliferation. The differences in bacterial population might also be due to the varied level of substrate availability and nutrient transformations taking place in the soil. The increased rhizosphere bacterial population in aforementioned best treatment was due to the prevalence of favourable environment for biological activity. This increase in bacterial count might be attributed to the consecutive addition of energy rich materials which increases the enzyme activities and ultimately the viable bacterial population. The least population was observed in M_4S_7 (check basin method of irrigation + 100% RD of NPK through inorganic fertilizers). The reduction of

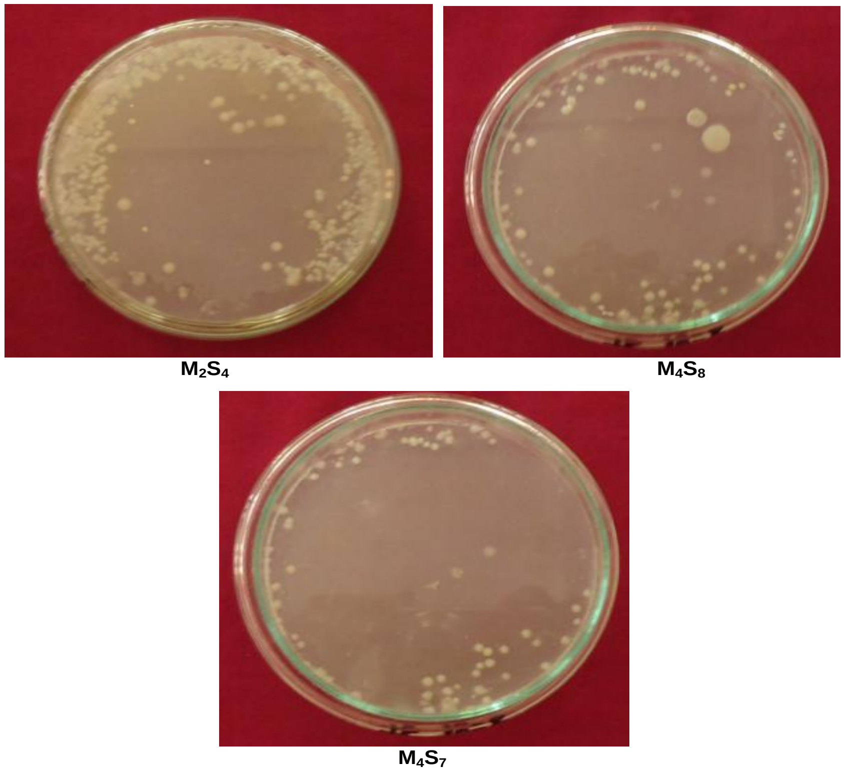

Figure 1. Effect of different water regimes and organic manures on rhizosphere bacterial population (x 10^3 cfu g^{-1} of soil) at harvesting stage.

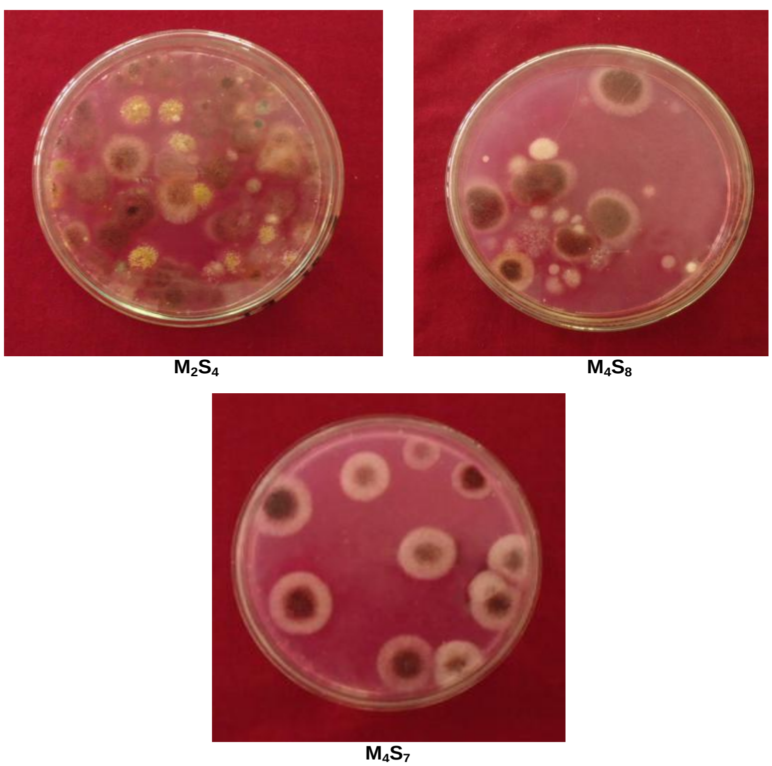

Figure 2. Effect of different water regimes and organic manures on rhizosphere fungal population (x 10^3 cfu g^{-1} of soil) at harvesting stage.

rhizosphere bacterial population in this treatment may be due to ill effect of inorganic fertilizers on bacterial population. The results are in line with the findings of Ravanachander (2009).

Manickam (1983) revealed that organic residues added to the soil underwent microbial decomposition and in that process it released organic acids and other products of decay which acted as strong binding agents in the formation of large stable aggregates which favours the growth of microbial population. The fungal population recorded was the highest in M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC). Since there was appreciable amount of N through applied organic manures in the soil and decomposition of it further encouraged multiplication of beneficial microorganisms. Moreover, *Azospirillum* would have released growth regulators which also might have been favourable for microbial population. The results were also in line with the findings of Ravanachander (2009) in black pepper. The actinomycetes population was found to be the highest in plots supplied with 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) as against the M_4S_7 (check basin method of irrigation + 100% RD of NPK through inorganic fertilizers). The drip irrigation provides optimum moisture level for microbial proliferation. The frequent application of irrigation through drip at optimum level maintained most of the rhizosphere soil as most conducive for microflora proliferation. The crops with conventional check basin method of irrigation affected by excess moisture which deleteriously affected the soil aeration. Similarly, the moisture availability is not uniform in check basin method of irrigation.

The excess water application under check basin method of irrigation tends to leach down the nutrients beyond the rhizosphere which creates nutrient deficient condition for microbial growth as a result, the microbial population was reduced. The highest actinomycetes population in M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) might also be due to the higher availability of carbonaceous materials in those of the treatments with optimum N availability. Moreover, application of optimum quantity of organic amendments would have provided a conducive environment for the activity of actinomycetes. This observation was in line with the findings of Sutopo and Kuwatsuka (1992) who suggested that FYM application stimulated the microbial proliferation and the process related to N cycling in soil. The lowest population was noticed in experimental plot receiving check basin method of irrigation + 100% RD of NPK through inorganic fertilizers (M_2S_7) which indicates the ill effects of mineral fertilization on soil actinomycetes. Higher population of soil microbes under organic treatments acted as an index of soil fertility because it serves as temporary sink of nutrients flux as found by Hassink et al. (1991).

Added organic manure improves the water holding capacity and inturn the soil moisture status which would have supported the proliferation of beneficial rhizosphere microflora namely, *Azotobacter*, *Azospirillum* and phosphobacteria. The improved beneficial microbial population may be due to optimum water and nutrient availability by the treatment combination M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC). This finding is in corroboration with the previous works by Thomas and Shantahram (1984) who indicated that application of organics helped the soil microbes to produce polysaccharides and thereby improving the soil structure. Chellamuthu et al. (1988) reported that the soil microbial population was increased due to addition of organic manure because they increase the proportion of labile carbon and nitrogen, directly stimulating the activity of the microorganism. Besides this, addition of organic manures would have resulted in increased secondary and micronutrients in the soil which might have helped to increase the load of beneficial microbial population. Combined use of organic manures with drip irrigation might have improved the microbial load of the soil, increasing the microbial population namely, bacteria, fungi and actinomycetes which conspicuously increased with application of different organic sources than the treatments with inorganic fertilizers and control plots as reported by Ravanachander (2009) in black pepper and Vanilarasu (2011) in banana.

The population dynamics of microorganism namely, bacteria, fungi, actinomycetes, *Azotobacter*, *Azospirillum* and phosphobacteria showed a favourable trend. Wherever organic manures were applied along with drip irrigation, there was an increase in the population of soil microbes. The enhanced population of soil microflora under drip irrigated, organic manures and biofertilizers treated plots might be due to the synergistic effect of applied drip irrigation, organic manures and biofertilizers on the proliferation of existing native soil microflora. The organic matter decomposition was found to be comparatively higher in treatment combination comprising 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4). The drip irrigation provide conducive environment for microbial proliferation. Similarly, vermicompost having good water holding capacity, aeration, porosity and increased surface areas which facilitate more micro sites for microbial decomposing organism. As a result, microbial decomposition and CO_2 generation was increased (Arancon and Edwards, 2005). The treatment combination M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) exhibited superior performance rhizosphere microbial population and organic matter decomposition.

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Full Length Research Paper

Soil and leaf nutrient status of noni (*Morinda citrifolia* L.) as influenced by drip irrigation and manurial treatments

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An investigation was carried out at Horticultural College and Research Institute, Tamil Nadu Agricultural University, Periyakulam to find out the effect of various irrigation regimes and manurial treatments on soil and leaf nutrient status of noni (*Morinda citrifolia* L.). The experiment was carried out in split plot design with irrigation regimes on main plot and manurial treatments on sub plot. Among the treatment combination, M_2S_7 (100% WRc through drip irrigation + 100% recommended dose of NPK through inorganic fertilizers) showed the highest soil available nitrogen, phosphorus and potassium content. The same treatment combination recorded the increased leaf nitrogen, phosphorus and potassium content during vegetative, flowering and harvesting stages.

Key words: *Morinda citrifolia* L., drip irrigation, check basin method of irrigation, farmyard manure, vermicompost, coir pith compost, inorganic fertilizers, soil nutrient status, leaf nutrient status.

INTRODUCTION

Morinda citrifolia L. popularly known as Indian Noni or Indian mulberry is an ever green small tree bearing flowers and fruits throughout the year. It belongs to the family Rubiaceae. It is grown in tropical regions of the world. It is one of the most significant sources of traditional medicines among Pacific islands. Noni has been used in folk remedies by Polynesians for over 2000 years and is reported to have a wide range of therapeutic effects including antibacterial, antiviral, antifungal, antitumor, analgesic, anti-inflammatory and immune enhancing effects. Recently, it has been regaining popularity as an herbal treatment and is beginning to show resurgence as a cultivated plant. The availability of irrigation water becomes dwindling day-by-day as such adoption of conventional methods of irrigation to crops leads to an acute scarcity of water and results in reduced production and productivity of crops. Therefore, it becomes imperative to go for alternate water saving methods and income for every drop of water through trickle irrigation which provides continuous supply of required quantity of water in drops right at the root zone of the plant. In the cultivation of modern crop cultivars and appropriate management strategies, use of recent day chemical fertilizers have contributed up to 50%, a raise in food grain output (Braun and Roy, 1983). Despite the key role played by these fertilizers, a total dependence on them in achieving a contemplated productivity goal is not fully justified. Furthermore, an unabated up rise in the use of chemical fertilizers can inflict irreparable damage to land and the prevailing environment (Katyal, 1989). Measurable decrease in fertilizer consumption without compromising the yield and quality of any crop can also be made practically possible through organic inputs.

Continuous and unscrupulous use of chemical

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Table 1. Initial soil chemical and physico-chemical characteristics of the experimental field.

Properties	Details
Chemical properties	
Available nitrogen	173 kg ha^{-1}
Available phosphorus	24 kg ha^{-1}
Available potassium	340 kg ha^{-1}
Physico-chemical properties	
EC	0.32 dSm^{-1}
pH	7.93

Table 2. Nutrient content of organic manures.

Organic manure	Nutrient content (%)		
	N	P	K
FYM	0.75	0.37	0.71
Vermicompost	1.67	1.51	0.80
Coir pith compost	1.06	0.87	1.20

fertilizers, pesticides and fungicides without the incorporation of organic manure cause environmental degradation especially, in the soil thereby affecting its fertility on long term basis. For effectively maintaining optimum productivity of the land and building up of soil fertility, the addition of organic manures to crops has been suggested as one among the best recommendation. Large scale cultivation under organic conditions is gaining momentum to produce toxic free medicinal and herbal plant products (Padmanabhan, 2003). Organically grown herbal materials are more preferred in the herbal preparations since they are residue free and more effective. A judicious and continuous use of one or more organic sources like animal manures, green manures, oil cakes, crop residues and biofertilizers such as *Azospirillum*, phosphobacteria, VAM etc., could improve the soil fertility levels on a long term basis. Plant nutrient availability in the soil is very critical for exploiting higher production.

The nutrients, applied at any stage of crop growth, should properly reflect in terms of available nutrient in soil so that the plants could absorb these nutrients efficiently without any hindrance. Hence, the study was undertaken to find out the effect of different irrigation regimes and manurial treatments on soil and leaf nutrient status of noni.

MATERIALS AND METHODS

This study was conducted at Horticultural College and Research Institute, TNAU, Periyakulam, Tamil Nadu, India which is situated at 77° E longitude, 10° N latitude and at an altitude of 300 m above mean sea level. The nature of soil of the experimental plot is sandy loam. The details of the initial soil chemical and physico-chemical characteristics of the experimental field were furnished in Table 1. The methods used were as follows:

a) Statistical design: Split plot design.
b) Factors: 2
c) Replications: 2
d) Spacing: 3.6 × 3.6 m
e) Number of plants per replication: 5

Treatment details

Main plot (irrigation)

M_1 - 75% WRc (computed water requirement through drip irrigation).
M_2 - 100% WRc (computed water requirement through drip irrigation).
M_3 - 125% WRc (computed water requirement through drip irrigation).
M_4 - check basin method of irrigation (5 cm depth).

Sub plot (organic manures)

S_1 - 100% farmyard manure (FYM).
S_2 - 100% vermicompost (VC).
S_3 - 100% coir pith compost (CPC).
S_4 - 50% FYM + 50% VC.
S_5 - 50% FYM + 50% CPC.
S_6 - 50% VC + 50% CPC.
S_7 - 100% recommended dose (RD) of NPK through inorganic fertilizers (60:30:30 g NPK $plant^{-1}$).
S_8 - Control (no manures and no fertilizers).

All organic manures were applied on equivalent weight of recommended dose of nitrogen (60 g $plant^{-1}$) on N equivalent basis. The treatments S_1 to S_6 are applied in addition with *Azospirillum* (10 g $plant^{-1}$) + phosphobacteria (10 g $plant^{-1}$) + VAM (20 g $plant^{-1}$). Nutrient content of organic manures were given in Table 2. In the treatment S_7, nitrogen is applied in the form of urea, phosphorus in the form of super phosphate and potassium in the form of murate of potash.

Computed water requirement

Computed water requirement of noni was calculated by using the following formula:

$$WRc = CPE \times K_p \times K_c \times A \times Wp \text{ lit plant}^{-1}$$

Where WRc is Computed water requirement (lit $plant^{-1}$), CPE is cumulative pan evaporation for two days (mm), K_p is pan co-efficient (0.75), K_c is crop factor (0.90 for vegetative stage, 0.95 for flowering and harvesting stage) (Allen et al., 1998), A is area occupied by the noni tree (3.6 × 3.6 m), Wp is wetting percentage (40).

The quantity of water applied during the study period (June 2011 to March 2013) is enclosed in Table 3.

Observations

Soil nutrient analysis

Soil sampling: A 'V' shape cut was made to a depth of 15 cm at each sampling spot. About 1.5 cm thick slices of soil were removed

Table 3. Total water used during the study period.

Treatment	Water applied (mm)	Effective rainfall (mm)	Total water used (mm)
M_1S_1	619.85	400.5	1020.35
M_1S_2	619.85	400.5	1020.35
M_1S_3	619.85	400.5	1020.35
M_1S_4	619.85	400.5	1020.35
M_1S_5	619.85	400.5	1020.35
M_1S_6	619.85	400.5	1020.35
M_1S_7	619.85	400.5	1020.35
M_1S_8	619.85	400.5	1020.35
M_2S_1	826.47	400.5	1226.97
M_2S_2	826.47	400.5	1226.97
M_2S_3	826.47	400.5	1226.97
M_2S_4	826.47	400.5	1226.97
M_2S_5	826.47	400.5	1226.97
M_2S_6	826.47	400.5	1226.97
M_2S_7	826.47	400.5	1226.97
M_2S_8	826.47	400.5	1226.97
M_3S_1	1033.09	400.5	1433.59
M_3S_2	1033.09	400.5	1433.59
M_3S_3	1033.09	400.5	1433.59
M_3S_4	1033.09	400.5	1433.59
M_3S_5	1033.09	400.5	1433.59
M_3S_6	1033.09	400.5	1433.59
M_3S_7	1033.09	400.5	1433.59
M_3S_8	1033.09	400.5	1433.59
M_4S_1	2450.0	565.4	3015.4
M_4S_2	2450.0	565.4	3015.4
M_4S_3	2450.0	565.4	3015.4
M_4S_4	2450.0	565.4	3015.4
M_4S_5	2450.0	565.4	3015.4
M_4S_6	2450.0	565.4	3015.4
M_4S_7	2450.0	565.4	3015.4
M_4S_8	2450.0	565.4	3015.4

and collected in clean polythene bags (Table 4). Samples of the same treatments were mixed thoroughly and the quantity was reduced by quartering for analysis.

Leaf nutrient analysis

Collection of leaf samples

The noni leaves were collected from the respective treatments and washed with distilled water and then dried (Table 5). The dried samples were powdered with pestle and mortar and used for analysis of nutrients. The leaf samples were analyzed at vegetative, flowering and harvesting stages.

Statistical analysis

The statistical analysis of data was done by adopting the standard procedures of Panse and Sukhatme (1985). The AGRES software (version 3.01) was used for analysis of data.

RESULTS

Soil nutrient status

Available nitrogen

The main plot treatment M_2 (100% WRc through drip irrigation) recorded the highest soil available nitrogen content (198.92, 172.05 and 154.25 kg ha^{-1}) compared to the treatment M_4 (check basin method of irrigation) with 188.56, 156.88 and 136.88 kg ha^{-1} in vegetative, flowering and harvesting stages, respectively (Table 6 and Figure 1). Between the sub plots, the treatment S_7 (100% RD of NPK through inorganic fertilizers) registered the increased available nitrogen content of 208.52, 180.08 and 162.55 kg ha^{-1} and this was followed by S_4 (50% FYM + 50% VC) with 200.36, 171.98 and 153.49 kg ha^{-1} in vegetative, flowering and harvesting stages,

Table 4. Methods of soil nutrient analysis.

Estimation	Methods	Author
Available nitrogen	Alkaline permanganate	Subbiah and Asija (1956)
Available phosphorus	Colorimetric	Olsen et al. (1954)
Available potassium	Flame photometry	Stanford and English (1949)

Table 5. Methods of leaf nutrient analysis.

Estimation	Methods	Author
Nitrogen	Microkjeldahl	Piper (1966)
Phosphorus	Vanadamolybdate	Piper (1966)
Potassium	Flame photometry	Piper (1966)

respectively. The treatment, S_8 (no manure and no fertilizers) showed the lowest soil available nitrogen content with 165.00, 138.13 and 121.25 kg ha^{-1} at different stages. Among the interactions, the treatment combination M_2S_7 (100% WRc through drip irrigation + 100% RD of NPK through inorganic fertilizers) exhibited the highest soil available nitrogen content (210.82, 184.03 and 167.20 kg ha^{-1}). Among the organic manure, applied treatment combinations, M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) observed with soil available nitrogen content of 206.29, 179.32 and 162.28 kg ha^{-1}.

The soil available nitrogen content was found to be lowest in M_4S_8 (check basin method of irrigation + no manure and no fertilizers) at various stages with 162.48, 133.52 and 116.20 kg ha^{-1}.

Available phosphorus

The data pertaining to soil available phosphorus recorded during vegetative, flowering and harvesting stages revealed a decreasing trend from vegetative to harvesting stages invariably (Table 7). Among the different main plot treatments experimented, the treatment M_2 (100% WRc through drip irrigation) showed the highest soil available phosphorus content (28.74, 25.76 and 21.88 kg ha^{-1}) at vegetative, flowering and harvesting stages. The soil available phosphorus content was found to be the lowest in M_4 (check basin method of irrigation) with 24.91, 21.78 and 17.63 kg ha^{-1}. When sub plot treatments were rated based on their performance for this trait, it came to be known that application of 100% RD of NPK through inorganic fertilizers (S_7) resulted in the highest soil available phosphorus content of 30.72, 27.64 and 23.67 kg ha^{-1} followed by S_4 (50% FYM + 50% VC) with 28.68, 25.55 and 21.55 kg ha^{-1} in vegetative, flowering and harvesting stages, respectively. The soil available phosphorus content was found to be the lowest in S_8 (no manure and no fertilizers) with 20.24, 17.91 and 14.12 kg ha^{-1} at three growth stages, respectively. In the combined effect of treatments, M_2S_7 (100% WRc through drip irrigation + 100% RD of NPK through inorganic fertilizers) expressed the highest soil available phosphorus content (31.93, 28.87 and 25.13 kg ha^{-1}) as against the lowest (19.52, 17.03 and 13.12 kg ha^{-1}) in M_4S_8 (check basin method of irrigation + no manure and no fertilizers) at vegetative, flowering and harvesting stages, respectively.

Among the organic manure combinations, M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) recorded with soil available phosphorus content of 30.89, 27.85 and 24.02 kg ha^{-1} in vegetative, flowering and harvestings stages, respectively.

Available potassium

Between the main plots, the treatment M_2 (100% WRc through drip irrigation) recorded the highest available potassium content (357.18, 336.42 and 326.38 kg ha^{-1}) as compared to that of M_4 (check basin method of irrigation) with 349.88, 328.97 and 318.74 kg ha^{-1} in vegetative, flowering and harvesting stages, respectively (Table 8). Among the sub plots, the treatment S_7 (100% RD of NPK through inorganic fertilizers) registered the increased soil available potassium content (363.12, 341.94 and 331.65 kg ha^{-1}) and this was followed by S_4 (50% FYM + 50% VC) with 358.08, 336.90 and 326.70 kg ha^{-1} in vegetative, flowering and harvesting stages, respectively. The lesser value (333.38, 315.16 and 305.90 kg ha^{-1}) was noticed in the treatment S_8 (no manure and no fertilizers) during three stages, respectively. Among the interactions, the treatment combination M_2S_7 (100% WRc through drip irrigation + 100% RD of NPK through inorganic fertilizers) resulted in increased score (365.26, 344.17 and 333.94 kg ha^{-1}) for soil available potassium content. Regarding the organic manure applied treatment combinations, M_2S_4 (100% WRc through drip irrigation + 50% FYM +

Table 6. Effect of different water regimes and organic manures on soil available nitrogen (kg ha^{-1}) content.

Treatment	Vegetative stage					Flowering stage					Harvesting stage				
	M_1	**M_2**	**M_3**	**M_4**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**Mean**
S_1	192.78	199.69	199.20	188.69	195.09	162.90	172.29	171.80	156.59	165.90	143.89	153.66	153.20	135.62	146.59
S_2	196.33	204.79	204.12	191.52	199.19	168.26	177.68	177.10	160.04	170.77	148.75	160.53	159.79	139.86	152.23
S_3	192.36	198.53	198.90	188.12	194.48	162.62	170.74	171.32	155.44	165.03	143.39	152.26	152.74	134.87	145.82
S_4	197.69	206.29	205.40	192.07	200.36	169.30	179.32	178.56	160.72	171.98	150.13	162.28	161.40	140.15	153.49
S_5	194.37	202.06	201.63	190.10	197.04	165.64	175.25	174.66	157.12	168.17	146.02	156.52	155.70	136.24	148.62
S_6	194.85	202.56	203.79	190.72	197.98	166.30	175.84	176.63	158.28	169.26	146.64	157.23	157.75	137.39	149.75
S_7	208.27	210.82	210.21	204.78	208.52	179.38	184.03	183.60	173.32	180.08	161.85	167.20	166.42	154.72	162.55
S_8	164.59	166.59	166.32	162.48	165.00	137.26	141.23	140.52	133.52	138.13	120.88	124.35	123.58	116.20	121.25
Mean	192.66	198.92	198.70	188.56	194.71	163.96	172.05	171.77	156.88	166.16	145.19	154.25	153.82	136.88	147.54
	M	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SE(d)	0.5085	0.6981	1.4014	1.3961		0.4366	0.5961	1.1976	1.1921		0.3906	0.5294	1.0647	1.0588	
CD at 5%	1.6182	1.4299	3.0800	2.8599		1.3895	1.2210	2.6337	2.4420		1.2432	1.0845	2.3435	2.1690	
CD at 1%	2.9703	1.9292	4.4409	3.8584		2.5505	1.6473	3.7996	3.2947		2.2820	1.4631	3.3836	2.9262	

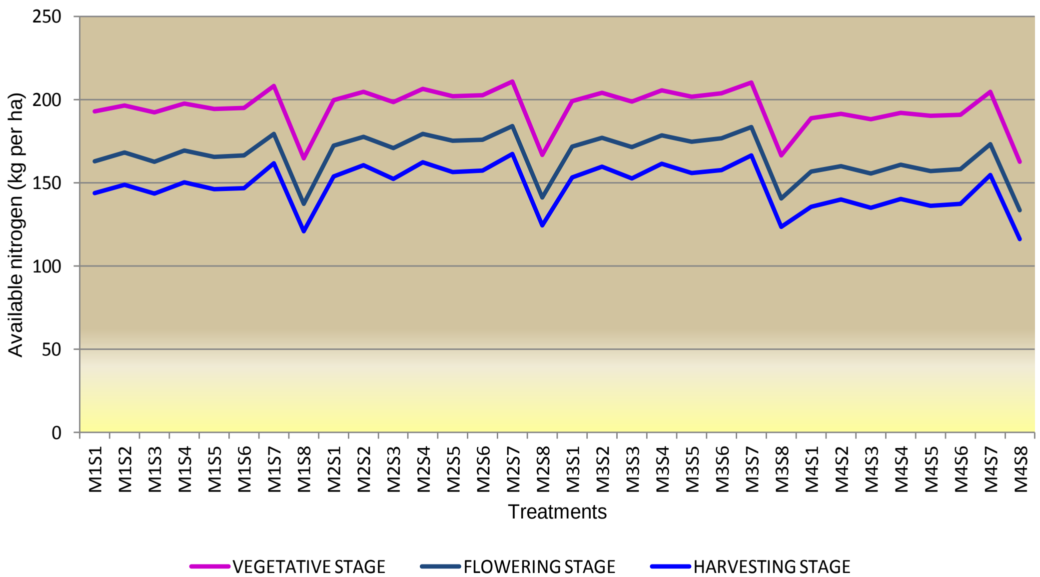

Figure 1. Effect of different water regimes and organic manures on soil available nitrogen (kg ha^{-1}) content.

Table 7. Effect of different water regimes and organic manures on soil available phosphorus (kg ha^{-1}) content.

Treatment	Vegetative stage					Flowering stage					Harvesting stage				
	M$_1$	M$_2$	M$_3$	M$_4$	Mean	M$_1$	M$_2$	M$_3$	M$_4$	Mean	M$_1$	M$_2$	M$_3$	M$_4$	Mean
S$_1$	26.21	28.55	28.96	24.36	27.02	23.05	25.43	25.84	21.13	23.86	18.95	21.49	21.78	17.04	19.82
S$_2$	27.21	30.29	30.12	25.50	28.28	24.06	27.17	26.98	22.28	25.12	19.89	23.23	23.04	18.08	21.06
S$_3$	26.60	28.34	28.12	24.70	26.94	23.41	25.25	25.03	21.46	23.79	19.30	21.20	20.96	17.24	19.68
S$_4$	27.54	30.89	30.58	25.69	28.68	24.39	27.85	27.49	22.48	25.55	20.28	24.02	23.60	18.29	21.55
S$_5$	26.83	29.20	29.39	25.01	27.61	23.64	26.08	26.25	21.77	24.44	19.47	22.13	22.30	17.63	20.38
S$_6$	27.03	29.90	29.68	25.43	28.01	23.85	26.79	26.56	22.20	24.85	19.68	22.85	22.62	17.98	20.78
S$_7$	30.36	31.93	31.54	29.06	30.72	27.29	28.87	28.53	25.85	27.64	23.15	25.13	24.78	21.63	23.67
S$_8$	20.05	20.79	20.58	19.52	20.24	17.68	18.65	18.27	17.03	17.91	13.85	14.96	14.53	13.12	14.12
Mean	26.48	28.74	28.62	24.91	27.19	23.42	25.76	25.62	21.78	24.14	19.32	21.88	21.70	17.63	20.13
	M	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SE(d)	0.0711	0.0981	0.1968	0.1962		0.0636	0.0871	0.1750	0.1743		0.0535	0.0729	0.1465	0.1458	
CD at 5%	0.2262	0.2009	0.4322	0.4018		0.2025	0.1785	0.3847	0.3569		0.1702	0.1493	0.3222	0.2986	
CD at 1%	0.4152	0.2710	0.6228	0.5421		0.3717	0.2408	0.5548	0.4816		0.3125	0.2015	0.4650	0.4029	

Table 8. Effect of different water regimes and organic manures on soil available potassium (kg ha^{-1}) content.

Treatment	Vegetative stage					Flowering stage					Harvesting stage				
	M$_1$	M$_2$	M$_3$	M$_4$	Mean	M$_1$	M$_2$	M$_3$	M$_4$	Mean	M$_1$	M$_2$	M$_3$	M$_4$	Mean
S$_1$	352.69	356.87	356.26	350.09	353.98	331.47	335.70	335.10	328.81	332.77	321.24	325.52	324.88	318.45	322.52
S$_2$	355.03	361.24	360.85	351.94	357.27	333.80	340.09	339.68	330.67	336.06	323.55	329.90	329.46	320.34	325.81
S$_3$	354.12	358.04	358.63	350.84	355.41	332.88	336.90	337.49	329.59	334.22	322.63	326.68	327.28	319.27	323.97
S$_4$	355.78	362.58	361.72	352.24	358.08	334.57	341.49	340.58	330.95	336.90	324.32	331.38	330.40	320.68	326.70
S$_5$	354.53	358.94	359.38	351.17	356.01	333.29	337.78	338.22	329.93	334.81	323.06	327.56	328.01	319.60	324.56
S$_6$	354.80	359.72	360.12	351.53	356.54	333.59	338.55	338.94	330.25	335.33	323.38	328.31	328.73	319.97	325.10
S$_7$	362.65	365.26	364.79	359.77	363.12	341.44	344.17	343.58	338.55	341.94	331.17	333.94	333.35	328.15	331.65
S$_8$	333.29	334.78	334.02	331.43	333.38	315.02	316.69	315.89	313.04	315.16	305.65	307.74	306.75	303.47	305.90
Mean	352.86	357.18	356.97	349.88	354.22	332.01	336.42	336.19	328.97	333.40	321.88	326.38	326.11	318.74	323.28
	M	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SE(d)	0.3738	0.5061	1.0179	1.0121		0.3524	0.4762	0.9581	0.9524		0.3419	0.4617	0.9290	0.9234	
CD at 5%	1.1897	1.0367	2.2408	2.0733		1.1216	0.9755	2.1096	1.9510		1.0882	0.9458	2.0458	1.8916	
CD at 1%	2.1838	1.3986	3.2357	2.7972		2.0587	1.3161	3.0468	2.6322		1.9975	1.2760	2.9549	2.5521	

Table 9. Effect of different water regimes and organic manures on leaf nitrogen content (%).

Treatment	Vegetative stage					Flowering stage					Harvesting stage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	1.623	1.648	1.646	1.608	1.631	1.881	1.914	1.910	1.863	1.892	1.724	1.748	1.747	1.707	1.732
S_2	1.635	1.663	1.661	1.617	1.644	1.894	1.932	1.930	1.873	1.907	1.737	1.765	1.763	1.716	1.745
S_3	1.622	1.641	1.643	1.606	1.628	1.880	1.904	1.908	1.860	1.888	1.722	1.743	1.745	1.704	1.729
S_4	1.638	1.668	1.665	1.620	1.648	1.898	1.937	1.934	1.875	1.911	1.740	1.771	1.768	1.718	1.749
S_5	1.628	1.655	1.653	1.613	1.637	1.889	1.923	1.920	1.866	1.900	1.731	1.755	1.753	1.710	1.737
S_6	1.630	1.657	1.658	1.615	1.640	1.891	1.924	1.927	1.868	1.903	1.732	1.758	1.759	1.712	1.740
S_7	1.673	1.684	1.682	1.662	1.675	1.938	1.951	1.949	1.919	1.939	1.769	1.784	1.781	1.750	1.771
S_8	0.929	0.936	0.934	0.922	0.930	1.057	1.064	1.063	1.046	1.058	0.911	0.918	0.916	0.903	0.912
Mean	1.547	1.569	1.568	1.533	1.554	1.791	1.819	1.818	1.771	1.800	1.633	1.655	1.654	1.615	1.639
	M	S	M at S	S at M		M	S	M at S	S at M		M	S	M at S	S at M	
SE(d)	0.0015	0.0023	0.0045	0.0045		0.0017	0.0026	0.0052	0.0053		0.0016	0.0024	0.0048	0.0048	
CD at 5%	0.0048	0.0047	0.0098	0.0093		0.0055	0.0054	0.0114	0.0108		0.0050	0.0049	0.0104	0.0099	
CD at 1%	0.0088	0.0063	0.0140	0.0126		0.0102	0.0073	0.0162	0.0146		0.0092	0.0067	0.0148	0.0133	

50% VC) recorded with soil available potassium content of 362.58, 341.49 and 331.38 kg ha^{-1} in vegetative, flowering and harvesting stages, respectively.

The treatment combination M_4S_8 (check basin method of irrigation + no manure and no fertilizers) exhibited the least value (331.43, 313.04 and 303.47 kg ha^{-1}) of soil available potassium content.

Leaf nutrient status

Leaf nitrogen

A higher leaf nitrogen content of 1.569, 1.819 and 1.655 was exhibited by the treatment M_2 (100% WRc through drip irrigation) as against 1.533, 1.771 and 1.615% in M_4 (check basin method of irrigation) in vegetative, flowering and harvesting stages, respectively (Table 9). Between sub plot treatments, S_7 (100% RD of NPK through inorganic fertilizers) recorded the highest leaf nitrogen content (1.675, 1.939 and 1.771%) followed by S_4 (50% FYM + 50% VC) with 1.648, 1.911 and 1.7495 in vegetative, flowering and harvesting stages, respectively. The leaf nitrogen content was found to be the lowest (0.930, 1.058 and 0.912) with S_8 (no manure and no fertilizers) during different growth stages. Among the treatment combinations, M_2S_7 (100% WRc through drip irrigation + 100% RD of NPK through inorganic fertilizers) recorded a greater nitrogen content (1.684, 1.951 and 1.784%). Between the organic manure applied treatment combination, M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) showed the leaf nitrogen content of 1.668, 1.937 and 1.771%. The leaf nitrogen content was found to be the lowest with 0.922, 1.046 and 0.903 in M_4S_8 (check basin method of irrigation + no manure and no fertilizers).

Leaf phosphorus

In the main plot, the treatment, M_2 (100% WRc through drip irrigation) expressed a higher leaf phosphorus content (0.288, 0.320 and 0.307%) in vegetative, flowering and harvesting stages, respectively; while the treatment, M_4 (check basin method of irrigation) exhibited a phosphorous content of 0.261, 0.289 and 0.273% in various crop growth stages (Table 10). Likewise in the sub plots, the treatment S_7 (100% RD of NPK through inorganic fertilizers) resulted in the highest score for leaf phosphorus content (0.309, 0.342 and 0.330%) and this was followed by S_4 (50% FYM + 50% VC) with 0.292, 0.326 and 0.313% in vegetative, flowering and harvesting stages, respectively; while lesser content (0.203, 0.218 and

Table 10. Effect of different water regimes and organic manures on leaf phosphorus content (%).

Treatment	Vegetative stage					Flowering stage					Harvesting stage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	0.272	0.288	0.291	0.260	0.278	0.303	0.319	0.323	0.289	0.309	0.288	0.306	0.310	0.273	0.294
S_2	0.281	0.302	0.300	0.270	0.288	0.313	0.338	0.335	0.300	0.322	0.298	0.326	0.322	0.283	0.307
S_3	0.275	0.286	0.284	0.263	0.277	0.305	0.318	0.315	0.293	0.308	0.291	0.304	0.302	0.277	0.294
S_4	0.283	0.309	0.305	0.271	0.292	0.314	0.347	0.342	0.302	0.326	0.299	0.335	0.329	0.287	0.313
S_5	0.277	0.292	0.294	0.266	0.282	0.308	0.325	0.328	0.295	0.314	0.295	0.312	0.315	0.278	0.300
S_6	0.280	0.297	0.296	0.268	0.285	0.310	0.332	0.330	0.297	0.317	0.296	0.320	0.318	0.281	0.304
S_7	0.305	0.319	0.316	0.296	0.309	0.335	0.356	0.353	0.323	0.342	0.323	0.344	0.340	0.311	0.330
S_8	0.202	0.209	0.208	0.194	0.203	0.217	0.224	0.222	0.210	0.218	0.198	0.205	0.202	0.191	0.199
Mean	0.272	0.288	0.287	0.261	0.277	0.301	0.320	0.319	0.289	0.307	0.286	0.307	0.305	0.273	0.292
	M	S	M at S	S at M		M	S	M at S	S at M		M	S	M at S	S at M	
SE(d)	0.0003	0.0004	0.0008	0.0008		0.0003	0.0004	0.0009	0.0009		0.0003	0.0004	0.0009	0.0009	
CD at 5%	0.0009	0.0008	0.0018	0.0016		0.0010	0.0009	0.0020	0.0018		0.0010	0.0009	0.0019	0.0017	
CD at 1%	0.0017	0.0011	0.0025	0.0022		0.0019	0.0012	0.0028	0.0025		0.0018	0.0012	0.0027	0.0023	

0.199%) were obtained from the treatment S_8 (no manure and no fertilizers). When interaction effects of these factors were rated based on their performance, it came to be known that application 100% WRc through drip irrigation + 100% RD of NPK through inorganic fertilizers (M_2S_7) had resulted in the highest phosphorus content (0.319, 0.356 and 0.344%) while the lowest (0.194, 0.210 and 0.191%) was found to be with check basin method of irrigation + no manure and no fertilizers (M_4S_8).

Regarding the organic manures applied treatment combinations, M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) recorded the leaf phosphorus content of 0.309, 0.347 and 0.335% in vegetative, flowering and harvesting stages, respectively.

Leaf potassium

In the main plot, the treatment M_2 (100% WRc through drip irrigation) expressed a higher leaf potassium content of 1.089, 1.316 and 1.206% in vegetative, flowering and harvesting stages, respectively (Table 11). The same was found to be the lowest (1.051, 1.275 and 1.164%) with check basin method of irrigation (M_4) in various growth phases of the crop. Pertaining to the sub plots, the treatment S_7 (100% RD of NPK through inorganic fertilizers) resulted in the superior score for leaf potassium content (1.131, 1.374 and 1.267%) and this was followed by S_4 (50% FYM + 50% VC) with 1.109, 1.352 and 1.242% in vegetative, flowering and harvesting stages, respectively; while lesser leaf potassium content (0.868, 0.979 and 0.862%) were obtained from the treatment S_8 (no manure and no fertilizers). Among the different treatment combinations, M_2S_7 (100% WRc through drip irrigation + 100% RD of NPK through inorganic fertilizers) recorded a greater leaf potassium content (1.142, 1.387 and 1.280%). Regarding the organic manures applied treatment combinations, M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) recorded the leaf potassium content of 1.132, 1.378 and 1.269% in different crop growth stages. The treatment combination comprising check basin method of irrigation + no manure and no fertilizers (M_4S_8) registered the lowest leaf potassium content in vegetative (0.859%), flowering (0.970%) and harvesting (0.853%) stages, respectively.

DISCUSSION

Soil available nutrient status

It was revealed that the application of 100% WRc through drip irrigation + 100% RD of NPK through inorganic fertilizers (M_2S_7) recorded the highest available NPK in soil, supporting the concept of readily available nature of inorganic fertilizers. The mobility of nutrients was well pronounced under

Table 11. Effect of different water regimes and organic manures on leaf potassium content (%).

Treatment	Vegetative stage					Flowering stage					Harvesting stage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	1.081	1.102	1.099	1.065	1.087	1.323	1.344	1.340	1.305	1.328	1.212	1.234	1.231	1.195	1.218
S_2	1.093	1.125	1.123	1.077	1.105	1.335	1.368	1.366	1.318	1.347	1.224	1.259	1.256	1.206	1.236
S_3	1.086	1.107	1.109	1.069	1.093	1.327	1.348	1.351	1.310	1.334	1.215	1.239	1.242	1.198	1.224
S_4	1.096	1.132	1.128	1.079	1.109	1.337	1.378	1.372	1.319	1.352	1.227	1.269	1.263	1.208	1.242
S_5	1.089	1.112	1.114	1.071	1.097	1.329	1.354	1.356	1.313	1.338	1.218	1.244	1.247	1.202	1.228
S_6	1.091	1.116	1.119	1.074	1.100	1.332	1.359	1.363	1.315	1.342	1.220	1.250	1.254	1.205	1.232
S_7	1.128	1.142	1.140	1.115	1.131	1.373	1.387	1.384	1.353	1.374	1.264	1.280	1.276	1.244	1.267
S_8	0.868	0.874	0.872	0.859	0.868	0.978	0.986	0.983	0.970	0.979	0.860	0.869	0.867	0.853	0.862
Mean	1.067	1.089	1.088	1.051	1.074	1.292	1.316	1.314	1.275	1.299	1.180	1.206	1.205	1.164	1.189
	M	S	M at S	S at M		M	S	M at S	S at M		M	S	M at S	S at M	
SE(d)	0.0011	0.0015	0.0031	0.0031		0.0013	0.0019	0.0038	0.0038		0.0012	0.0017	0.0034	0.0034	
CD at 5%	0.0035	0.0032	0.0068	0.0063		0.0042	0.0038	0.0082	0.0077		0.0038	0.0035	0.0075	0.0070	
CD at 1%	0.0065	0.0043	0.0098	0.0085		0.0077	0.0052	0.0118	0.0104		0.0070	0.0048	0.0108	0.0095	

drip irrigation system. Nutrients were carried along with the water movement and concentrated near the outer periphery of the wetting zone. Similar reports were given to Prakash (2010). Combined application of 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) showed an increase in soil available nitrogen content compare to M_4S_8 (check basin method of irrigation + no manure and no fertilizers). This is due to continuous availability of higher soil moisture content under drip irrigation which helped to solubilize the plant nutrient near the root zone and favoured easy availability and absorption of plant nutrients by the noni crop. Added organic manures not only acted as source of nutrients but also influenced their availability. Cumulative effects of this treatment combination seem to ensure adequate supply of nutrients slowly and steadily throughout the crop growth period at optimum level. Farmyard manure could supply 5.0 Kg N t^{-1} (Katyayan, 2001). The increase in the contents of total nitrogen might be attributed to the better availability of nitrogen coupled with retarded nitrification process by restricting the movement of nitrates to lower depth, enabling the slow availability of nitrogen to plants.

Optimum availability of nitrogen in soil under farmyard manure addition could be due to favourable congenial microbial activity and the enhanced biomass addition to the soil and also as result of improved soil physical properties. Organic nitrogen and P_2O_5 availability in the soil increased with the application of farmyard manure, due to the increase of decomposition of products of organic matter. This is in agreement with the previous works of Ismail et al. (1998). Singh et al. (1992) opined that the addition of organic matter influences the transformation and availability of N through its impact on chemical and biological properties of soil. Moreover, the beneficial microbial biomass would have been multiplied in the applied organic manure itself and released into soil which might have contributed to increased N for reuse by the succeeding crop. Similar results were also recorded by Padmapriya (2004) and Vanilarasu (2011). Regarding their superior chemical attributes, Arancon and Edwards (2005) reported that vermicomposts, usually contained more mineral elements than commercial plant growth media and many of these elements were changed to forms more that could be readily available for taken up by the plants such as nitrates, available phosphorus and exchangeable potassium, calcium and magnesium. Lowest nutrient availability with check basin method of irrigation may be due to leaching and volatilization losses of nutrients under conventional check basin method of irrigation which leads to quick depletion of nutrients from the root zone which resulted in low availability of nutrients. Prakash (2010) reported that in surface irrigation, the plant nutrients leached beyond the root zone due to higher quantity of irrigation water and also observed leaching of plant nutrients when downward soil moisture movement exceeded effective root zone.The available phosphorus was found to be higher in the treatment combination comprising 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) compare to M_4S_8 (check basin method of irrigation + no manure and no fertilizers), which might be due to the result of reduced fixation of native phosphorus through the release of organic acids during the decomposition and increased its mobilization in soil. Usually, farmyard manure with a narrow CN ratio produces more chelated phosphates, which are more soluble in water. This easily available form might have triggered the synthesis of more protein in roots as reported by Upadhyay and Misra (1999) in turmeric. Higher phosphorus content in vermicompost treated plot may be due to increased phosphatase activity from the direct action of gut enzymes of earthworm and indirectly by the stimulation of microorganisms (Arancon and Edwards, 2005). Moreover, vermicompost possesses high ‘P’ content. Application of vermicompost in this treatment could be responsible for the higher soil ‘P’ content. The inoculation of phosphobacteria resulted in the increased availability of phosphorous, since these bacteria helps to degrade the complex forms of phosphate into more soluble and simple forms of phosphorous. The result of present investigation is in agreement with that of Vanilarasu (2011).

The applied organic inputs form a cover on sesquioxides, thus reducing the phosphate fixing capacity of the soil and promote solubilisation of insoluble P fractions resulting into release of available P. The potassium availability was also higher in the treatment combination comprising 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) compare to M_4S_8 (check basin method of irrigation + no manure and no fertilizers). The increase in exchangeable potassium could be due to increased potassium release from farmyard manure. Normally, all the organic manures improve the fertility status of soil due to slow release of nutrients thereby avoiding the wastage. Such manures augment the humus content in soil. This is in concurrence with previous findings of Padmanabhan (2003) in ashwagandha and Vanilarasu (2011) in banana. The combined application of farmyard manure and vermicompost in the present treatment would be the reason which might have caused the mineralization by solublising the insoluble components through the action of organic acids (malic, succinic and oxalic acids) released during decomposition process thereby minimizing losses due to fixation. The increased nutrient in organic manure amended soil was due to the dissolution of native insoluble compounds and reduction of loss through immobilization and chelating action.

The decomposing FYM would have produced organic acids (malic, succinic and oxalic acids) thereby reducing the pH which would have contributed to the formation of soluble hydroxy complexes of Zn, Mn and Fe. Similar line of result was obtained by Nipunage et al. (1996).

Leaf nutrient status

Plant leaf nutrient analysis is a more helpful tool for assessing the content of nutrient in plant system. The actual nutrient concentrations, contents and the rate of changes of these nutrients during vegetative growth and transitional period between the vegetative and the reproductive phase might eventually determine the final reproductive mass. Nutrient content plays a critical role for higher yield and quality of fruits in noni. Nitrogen is an important constituent of amino acids, proteins, enzymes, nucleic acids and chlorophyll content. Phosphorus plays a key role in energy transfer system of plants. Potassium being a protoplasmic factor is also an essential plant nutrient. Many enzymes are activated by potassium and it is also involved in photo and oxidative phosphorylation, thus augmenting the synthesis of energy required for fruit growth. In the present study, application of 100% WRc through drip irrigation + 100% RD of NPK through inorganic fertilizers (M_2S_7) led to accumulation of higher nutrient content in leaves. This might be due to increased nutrient uptake and better moisture availability which could have contributed to higher growth and development of plants (Prakash, 2010). Drip irrigation system provide conducive environment for plant growth and nutrient uptake. Nutrient loss under drip irrigation was meager compared to check basin method of irrigation.

Nutrients applied in the form of inorganic fertilizers may be easily available to plants. This may be the reason for enhancement in leaf nutrient status. Increased nutrient status in leaves may also be attributed due to accumulation of photosynthates (Prakash, 2010). Application of 100% WRc through drip irrigation + 100% RD of NPK through inorganic fertilizers (M_2S_7) registered the highest nutrient content in leaf. Application of macro nutrients had resulted in the enhanced absorption of nutrient by noni crop that ultimately led to higher leaf nutrient status. It is also possible that the application of 100% WRc through drip irrigation + 100% RD of NPK through inorganic fertilizers (M_2S_7) might have activated the physiological processes for the rapid absorption and utilization of nutrients for the primary metabolic processes. Among the organic manure treatment combinations, M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) registered the increased leaf nutrient status compared to M_4S_8 (check basin method of irrigation + no manure and no fertilizers), which might be due to availability of adequate moisture required by the crops to absorb the available nutrients effectively. The continuous availability of required soil moisture content under drip irrigation system may be helped to solubilize the plant nutrient near the root zone and favoured easy absorption of plant nutrients by the noni plant under 100% WRc through drip irrigation. The cyclic regulation and continuous wetting of soil through drip irrigation maintained optimum moisture in the crop root zone. Due to this, the force exerted by the plant to extract water and nutrients would be less.

Added organic manures namely, farmyard manure and vermicompost not only acted as a source of nutrients, but also had influenced their availability. Cumulative effects of these treatments seemed to be adequate supplier of nutrients slowly and steadily in optimum level throughout the crop growth period. The increase in leaf phosphorus content in the M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) over M_4S_8 (check basin method of irrigation + no manure and no fertilizers) may be due to fact that application of FYM along with biofertilizers may be attributed to better availability of P in rhizosphere (Shashidhara, 2000). The complex organic anions chelate Al^{+3}, Fe^{+3} and Ca^{+2}; and decrease phosphate precipitating power of these cations and thereby increase the phosphorus availability. Also, phosphobacteria might have helped in solubilising phosphorous that were immobilized and fixed in soil to utilizable form and aided in easy uptake (Krishnamoorthy and Rema, 2004). Moreover, increased root proliferation due to the application of VAM also might had contributed to the increased uptake of 'P' content from the soil. Similarly, this may also be due to better soil moisture regime prevailing in root zone through drip irrigation which is crucial for better nutrient availability and assimilation as observed by Chauhan et al. (2005) in apple. The treatment combination M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) registered higher leaf potassium content over M_4S_8 (check basin method of irrigation + no manure and no fertilizers). The optimum potassium level of the soils of the experimental plot might have also contributed to this trend. The reason for higher concentration of potassium under various treatments may be the consequence of higher demand of the expanding foliage and increased absorption to maintain the growth (Alexander and Crizinszky, 1992).

From the present study, it could be concluded that application of 100% WRc through drip irrigation + 100% recommended dose of NPK through inorganic fertilizers (M_2S_7) resulted in improved soil and leaf nutrient status of noni.

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Review

M-mode echocardiographic study in dogs

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Echocardiography is a unique non-invasive application of ultrasound for imaging of living heart. It is based on detection of echoes produced by a beam of ultrasound pulses transmitted into the heart. Conventional echocardiographic modalities include two-dimensional (2D), M-mode and Doppler modes. M-mode is the first ultrasound modality used in which the ultrasound beams are aimed manually at selected cardiac structures to give a graphic recording of their positions and movements. M-mode recordings permit quantitative measurement of cardiac dimensions and detailed analysis of complex motion patterns depending on transducer angulation. It facilitates analysis of time relationships with other physiological variables such as echocardiographic, heart sounds, and pulse tracings, which can be recorded simultaneously. However, it cannot be used to measure velocity, the direction or type of the blood flow but can be combined with contrast or colour-coded Doppler studies for accurate timing of flow events. Variations in M-mode echocardiographic parameters with breed, age, sex and body weight occurs and need to be kept in mind while interpreting the findings. Its variables are usually subjected to change and needs experienced sonologist to diagnose any condition. The present review covers the M-mode echocardiographic developmental history in general and its diagnostic role for dogs in particular.

Key words: M-mode, echocardiography, dogs, ultrasound.

INTRODUCTION

Echocardiography, cardiac ultrasound, is an important diagnostic tool in cardiology which has been introduced in the veterinary medicine as a non-invasive method for evaluating the anatomy and function of heart (Boon, 1998). An ultrasound examination of heart and large vessels represent a significant technological advance in veterinary medicine. Echocardiography allows an evaluation of the space relationship between structures, cardiac movement and blood flow features, the precise and non-invasive diagnosis of cardiac alterations, as well as follow-up therapy and to determine the prognosis through direct vision of cardiac chambers (Gugjoo et al., 2013a). It allows assessment of cardiac chamber sizes, cardiac function and blood flow all of which provide information on hemodynamic status and extent of disease process together with follow up therapy (Boon, 1998). Defects which can be visualized including valvular lesions (Bonagura and Schober, 2009), cardiac shunts (Kittleson, 1998), cardiac and thoracic masses, pleural and pericardial effusions (Gugjoo et al., 2013b), myocardial diseases (Gugjoo et al., 2013a), stenotic lesions, congenital and vegetative anomalies (Boon, 1998; Bonagura, 1983). Therefore, it is important that an echocardiographic examination be considered as part of a thorough cardiovascular examination *viz*. clinical radiographic and electrocardiographic examination.

Ability of ultrasonic waves to distinguish between fluid and soft tissues (unlike conventional radiography); to define spatial relationships between structures and to detect quantitative motion has made it a particularly valuable tool in cardiovascular diagnosis (Feigenbaum, 1981). As ultrasound images can discriminate between

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blood filled cardiac chambers and soft tissue structures of heart while radiographs can distinguish lungs from soft tissues and fluid density, echo images are complimentary to radiographic images for cardiac assessment. When complimented with electrocardiographic data, one can arrive at a conclusive diagnosis (Gugjoo et al., 2011).

Echocardiographic examination includes both qualitative as well as quantitative cardiac assessment. For quantitative examination, M-mode echocardiography is primarily being utilised for dimensional measurements and subsequently the functional activities of heart are being calculated. Reliable, normal echocardiographic values for chamber size, wall dimensions and myocardial function are needed for comparison and evaluation of dogs suspected for having heart diseases (O'Grady et al*.,* 1986).

Earlier studies established normal reference values of echocardiographic parameters in general dog and cat population (Lombard, 1984; Jacobs and Knight, 1985). Later on studies reported the influence of body weight, body surface area and heart rate on selected echocardiographic measurements in both dogs and cats as previously described for humans. As echocardiographic values show significant breed variations, it is important to know the normal echocardiographic value for each breed of dog (Thomas et al*.,* 1993; O'Leary et al*.,* 2003). Therefore, currently stress is being given for breed specific studies as echocardiographic reference ranges derived from some breed of dog may be misleading to other dog breed (Snyder et al*.,* 1995; Jacobson et al., 2013).

Historical background

Ultrasound history can be correlated with the advent of piezoelectric crystals (basic units for ultrasound production) discovered by Curie and Curie. It was observed that if piezoelectric crystals are compressed, an electric charge is produced between opposite surface and if electric potential is applied to such crystals, compression and decompressed rare fraction occurs depending upon the polarity of electric charge and thus very high frequency sound is produced (Curie and Curie, 1880). After a gap of around 70 years, Kiedel in 1950 first used transmitted ultrasound waves through the heart and recorded the acoustic shadow on the other side of the chest. He found that changes in cardiac volume would cause change in the acoustic shadow. In 1952, the first two-dimensional ultrasound unit appeared (Weyman, 1982) and in 1954, Edler and Hertz initiated the use of pulsed, reflected ultrasound for the examination of heart. They were able to identify the signal that moved with cardiac action and started in earnest, the era of time motion mode. They found this signal to be coming from anterior leaflet of mitral valve on their retrospective study on autopsy investigation, contradicting their initial thought of signal coming from posterior left atrial wall. Later, Wild et al. (1957) used the reflected ultrasound to examine the autopsy specimen of heart.

In 1973, instrumentation for satisfactory clinical use of ultrasound in cardiac investigation was developed. In 1977, M-mode as a clinically useful tool in veterinary medicine was described (Boon, 1998). Since then it has developed into a prominent diagnostic tool in veterinary cardiology. Earlier approach to M-mode echocardiography was invasive and employed implanted catheters and catheter tipped transducers, removal or displacement of lung lobes and transducer placement directly on cardiac surface (Bishop et al., 1969; Franklin et al., 1977). Transesophageal and transcutaneous were two popular invasive echocardiographic techniques with transesophageal echogram first reported by Frazin et al. (1976). In transesophageal technique, distance from the canine tooth to the fourth intercostal space was measured and the oesophageal probe transducer was introduced through oesophagus to this site, which was considered a good indicator of mitral valve location (Dennis et al., 1978).

M-mode echocardiography provide a non- invasive method of evaluating cardiac chamber size, interventricular septum, left ventricular free wall thickness, systolic and diastolic function (Calvert and Brown, 1986). Jacobs and Mahjoob (1988a) recorded M-mode echocardiograms from 10 conscious, clinically normal dogs at various heart rates during atrial pacing. Heart rate was recorded as cycle length (seconds), and measurements were made only during sustained 1:1 atrial-to-ventricular conduction. In all dogs studied, there was a significant ($P<0.01$) positive correlation of left ventricular internal chamber dimension in diastole and systole to cycle length. Also, there was positive correlation between these left ventricular dimensions and the square root of cycle length.

The same authors adopted multiple regression analysis in dogs using body size in cardiac cycle length in predicting echocardiographic variables and found positive correlation between left ventricular internal chamber dimension in diastole and systole and body weight, body surface area, cycle length, square root of cycle length, and shortening fraction had a significant negative correlation and left ventricular free wall measurements had a significant positive correlation to body weight and body surface area. For these echocardiographic variables, correlation to square root of cycle length was insignificant and a multiple regression model was not helpful in developing confidence intervals. Septal wall measurements were not correlated with body weight, body surface area, cycle length, or square root of cycle length. They further found that fractional shortening and ejection fraction estimated by M–mode measurements decreased with increased body weight (Jacobs and Mahjoob, 1988b). Lombard (1984) and Cornell et al. (2004) later reported that the various variables that could influence echocardiographic evaluation of systolic function include age, sex, breed, weight and co-morbid factors (hypothyroidism and hydration factors).

ECHOCARDIOGRAPHIC STUDY IN CANINES

The earliest work carried on dogs was conducted by Mashiro et al. (1976) who performed uni-dimensional M-mode echocardiography as a non- invasive tool for the quantitative study of heart. The first structure to be identified during the development of echocardiography was the mitral valve and detailed structures of mitral valves together with ventricular walls were studied (Yamamura et al., 1977). Later studies focused on these structures in normal (Dennis et al., 1978) as well as abnormal dogs (Pipers et al., 1981) affected with left sided heart failure. The normal dogs have a characteristic mitral valve motion in systole and diastole and they open in response to early rapid diastolic filling of the ventricle shortly after the completion of T-wave of electrocardiogram. The anterior leaflet inscribes an 'M' like motion during diastole with initial opening usually greater and longer than atrial systole. The posterior leaflet forms images of opposite configuration of 'W', but of lesser magnitude. There is a definite alteration of these relationships during cardiac diseases (Pipers et al., 1981). Different components of valve excursion observed were: C point – valve cooptation during ventricular systole, D point – initial opening during diatole, E point – maximal opening during rapid ventricular filling, F point – end of rapid ventricular filling and A point – maximal opening during atrial systole (Figure 1).

The basic principles of M-mode echocardiography, including technical considerations were put forward by Bonagura (1983). He observed that normal structures of heart can be scanned by changing the angle or location of transducer. If the transducer is maintained in a constant position during the cardiac cycle, the phasic motion of cardiac structures can be recorded. The resultant record is termed as motion or M-mode echocardiogram. A year later, Thomas (1984) performed systemic studies to determine optimum transducer location and orientations for standardizing imaging of various cardiac structures to validate cardiac anatomy and function in dogs by two-dimensional and M-mode echocardiography. The two most useful transducer locations observed were the right intercostal and left intercostal locations in a laterally recumbent dog imaged from a dependent side using a slit on the table. Potential echo window for right intercostals space was found to be between 3rd and 7th intercostal space with best results in between 3rd and 5th intercostal space, 1 to 8 cm, lateral to sternum. Left atrium was imaged best with long axis plane. Papillary muscles were seen at 4 and 6 o'clock position in the short axis view. Potential echo window for left intercostal space location was found to be between 3rd to 7th intercostal spaces with best results between 3rd to 6th intercostal spaces, 1 to 5 cm, lateral to sternum. This location was further sub-divided between left cranial intercostal and left caudal intercostal locations. It was reported that left-sided cardiac structures were consistently easier to image as compared to right-sided cardiac structures. The structure images were validated using micro bubble laden saline injections and by insertion of intramedulary pins in to the heart of dog along the plane of ultrasound beams with subsequent necropsy confirmation of structures penetrated by pins.

Initially, reference values for the general dog population were developed but later on the effect of sex and body weight was observed. Boon et al. (1983) determined the reference ranges of echocardiographic structures and their relationship with body weight and body surface and they found that statistically significant correlation exists between body surface area and aortic, left atrial, left ventricular, septal and posterior wall dimensions and mitral valve amplitude of motion while velocity of circumferential fibre shortening, ejection time, percent systolic thickening of septum and posterior wall, percent change in minor diameter and mitral valve velocities were not statistically correlated. Later Lombard (1984) recorded M-echocardiogram from healthy dogs, awake and unsedated, in left lateral recumbent position. Echocardiographic measurements were taken and correlated with body weight using linear regression equation. The left ventricular internal dimension in systole and diastole, the left ventricular wall thickness, the aortic root dimension, and the left atrial dimension had high correlation (r^2) ranging from 0.756 to 0.619. The fractional shortening of the left ventricle in systole (39 ± 6%) and the left atrial to aortic root ratio (0.99 ± 0.10%) were not linearly related to body weights and had constant values.

Later O'Grady et al. (1986) studied tomographic planes for echocardiography of normal canine heart and were further elucidated and compared with that of previous studies by subsequent researchers. Normal chamber and wall dimensions were established to derive indices for normal ventricular functions and comparison of results obtained when structures were imaged and measured from different tomographic planes. The imaging planes were described using three variables relative to the transducer and interrogating beam *viz*. transducer location on chest wall, approximate direction of centre of beam and directions of extremities of ultrasound plane. The intracardiac structures were identified on the bases of position within chest, general anatomic appearance, motion, association with known structures and selective injection of echo dense micro bubbles. The measurements were made from the trailing endocardial edge of anterior wall to the leading endocardial edge of posterior wall for every structure.

However, later studies recommended leading edge method (Wyatt et al., 1980) in which measurements are made from leading endocardial edge of anterior wall to leading endocardial edge of posterior wall (Figure 2).

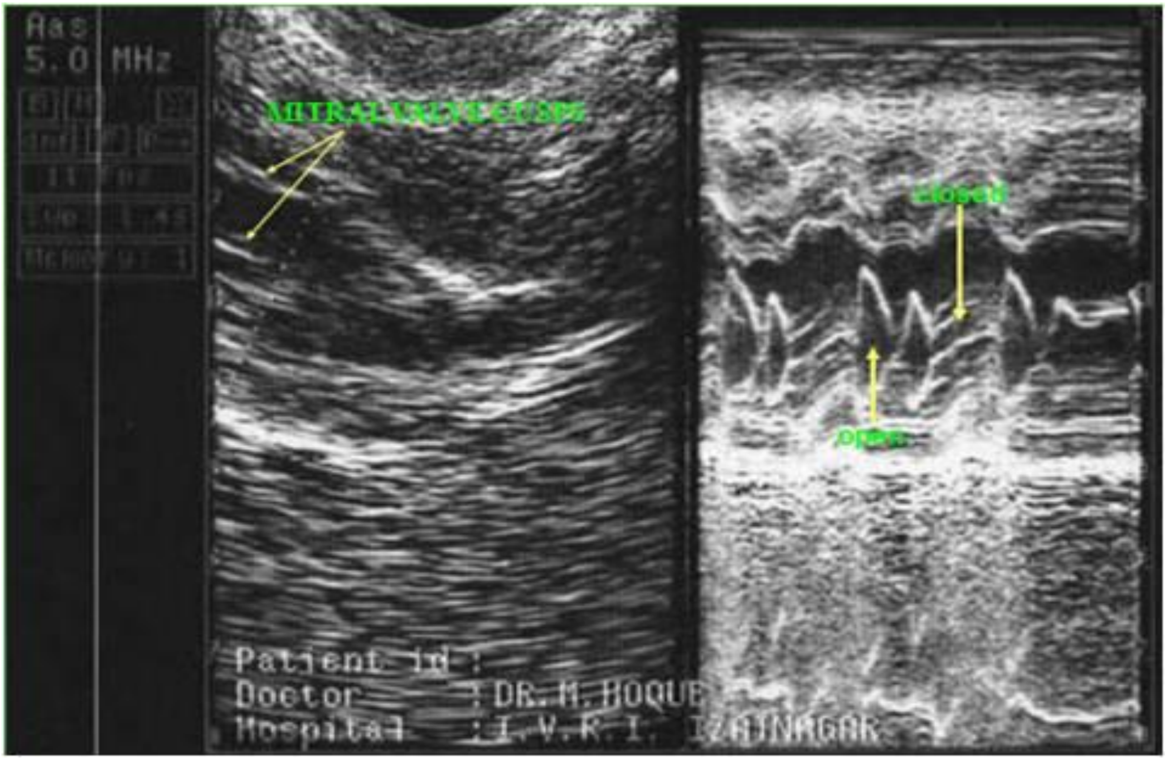

Figure 1. Mitral valve in M-mode showing M and W images of anterior and posterior valves.

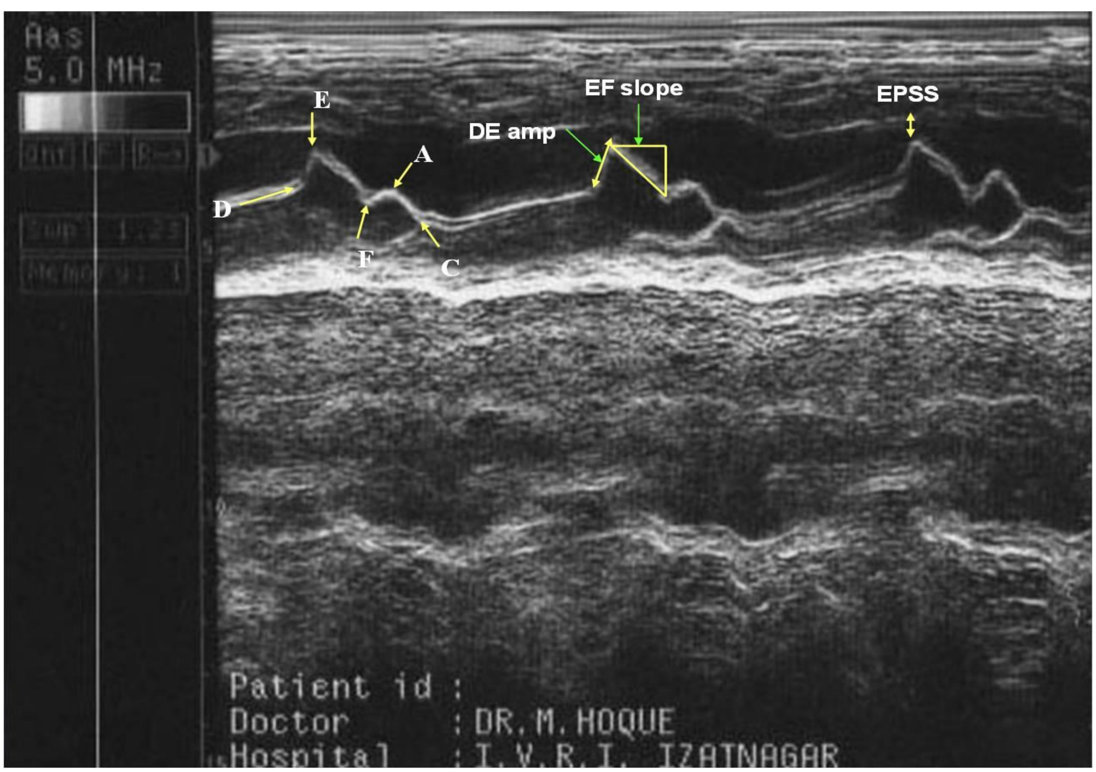

Figure 2. Marking of Mitral valve leaflets on M-mode echocardiogram: D point – initial opening during diastole; E point – maximal opening during rapid ventricular filling; F point – end of rapid ventricular filling; A point – maximal opening during atrial systole; C point – valve cooptation during ventricular systole.

Quantitatively different parameters that were determined include fractional shortening, left ventricular volume, stroke volume, ejection fraction, fractional thickening of left ventricular free wall & interventricular septum and ratio of mitral valvular orifice area to left ventricular internal cavity area. It was found that all linear and area measurements were significantly correlated to body size while most indices of left ventricular function were independent of body weight.

Relative development of heart with body weight observed by M-mode echocardiography was measured by Sisson and Schaeffer (1991). Echocardiographic measurements were obtained from 16 English Pointers at 1, 2, 4 and 8 weeks of age and at 3, 6, 9 and 12 months of age. Left atrial (LA), aortic (Ao), left and right ventricular internal dimensions, interventricular septal and left ventricular wall thickness increased in curvilinear fashion relative to increasing body weight. Least-squares regression analysis, performed on logarithmically transformed data, was used to develop power-law equations describing the relationship of echocardiographic measurements to body weight.

Linear dimensions of the LA, Ao, left and right ventricular internal dimensions and interventricular septal and left ventricular wall thickness changed proportionally to slightly differing exponential powers of body weight (BW), varying from 0.31 to 0.45 ($BW^{0.31}$ to $BW^{0.45}$). Fractional shortening and the LA/Ao ratio decreased slightly but significantly as the body weight increased. Indexing echocardiographic measurement to $BW^{1/3}$ was more appropriate than indexing such measures linearly to body weight, offering a practical method for developing accurate normative graphs or tables for M-mode echocardiographic dimensions on growing dogs.

With age cardiac dimensions increase with significant effect observed only on the left ventricular wall thickness after animal attains maturity (Sisson and Schaeffer, 1991; Bayon et al., 1994). Heart rate has an inverse relation with the left ventricular systolic and diastolic dimensions and left atrial size (Jacobs and Mahjoob, 1988a)

Varability of left ventricular (LV) M-mode echocardiogram in relation to axis (Long v's Short axis) in healthy and diseased dogs was observed by Schober and Baade (2000). Mean left ventricular diameter (LVD) in systole and diastole and mean interventricular septum (IVS) in systole were significantly ($P < 0.001$) larger when measured from short-axis compared to long-axis measurements. An increased magnitude of measurement resulted in increased differences between the methods for LV dimensions and fractional shortening. Differences between the two methods were small and within clinically acceptable limits in normal dogs. However, in some of the dogs with cardiac abnormality, one or more LV M-mode derived dimension obtained from one imaging plane did not agreed sufficient enough with the same measure from the other plane.

Only for measurement of FS was there good agreement between methods in dogs with cardiac disease. Therefore, with the exception of FS, data gained from LV short-axis and long-axis M-mode recordings should not be used interchangeably in dogs with cardiac disease. In the same year, four 2-dimensional echocardiographic methods were used for evaluating left atrium (LA) size in dogs *viz*. LA diameter in short axis, LA diameter in long axis, LA circumference in short axis, and LA cross-sectional area in short axis (Rishniw and Erb, 2000). Comparisons of these LA dimensions to appropriate aortic dimensions provided body weight-independent estimates of LA size. They observed strong associations of LA dimensions with body weight (r^2 = 0.76-0.88). Comparable body weight-independent 2D echocardiographic estimates of LA size in short axis exceeded historical M-mode reference intervals.

The left ventricular volumes (end diastolic volume and end systolic volume) are being calculated by Teicholz formulae (Teicholz et al., 1976) as under:

End diastolic volume (EDV in ml) = 7 (X) $LVDd^3$/ (2.4+ LVDd)

End systolic volume (ESV in ml) = 7 (X) $LVDs^3$/ (2.4 +LVDs).

The rest of the parameters are calculated using established formulae (Kienle, 1998; Riedesel and Knight, 2005) as follows:

Stroke volume (SV in ml) = EDV - ESV

Ejection fraction (%) = (EDV- ESV) (X) 100/ EDV

Left ventricle fractional shortening (LVFS in %) = (LVDd – LVDs) (X) 100/ LVDd

To determine the reference values of M-mode echocardiogram in dogs, different models (linear, logarithmic and polynomial) were compared (Goncalves et al., 2002). Logarithmic or second- order polynomial models predicted reference values of M-mode measurements for size of the cardiac chambers were found better than simple linear models for dogs with a wide range of body weights. However, no significant differences were observed with respect to cardiac wall thickness.

Brown et al. (2003) introduced a novel method for quantitative echocardiographic interpretations based on the calculation of ratio indices in which each raw M-mode measurement was divided by the aortic root dimension (Ao) (Figure 3). "Aorta-based" indices were calculated with the animal's measured aortic root dimension (Ao (m)) as the length standard. Conversely, "weight-based" indices employed an idealized estimate of aortic dimension (Ao(w)) with a weighted least squares linear regression against the cube root of body weight (Ao(w) =

Figure 3. Measurements of left ventricular structures during systole and diastole (LVDd,s-left ventricular diameter during diastole and systole; IVSd,s - interventricular diameter during diastole and systole; LVPWd,s - left ventricular posterior wall during diastole and systole).

kW(1/3)). Use of these indices circumvented undesirable statistical characteristics inherent in linear regression of echocardiographic dimensions against body weight and, to a lesser extent, body surface area. Compared with the regressions, ratio indices resulted in substantial refinement of the predictive range for each M-mode measurement in dogs, particularly with decreasing body size.

Weight-based indices outperformed aorta-based indices in this regard. To refine the predictive range, neither type of index was clearly advantageous in cats compared with the simple average method typically employed for that species. Several of the raw M-mode measurements, however, were correlated with body weight in cats and horses, indicating the need for an appropriate correction for body size in these species. The ratio index method was suitable for this purpose. Summary statistics derived from normal dogs (n = 53), cats (n = 32), and horses (n = 17) were presented for each index, including novel clinical indices calculated from area ratios. The latter were designed to represent body size-adjusted left ventricular stroke area (that is, volume overload) and myocardial wall area (that is, hypertrophy). This was followed by introduction of the more advanced echocardiographic technique which explained more so than other diagnostic techniques, echocardiography is highly operator dependent and relies on the proper acquisition and interpretation of results by an examiner who is familiar with the principles, capabilities, and limitations of ultrasound imaging (Oyama, 2004). He reviewed the basics of echocardiography, measurements of cardiac dimensions, and assessment of cardiac function and introduced emerging technologies that expanded the capabilities of the echocardiography examination.

Oyama and Sisson (2005) assessed cardiac chamber size using Anatomical M-mode (AMM) and compared the results of the AMM and conventional M-mode (CMM) with 2-dimensional (2D) study via linear regression and calculation of a coefficient of correlation. In healthy dogs, cardiac AMM measurements were associated with greater accuracy and less variability than CMM. AMM has potential to improve quantification of cardiac dimensions. Chetboul et al. (2005) studied the effects of animal position and number of repeated measurements on selected two-dimensional and M-mode echocardiographic variables in healthy dogs and concluded that within day variability of conventional echocardiography performed with the dog in the standing position was at least as good as that obtained with dog in lateral recumbency for most measured variables. Single measurements of each variable may be sufficient for trained observers examining dogs that do not have arrhythmia. The standing position should be used, particularly for stressed or dyspnoeic dogs.

ECHOCARDIOGRAM OF CARDIAC PATIENTS

Echocardiographic evidence of myocardial failure include decreased fractional shortening, decreased septal and left ventricular free wall percent systolic thickening, increased end point septal variation (EPSS), increased left atrial systolic diameter, increased LA/Ao ratio, and decreased aortic excursion. Bonagura et al. (1985) diagnosed congenital heart defects by echocardiography and found it superior to other available non-invasive studies in the recognition and assessment of malformation of the heart. Most frequently encountered cardiac malformations that can be diagnosed include left-to- right shunts, like atrial septal defect, ventricular septal defect, and patent ductus arteriosus; ventricular outflow obstructions like subaortic stenosis and pulmonic valve stenosis; insufficiency of the mitral or tricuspid valves owing to atrioventricular valve dysplasia; complex lesions like teratology of Fallot and reversed patent ductus arteriosus. DeMadron et al. (1985) studied normal and paradoxical ventricular septal motion in the dogs and suggested that abnormalities in ventricular septal motion should cause a clinician to suspect right volume and pressure overload.

Echocardiographic features of pericardial effusion echo-free separation of parietal and visceral pericardium, dampening of parietal pericardial motion, exaggerated or paradoxical motion of intracardiac structures and thickened epicardial echoes (Gugjoo et al., 2013c; Bonagura and Pipers, 1981). Bonagura and Frank (1983) studied valvular lesions in other disease conditions. Studies on valvular endocarditis in a dog, cow and horse revealed following features of valvular lesions – irregular thickening of valves, multiple linear echoes in aortic root, diastolic prolapse of aortic vegetations and diastolic fluttering of aortic valves. In the same study consequences of aortic regurgitation were also elaborated as – left ventricular dilatation, diastolic fluttering of mitral valve, premature closure of mitral valve and left ventricular hyperkinesias.

ECHOCARDIOGRAPHIC STUDY IN DIFFERENT DOG BREEDS

The echocardiographic values show significant breed variations and it is important to know the normal echocardiographic values for each breed of dog (Jacobson et al., 2013; Gugjoo, 2011). Therefore, stress has given for breed specific studies as echocardiographic reference ranges derived from some breed of dog may be misleading to other breed of dog (Snyder et al., 1995). The variation in echocardiographic values among different breeds may be due to variation in thoracic shape leading to the variation in the direction of the ultrasound beam. Table 1 presents the breeds for which the reference ranges of M-mode echocardiographic measurements have been standardised.

The major differences that are being observed in dog breeds are related to the left ventricular dimensions or the systolic functional parameters. The larger left ventricular dimensions has been reported in athletic breeds *viz*. Whippets (Bavegems et al., 2007), Greyhounds (Page et al., 1993), Alaskan Sled Dogs (Stepien et al., 1998) and border Collies. This is quite obvious as the heart size is a key determinant of cardiac output, which in turn determines the exercise performance in athletic breeds. To consider it only due to the exercise, it may not be justifiable as even the dogs which do not have daily active training like Border Collies still have the higher values for the left ventricular parameters (Jacobson et al., 2013). It is also unlikely that the larger left ventricular diameters in Border Collies may arise due to slower heart rate, as no correlation between heart rate and chamber size was found. With respect to the fractional shortening (FS), usually smaller values are being observed in athletic dogs like the Border Collies, Whippets, Greyhounds, etc. (Jacobson et al., 2013).

CLINICAL APPLICATIONS

LVID parameter is of great help in the direct assessment of cardiomyopathies. In case of hypertrophic cardiomyopathy, left ventricular internal diameter decreases in both systole and diastole while in dilation cardiomyopathy, both these parameters increase (Boon, 1998). Unlike ventricles, left atrium increases in size in response to both pressure and volume overload. For confirmatory diagnosis, primary abnormality which is causing the increase in atrial pressure and volume should be identified (Kienle, 1998). Absolute increase in the left atrial diameter is not confirmatory of left atrial dilation and left atrium to aortic root ratio (LAD/AoD) is a better parameter to assess this abnormality. Instead of going for comparison of absolute measurement in a normogram or with a regression equation, this ratio can be solely relied upon to assess left atrial enlargement. A significant increase in left atrial dimension results in a greater left atrial to aortic root ratio with advancing age, as aortic root significantly diminished with age (Vollmar, 1999).

Decreased systolic function evidenced by reduced fractional shortening (FS%) and ejection fraction (<45%) is the most commonly used clinical measurement of the left ventricular systolic function and is considered a good indicator of ventricular compliance and contractility (Voros et al., 2009). Fractional shortening is an important parameter to distinguish between hypertrophic and dilated cardiomyopathy (Borgarelli et al., 2007). The three conditions that affect the fractional shortening are preload, afterload and contractility and each one of these may act individually or together to affect the FS (Boon, 1998). Ejection fraction (EF) is quite constant in mammals ranging in size from a rat to horses (Riedesel and Knight, 2005).

Clinical significance of EPSS lies in the fact that during the left ventricular or left atrial dilation, an increase in the value of this parameter is seen as the mitral valve is pushed more posterior in these conditions (Feigenbaum,

Table 1. The breeds for which the reference ranges of M-mode echocardiographic measurements have been standardised.

S/N	Breed	Reference(s)
1	English Pointer	Sisson and Schaeffer (1991)
2	Beagle	Crippa et al. (1992)
3	Miniature Poodle, Welsh Corgi, Afghan Hound and Golden Retriever	Morrison et al. (1992)
4	Greyhound	Page et al. (1993), Snyder et al. (1995)
5	Spanish Mastiff	Bayon et al. (1994)
6	Boxer	Herrtage (1994)
7	New Foundland, Wolfhound and Great Dane	Koch et al. (1996)
8	Whippet, Italian Greyhound and Greyhound	DellaTorre et al. (2000)
9	Bull Terrier	O'Leary et al. (2003)
10	Karabash	Kayar and Uysal (2004)
11	German Shepherd	Kayar et al. (2006), Muzzi et al. (2006)
12	Whippet	Bavegems et al. (2007)
13	Indian Spitz	Saxena (2008)
14	Hungarian breed	Voros et al. (2009)
15	Indonesian mongrel	Noviana et al. *(*2011)
16	Labrador Retriever	Gugjoo (2011)
17	Border Collies	Jacobson et al. (2013)

1981). However, EPSS is only a qualitative indication of the left ventricular function. It should be noted that a normal EPSS value might also occur in the presence of severe cardiac disease. It is a simple measurement, which if altered, should alert the examiner to the possibility of cardiac disease (Kirberger, 1991). Moreover, excessive EPSS correlates well with decreased ejection fraction, although EF may be subnormal while the EPSS remains normal (Massie et al., 1977).

M-mode echocardiography is limited to quantitative measurements of the chamber walls or internal dimensions and cannot be used to measure velocity or the direction of blood flow. However, it can be combined with contrast or colour-coded Doppler studies for accurate timing of flow events (Bonagura and Blissitt, 1995). Its variables are usually subjected to change and needs experienced sonologist to diagnose any condition. It is helpful diagnostic technique when employed with other diagnostic modalities (Gugjoo et al., 2013b).

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Biomass yields and crude protein content of two African indigenous leafy vegetables in response to kraal manure application and leaf cutting management

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African indigenous leafy vegetables have the important role of providing essential minerals, vitamins and amino acids in diets of poor smallholder farmer households in sub-Saharan Africa. A study was conducted to quantify the influence of applying cattle and goat manure on the biomass yields and crude protein content of two commonly used African leafy vegetables (*Cleome gynandra* and *Amaranthus hybridus*) when subjected to varying leaf cutting management. Treatments for each vegetable consisted of a combination of three manures (control, cattle and goat) and three cutting regimes (cutting edible leaves, all harvestable leaves and cut only at the end) utilised in randomised block design. The results showed significant increase in leaf biomass yields and crude protein content of both vegetables due to manure application. Goat manure was superior to cattle manure due to its higher quality in terms of nutrient content and lower C:N ratio. Cutting the edible leaves more frequently, every fortnight, was associated with the highest leaf biomass yield and crude protein in treatments where manure was applied. It was concluded that potential exist for smallholder farmers to benefit from adopting appropriate manure and leaf cutting regime. A combination of goat manure and frequent cutting of the tender edible leaf tips is recommended. The results point to the potential of maximizing biomass yield and quality of the vegetable leaves by adopting appropriate nutrient supply and leaf cutting regime.

Key words: Animal kraal manure, nutritional security, smallholder farmers, indigenous vegetables, leaf defoliation.

INTRODUCTION

African indigenous leafy vegetables, also referred to as traditional leafy vegetables, are crops that grow wild or are cultivated and are gathered or harvested for food within a particular African ecosystem (Alleman et al., 1996; Aphane et al., 2003). Van Rensburg et al. (2007) and Schippers (2000) have described leafy vegetables as plant species of which the leafy parts, which may include young succulent stems, flowers and very young fruits are used as vegetables. Oniang'o et al. (2004) and Flyman and Afolayan (2006a) have suggested that the food and nutritional insecurity that most African countries face today could potentially be mitigated and sustainably reversed if a manifest change can be realised through the appreciation and domestication of African indigenous foods including leafy vegetables. This is because indigenous leafy vegetables constitute important sources

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of both micronutrients and non-nutrient bio-active phytochemicals that have been linked to protection against cardiovascular and other degenerative diseases (Akhtar et al., 2012; Aphane et al., 2003; Flyman and Afolayan, 2006a; Modi et al., 2006, Uusiku et al., 2010; Smith and Eyzaguirre, 2007). In South Africa, however, African indigenous vegetables are mostly underexploited and have received insufficient attention within the mainstream research on food security and management interventions (Van Rensburg et al., 2004). The consumption of African indigenous vegetables has however increased over the years in South Africa (Venter et al., 2007; Van Rensburg et al., 2004). The reawakening of demands for superior nutrition and health by modern communities has gradually created an increase in consumer demand for traditional food crops and African indigenous leafy vegetables are on the spotlight again due to their superior nutritive and medicinal value (Flyman and Afolayan, 2006a; Mwangi and Kimathi, 2006; Smith and Eyzaguirre, 2007; FAO, 1988).

The yield of leafy vegetables has been shown to be affected by the leaf cutting regime and sequence (Diz et al., 1995). In the context of African tradition, there are many techniques used to harvest African indigenous leafy vegetables (Chweya and Mnzava, 1997). In many African communities, the harvesting of the leaves is done sequentially at different times during the growing period to enable the plant to grow and produce more leaves (Schippers, 2000). In some cases, African indigenous leafy vegetables can be harvested by uprooting the whole plants or by cutting the top part, cutting back to ground level or picking individual leaves or leafy branches at frequent intervals (Mnzava, 1997). Defoliation is an important leaf management factor, especially in the productivity of C_4 crops such as leaf amaranth (Abou-khalefa et al., 2008). In leaf amaranth, and other vegetables, the type and frequency and stage of development of leaves that are removed can have a significant effect not only on the development (Baloyi et al., 2013; Odeleye and Olufolayi, 2010; Lestiene et al., 2006), but also on the yield and quality of leaves (Diz et al., 1995). The harvesting of consumable parts of indigenous leafy vegetables among rural households generally involves different practices, which include uprooting the entire young plants, cutting back established plants to encourage growth and picking of the top part of stem and branches close to the growing point (Schippers, 2000).

Soil fertility depletion in small scale farming areas has been cited as a fundamental biophysical cause of the declining per-capita food production in sub-Saharan Africa (Bationo and Mokwunye, 1991). Soil fertility problems under small scale farming in South Africa are no exception. Chemical fertilisers are expensive for the poor farmers who often utilize African leafy vegetables (Van Rensburg et al., 2003). In the case of the South African smallholder sector, which is largely responsible for the production of most African indigenous leafy vegetables, animal manures have long been the primary way in which plant nutrients are returned to cultivated soils (Van Averbeke and Yoganathan, 2003; Edmeades, 2003). Kraal manure is an important resource for the supply of plant nutrients especially nitrogen and phosphorus under most crop production systems (Mhlontlo et al., 2007).

The production of African indigenous leafy vegetables has been advocated as part of a food security strategy aimed at combating micronutrient deficiencies among many rural communities in South Africa (Faber et al., 2010; Van Rensburg et al., 2004). Consequently, many smallholder farmers, who are presently largely responsible for the production of African indigenous leafy vegetables, have taken to the cultivation of indigenous leafy vegetables on their farms (Cunning et al., 1992; Odhav et al., 2007). However, there is generally limited information on the agronomic practices related to the cultivation of African indigenous vegetables including the effects of cutting on the leaf yields of African indigenous vegetables and how this would interact with availability of soil nutrients. Harvesting of leaves of leafy vegetables for human consumption is becoming an important management practice among African communities (Baloyi et al., 2013; Materechera and Medupe, 2006). This is because leaf harvesting practices and procedures have the potential to reduce or improve the yield of essential components of the crop (Rahman et al., 2008). Saidi et al. (2010) and Baloyi et al. (2013) have shown that the intensity or extent, frequency and timing of foliage removal from leafy vegetables can affect the performance, in terms of biomass yield and nutritional quality of the crop. Furthermore, information on the influence of kraal manure on growth of African indigenous leafy vegetables especially under smallholder farming management is still rudimentary. This information is important as it underpins the agronomic practices necessary for the production of African indigenous leafy vegetables.

The aim of this study was therefore to investigate the response of two commonly utilized African indigenous leafy vegetables, amaranth (*Amaranthus hybridus*) and cleome (*Cleome gynandra*), to additions of different kraal manures (cattle and goat) and leaf cutting management. It was hypothesized that the biomass yield and quality of the two African indigenous leafy vegetables will improve with manure and appropriate leaf cutting management regime.

MATERIALS AND METHODS

Soil sampling and analysis

The soil used was collected at Molelwane University farm located 8 km from the city of Mafikeng (25°48’ S 25°38’ E) on the road to Gaborone, Botswana. The soil is a dark reddish brown sandy loam classified as Hutton form according to the South African Soil Classification System (Soil Classification Working System, 1991). It

Table 1. Dates of cutting the leaves of *A. hybridus* and *C. gynandra* and mean daily temperature during the growing period.

Activities	*A. hybridus*		*C. gynandra*		Mean daily temperature (°C)
	Date	WAT	Date	WAT	
Transplanting	13th Oct 2010	0	15th Oct 2010	0	n/a
Thinning	25th Oct 2010	2	28th Oct 2010	2	25 ±3.5
1st cutting	7th Nov 2010	4	12th Nov 2010	4	24 ±3.8
2nd cutting	16th Nov 2010	5	21th Nov 2010	5	27 ±2.3
3rd cutting	22th Nov 2010	6	28th Nov 2010	6	22 ±3.6
4th cutting	29th Nov 2010	7	5th Dec 2010	7	24 ±2.6
5th cutting	6th Dec 2010	8	12th Dec 2010	8	27 ±3.2
Harvest	15th Dec 2010	9	18th Dec 2010	9	24 ±2.5

WAT = Weeks after transplanting. n/a=not applicable.

was collected randomly at a depth of 0-20 cm from a 0.5 ha area of uncultivated land within the farm whose natural vegetation is composed of grasses with scattered shrubs and bushes of mostly *Acacia* species.

The soil was air dried, passed through a 2 mm sieve and analysed. Organic carbon was determined using the procedure of Walkley-Black method (Okalebo et al., 1993). Soil pH and EC were determined as outlined by The Non-Affiliated Soil Analysis Work Committee (1990). Available P was measured using the Bray 1 method (Bray and Kurtz, 1945). Extractable cations were extracted with 1.0 N ammonium acetate (Anderson and Ingram, 1993) and analysed for the elements (Ca, K, Mg) using atomic absorption spectroscopy.

Collection and analysis of manure samples

Both cattle and goat kraal manures were collected with a spade from kraal floors at Molelwane University research farm. Both manures were air dried and passed through a 4 mm sieve to homogenize and achieve proper mixing with soil. The manure was thoroughly mixed with soil (1:2 ratio of manure: water, v/v) in 7 L capacity plastic garden pots with bottom holes to allow drainage of excess water. The soil:manure mixture was kept moist for 3 weeks to allow decomposition to commence before planting. The mixture was kept moist to near field capacity to speed up the decomposition and mixing of manure and soil. The manure was analysed for moisture, ash, organic carbon, total N and P, pH and EC using by the procedure described by Okalebo et al. (1993). Four replicate sub-samples were analysed for each manure type.

Treatments and experimental design

Two separate experiments were conducted at the same time which involved two African indigenous leafy vegetables species, viz amaranth (*A. hybridus*) and cleome (*C. gynandra*). For each vegetable species, there were nine treatments resulting from a combination of three types of manure (M) and three cutting management (C) The treatments were utilized in a 3 × 3 factorial. The factors were three types of kraal manure (cattle, goat and control) and three leaf cutting techniques. The three cutting techniques involved (i) cutting all leaves throughout: this involved cutting by hand all the fully extended young and mature leaves, (ii) cutting only edible tips which involved cutting all young but fully extended leaves, usually pale green in colour, smoother and tender than mature leaves, and (iii) cutting once at final cut. The treatments were laid in a Randomized Complete Block Design with four replicates.

Raising and transplanting of seedlings

Seeds of the two indigenous vegetables (*A. hybridus* and *C. Gynandra*) were sown in seedling trays filled with growing media hygromix. The seedling trays were kept moist by watering regularly using a watering can whenever the growing medium looked to be dry. The seedlings were transplanted after they had grown 5 to 6 leaves. Three seedlings were transplanted into large 7 L PVC pots with perforations at the bottom to allow drainage. They were later thinned to leave two plants per pot. Seedlings were watered regularly to ensure that the soil was moist throughout the growing period. The plants grew for two months in a screen net house where temperature was controlled by a fun. Weeds were uprooted by hand whenever they appeared and Aphids were controlled by applying Malathion (50% EC) while locusts were picked by hand.

Leaf cutting management

In both vegetable species, cutting of leaves began three weeks after transplanting when the plants showed an extended flower stalk of at least 10 cm. The leaves were cut by hand once every week over a two month period as shown in Table 1. After cutting, the fresh leaves were weighed to obtain biomass yields. The height of each plant was measured at the final cut using a ruler. The harvested materials were placed in envelopes and dried in the oven set at 60°C for 48 h and weighed to obtain dry biomass yields. The total biomass of leaves for each treatment was obtained by adding the yields for all the cuttings during the experiment.

Determination of crude protein in leaves

The harvested leaves from both vegetable species were analysed for crude protein content following the procedure described by the AOAC (1990). The leaves from all cuttings in each treatment were bulked and a sample was collected and ground in a Wiley mill with 0.5 mm sieve. About 0.5 g of the ground plant material was placed digested in Kjeldahl tube and crude protein was calculated by first determining the percent N and multiplying it by 6.25 to obtain crude protein (AOAC, 1990).

Table 2. Properties of manure used in the study.

Property	Unit	Cattle	Goat
pH		7.9	7.6
Organic carbon	%	42	47
Total nitrogen	%	1.81	2.53
Total phosphorus	%	1.04	0.94
Electrical conductivity	mS cm^{-1}	4.45	5.9
Ash	%	27.07	19.99
Moisture content at sampling	%	3.38	3.57
C:N ratio	-	23:1	18:1
C:P ratio	-	40:1	50:1

Values are means of four replicates.

Table 3. Properties of soil used in the study

Property	Unit value
Sand (%)	68.7
Clay (%)	16.9
Silt (%)	14.4
Textural class	Sandy loam
Soil pH (KCl)	5.38
Organic carbon (%)	0.43
Available phosphorus (%)	1.2
Total nitrogen (%)	0.49
Electrical conductivity (ms cm^{-1})	0.07
K^+ (mg kg^{-1})	418
Ca^{2+} (mg kg^{-1})	614.19
Mg^{2+} (mg kg^{-1})	240.28

Values are means of four replicates.

Statistical analysis of data

All the data was subjected to analysis of variance (ANOVA) using the General Linear Model procedure of the Statistical Analysis System (SAS) programme (SAS Institute Inc., 2006). Tukey's t test was used to compare treatment means at 5% probability.

RESULTS

The goat manure had a higher concentration of nutrients and lower C:N ratio than the cattle manure (Table 2). Both manures had not decomposed completely. Table 3 shows that the soil pH was optimum for most crops. The soil has low organic carbon, available phosphorus and total nitrogen (Table 3). Although the soil pH was ideal, the N and P concentrations were very low. The organic carbon concentration was high in both kraal manure types. Cattle manure had higher total phosphorus level than goat manure. There was a high electrical conductivity in both kraal manure types and goat manure had higher EC than cattle manure. The C:N ratio of cattle was higher than that of goat manure.

The ANOVA showed that in both vegetables, both manure type and leaf cutting management had significant influence on all the parameters measured (Table 4). The interaction of manure type and leaf cutting management were also significant except for total dry leaf mass. There was a significant influence of kraal manure and leaf cutting management on protein content of *C. Gynandra* but not of *A. hybridus*. In both vegetable species, plants that were grown in soil amended with goat kraal manure produced the highest fresh leaf mass across all the manure types followed by cattle kraal manure (Table 5). Dry leaf biomass followed a similar pattern as in that of fresh leaf biomass. Plants that were grown in soil amended with cattle kraal manure recorded highest leaf moisture content except in *A. hybridus* whereby highest leaf moisture content was obtained from plants that were added with goat manure. Stem and root yield followed the same trend as fresh leaf biomass and dry leaf biomass.

Table 4. Analysis of variance (F values) for total fresh leaf mass, total dry leaf mass, leaf moisture content, fresh stem mass, dry stem mass, fresh root mass and dry root mass of *C. gynandra* and *A. hybridus*.

Source of variation	df	Total fresh leaf mass (g/pot)	Total dry leaf mass (g/pot)	Leaf moisture content (%)	Fresh stem mass (g/pot)	Dry stem mass (g/pot)	Fresh root mass (g/pot)	Dry root mass (g/pot)	CP (%)
C. gynandra									
Block	3	0.47[ns]	0.07[ns]	1.07[ns]	0.21[ns]	0.17[ns]	0.68[ns]	2.82[ns]	2.33[ns]
Manure type (MT)	2	255.59***	160.1***	70.78**	160.49**	195.03***	34.62*	47.96*	25.3**
Cutting technique (CT)	2	81.38***	18.9***	31.68***	124.76***	353.20***	17.28***	26.63***	4.97*
MT × CT	4	17.91***	10.33***	3.95*	16.87***	53.49*	3.15***	3.33*	0.52ns
Error	24								
Total	35								
A. hybridus									
Block	3	1.92[ns]	1.73[ns]	2.01[ns]	1.30[ns]	1.92[ns]	1.77[ns]	1.63[ns]	1.13[ns]
Manure type (MT)	2	163.3***	8.16**	221.81***	21.99***	27.57***	25.11***	21.29***	14.51
Cutting technique	2	63.4***	1.52[ns]	71.90***	31.26***	77.96***	41.13***	71.41***	2.66[ns]
MT × CT	4	7.4**	2.65[ns]	6.97**	4.61*	11.47**	6.27**	15.04***	0.83[ns]
Error	24								
Total	35								

ns = Not significant; * = significant at (p<0.05); ** = significant at (p=<0.01); *** = significant at (p<0.0; CP = crude protein.

Table 5. Effect of kraal manure application on biomass yields, moisture content and crude protein of *C. gynandra* and *A. hybridus*.

Manure type	Fresh leaves (g/pot)	Dry leaves (g/pot)	Leaf moisture content (%)	Fresh stem (g/pot)	Dry stem (g/pot)	Fresh roots (g/pot)	Dry roots (g/pot)	Crude protein (%)
Cleome gynandra								
No manure	80.14[c]	14.99[c]	78.97[c]	29.98[c]	6.73[c]	14.35[b]	2.91[c]	5.8[c]
Cattle	328.42[b]	41.26[b]	86.96[a]	98.49[b]	15.56[b]	27.74[b]	5.19[b]	12.2[b]
Goat	470.86[a]	65.49[a]	84.89[b]	169.79[a]	29.77[a]	41.37[a]	8.57[a]	14.2[a]
Mean	293.14	40.58	83.61	99.42	17.35	27.82	5.55	10.7
Amaranthus hybridus								
No manure	116.45[c]	22.38[c]	80.59[c]	52.06[c]	8.66[c]	39.82[c]	6.78[c]	6.7[c]
Cattle	259.56[b]	27.16[b]	88.91[b]	90.09[b]	11.15[b]	67.52[b]	8.36[b]	11.44[b]
Goat	366.13[a]	33.31[a]	90.09[a]	159.22[a]	23.01[a]	88.62[a]	14.38[a]	13.44[a]
Mean	247.38	27.61	86.53	100.45	14.27	65.32	9.84	10.5

Values are means, n = 36; Means within a column with similar letter are not significantly different (p<0.05) by the LSD test.

Table 6. Effect of leaf cutting management on biomass yields and moisture content of *C. gynandra* and *A. hybridus* .

Leaf cutting techniques	Fresh leaves (g/pot)	Dry leaves (g/pot)	Leaf moisture content (%)	Fresh stem (g/pot)	Dry stem (g/pot)	Fresh roots (g/pot)	Dry roots (g/pot)	CP (%)
C. gynandra								
Only edible tips throughout	342^b	45.38^a	84.61^b	84.01^b	10.32^b	23.01^b	4.46^b	8.6^c
All leaves throughout	371.24^a	45.79^a	85.74^a	46.95^c	6.46^c	21.64^b	4.21^b	12.33^a
Cut once at harvest	165.35^c	30.58^b	80.47^c	167.31^a	35.27^a	38.81^a	7.99^a	11.33^b
Mean	292.86	40.58	83.61	99.42	17.35	27.82	5.55	10.75
A. hybridus								
Only edible tips throughout	294.52^a	29.77^a	87.95^b	82.53^b	8.99^b	57.80^b	6.70^b	9.4^c
All leaves throughout	290.34^a	27.99^a	88.49^a	46.53^c	4.85^c	38.45^c	4.58^c	12.2^a
Cut once at harvest	157.28^b	25.09^b	83.14^c	172.31^a	28.97^a	99.72^a	18.23^a	9.9^b
Mean	247.38	27.61	86.53	100.45	14.27	65.32	9.84	10.5

Values are means, n = 36; Means within a column with similar letter are not significantly different ($p<0.05$) by the LSD test.

The results indicated that *C. gynandra* produced highest leaf yield when compared to *A. hybridus.* For both vegetables, application of kraal manure increased the crude protein content of leaves and the increase was higher with goat than cattle kraal manure. In both vegetable species, the crude protein content was increased when plants were cut every fortnight than when they were cut once at the end (Table 6).

The interactive effects of kraal manure and leaf cutting regime showed that both the leaf biomass yields and crude protein content of leaves of both vegetables depended on a combination of manure and leaf cutting regime (Figure 1). The results showed that fresh leaf biomass of *C. gynandra* and *A. hybridus* were increased when kraal manure was added. Goat manure produced higher biomass than cattle manure. The yield was higher in goat manure when all the leaves were cut than in cattle manure for both vegetables. When edible tips were cut, better biomass from *C. gynandra* was obtained than in *A. hybridus*. There was no significant difference in fresh leaf biomass for both vegetables when leaves were cut once at the end of study. *C. gynandra* obtained highest fresh leaf yield than *A. hybridus*. *A. hybridus* responded better than *C. gynandra* where kraal manure was not added. Figure 2 shows that the application of kraal manure in both *C. gynandra* and *A. hybridus* was associated with improved biomass yields of loves for a longer time after transplanting than the control (without manure amendment). This may suggest that the manure provided nutrients to the plants longer. The yields for *C. gynandra* were generally higher than *A. hybridus* across the cutting regimes. The results in Figures 3 and 4 suggests that cutting only of the tender edible leaves at the tip of the plants produced slightly higher albeit not significant biomass yields. This implies that farmers could still gain by selectively cutting the tender edible leaves as long as nutrients were available to the plants.

DISCUSSION

The increase of biomass yield when kraal manures were applied is consistent with the results of the chemical properties of soil and manure used in the present study. This suggests that the observed increase in biomass yield of plants amended with kraal manure could be due to higher contents of N, P and organic carbon in kraal manure compared to soil. This was confirmed by Azeez et al. (2010) in their study. They found that manure at the tested levels contained highest levels of N, P and K and suggested that the positive effect of kraal manure was due to the release of plant nutrients contained in the manure. The increased biomass yields of vegetable species in the present study could be due to highest levels of N and P following kraal manure applications as suggested by Azeez et al. (2010).

Makinde et al. (2010) has shown that the protein content of amaranth leaves was improved with high NPK fertilisation in Nigeria and suggested that the increase in protein content might be because N is an important element in protein synthesis. In our case, the high nitrogen content that was available in the manure amended soils compared to the control provided the base for improved crude protein. Similar explanations were given by Mhlontlo et al. (2007) who found that the uptake of N and P in the leaves of vegetables was increased by increase in manure application and they suggested that because of close relationship between N and protein, crude protein was increased in the leaves with highest N and P uptake. The finding that the tender edible leaves had highest crude protein can be explained by the translocation of nitrogenous compounds are out of senescent leaves and flowers and relocation into younger areas of the plant (Baloyi et al., 2013). Flowers and Yeo(1992) have shown that if growing tips are removed from plants more frequently, senescence of other parts

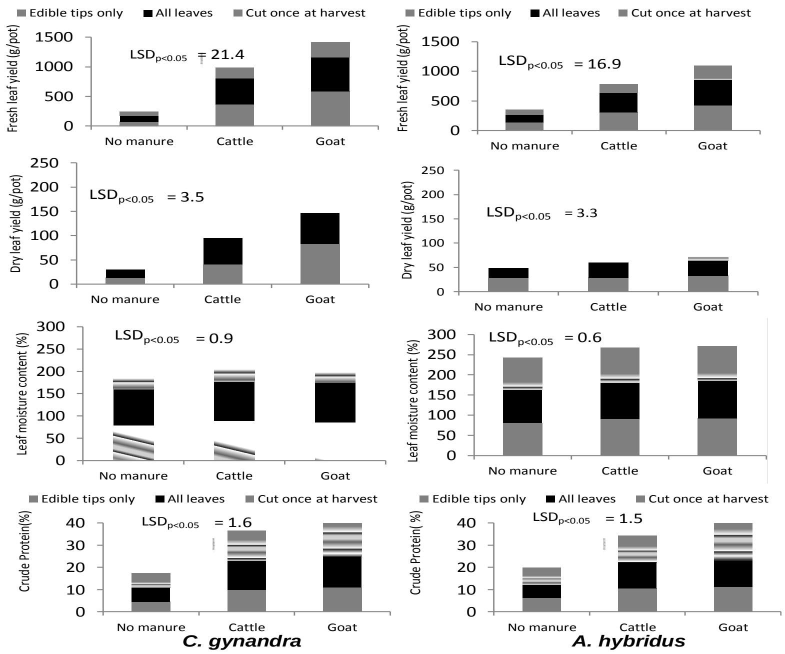

Figure 1. The interactive effects of manure type and cutting techniques on the biomass of fresh leaf , dry leaf, leaf moisture content and crude protein of *C. gynandra* and *A. hybridus*.

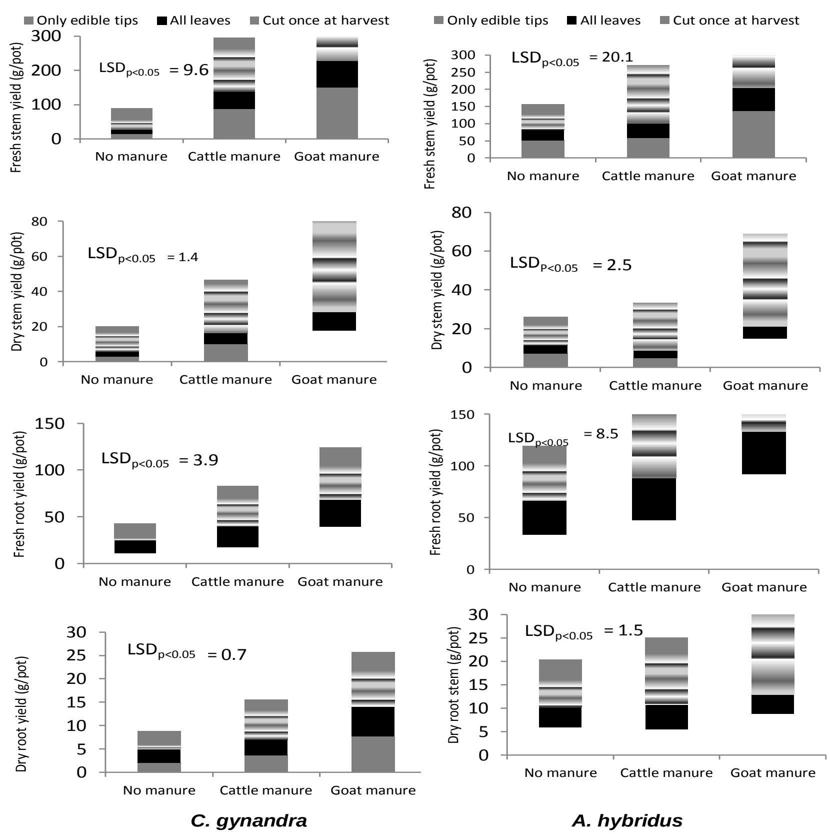

Figure 2. The interactive effects of manure type and cutting techniques on biomass yield of fresh stem , dry stem , fresh root and dry root of *C. gynandra* and *A. hybridus.*

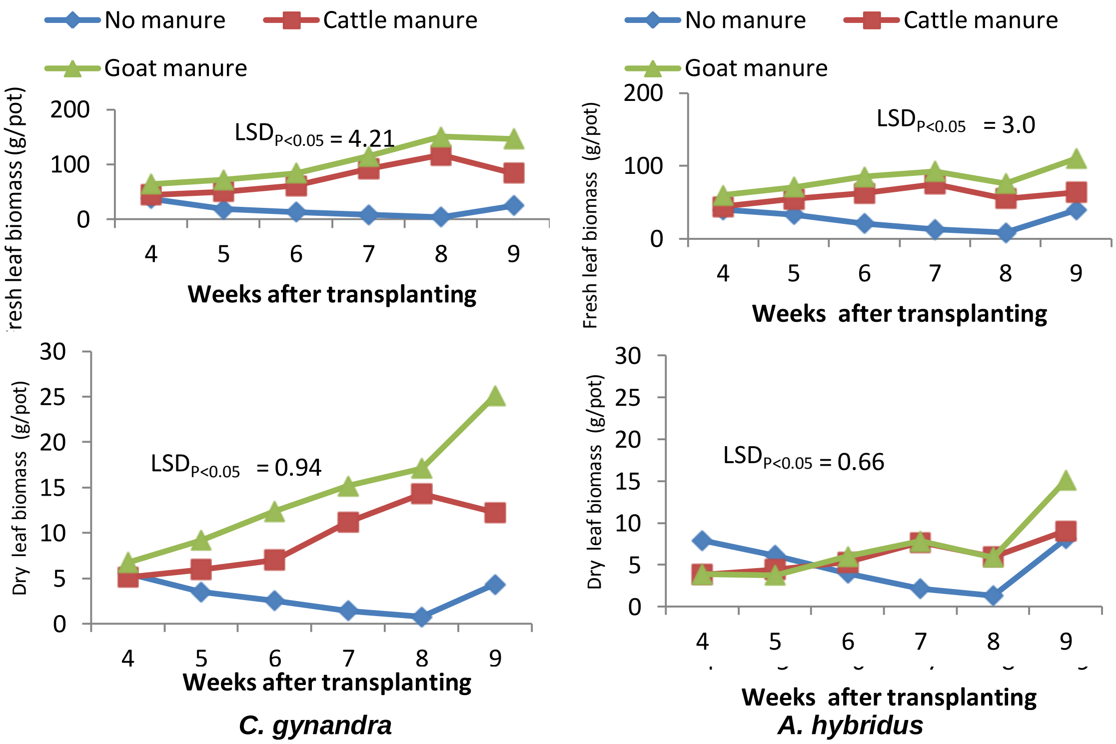

Figure 3. Trends in the leaf biomass yields of *C. gynandra* and *A. hybridus* during the experimental period as influenced by manure types.

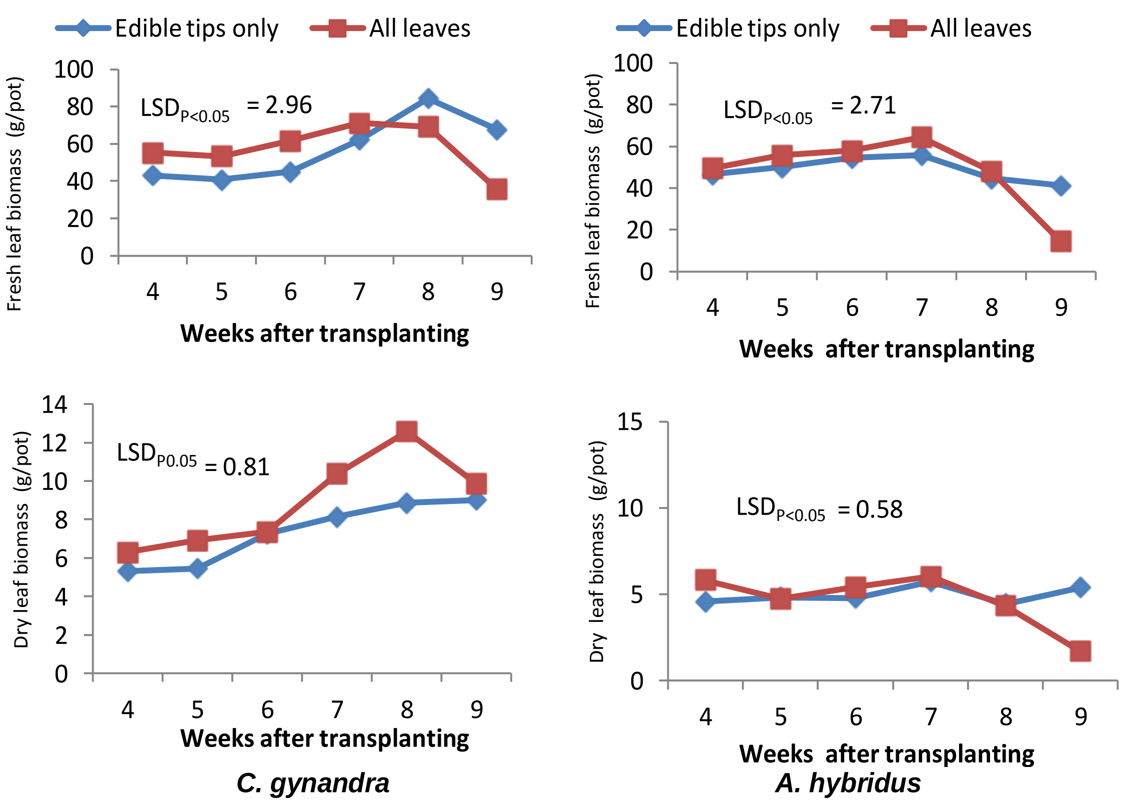

Figure 4. Trends in the leaf biomass yields of *C. gynandra* and *A. hybridus* during the experimental period as influenced by cutting techniques.

such as leaves is delayed but that more nutrients accumulate in the leaves. Alleman et al. (1996) have suggested that more nutrients might have been used for leaf proliferation and growth as leaves were cut frequently but to those plants which were cut once, some nutrients might have been translocated to the stems and roots. Barimavandi et al. (2010) reported that when vegetable leaves are not cut, there is least use of stored assimilates because of sufficient amount of nutrients from photosynthesis via leaves and this can increase in other parts of the plant such as stems and roots. Similar explanations have been suggested by other authors (Asiegbu, 2005; Belesky and fedders, 1994; Lestiene et al., 2006; Ogar and Asiegbu, 2005; Boogoard et al., 2001).

Conclusion

Both cattle and goat kraal manure improved the growth and biomass yields of African indigenous leafy vegetables but the effect of goat manure was superior to that of cattle manure. The biomass yields of leaves of African indigenous leafy vegetables can significantly be improved by cutting leaves frequently with enough soil nutrients and water. It must be mentioned that the experiments in this study were conducted in pots and cognisance must be taken of the limitation of extrapolating these results to field conditions. However, these results provide a useful indication of the nature of the responses that can be expected in the field and justifies further validation under field conditions.

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Full Length Research Paper

Diffusion of crossbreeding technology in piggery: A case of 'T&D' breed in Eastern region of India

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The paper throws light on the genesis and diffusion of a new breed of pig developed and propagated in India. The breed named 'T&D' was developed by crossing and continuous selection of Tamworth with local indigenous (Desi) pig which is distinctively black in colour. The extent of dissemination of the technology was assessed through random selection and interviewing 240 farmers across four states of India. It was interesting to see color as a trait significantly influencing the choice of farmers especially among the tribal communities. The 'T&D' pig innovation has spread beyond its place of origin to distant places especially in Eastern and North eastern parts of India, where pork consumption is comparatively very high. The study revealed that due to desired innovation attributes like relative advantage, observability, cultural compatibility and trialability, there was faster rate of adoption of 'T&D pig'. Favourable impact of adoption of 'T&D' pig innovation was observed in terms of guarantying farmers price premium, mitigating marketing uncertainty, reducing drudgery and compatibility with existing farming system.

Key words: Diffusion, adoption, crossbred pigs, India.

INTRODUCTION

Developing countries of Asia and Africa have witnessed unprecedented economic growth and increase in real per capita income in last two decades. These two key factors have resulted in increased consumption led demand of livestock products. Although, increase in consumption of food products of animal original has been most prominent for milk and milk products, recent trends in dietary patterns suggest that consumption of meat is increasing albeit from a low base. The rise in meat consumption has primarily been overshadowed by poultry meat consumption. However, among livestock species an important but understated change has been observed in case of consumption of pig meat and pork products. During the past three decades, per-capita consumption of pig meat has increased at a rate of 1.40% per annum as against 0.48 and 0.20% growth rate observed in case of bovine and ovine (sheep and goat) meat, respectively (Bardhan, 2007). Though, pig husbandry in India has

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Abbreviations: 'T&D', Tamworth and *desi* (Local); **KVK,** Krishi Vigyan Kendra; **DAH,** department of animal husbandry; **GDP,** gross domestic product.

been considered as an occupation for scheduled tribes and other economically backward classes, status regarding livestock ownership at national level suggests that pig production is an economic activity dominated by marginal and smallholders (NSSO, 2003). The growth in domestic demand for pork, thus, presents a potential for increased smallholder income and for poverty alleviation among rural households.

Local/indigenous pigs constitute the bulk of pig population in India with poor growth rate and productivity and are reared under extensive and scavenging system and to a lesser extent in a semi-intensive system under subsistence farming, with few or no inputs. Average meat yield of pigs in India is 35 kg/animal, which is about 55% less than the corresponding value of world average (FAO, 2011). An important development in India's livestock production system including piggery has been the introduction of high-producing exotic germplasm to improve the productivity of indigenous stock (Birthal and Taneja, 2006). A plethora of studies have highlighted the impact and consequences of crossbreeding in dairy sector (Rao et al., 1995; Patil and Udo, 1997; Samdup, 1997; Staal et al., 2005; Patil, 2006). However, there exists a black box regarding pattern of adoption and diffusion process of crossbreeding technologies in piggery; relative importance of various factors associated with adoption and various channels and factors involved in diffusion. Adoption and diffusion studies assume critical importance, as they provide crucial inputs to policy makers in increasing the efficiency of dissemination process of technologies, and also ensuring their effective uptake by the farmers.

The present study is an attempt to address specific crossbreeding technology, viz. 'T&D' pig, which is black colour pig obtained by crossing exotic pig 'Tamworth' with 'local Pig'. The 'T&D' pig has faster growth rate, better reproductive performance, higher disease resistance and better adaptability at farmers' door. The profitability of 'T&D' breeds over traditional breeds has been established in several earlier studies (Verma, 2003; Mahto, 2008). This breed has been developed in Agricultural University at Ranchi, Jharkhand State of India and promoted in native and adjoining States, viz. Bihar, West Bengal, Madhya Pradesh and North Eastern States, for enhancing sustainable livestock production with both environmental and socio-economic benefits. The specific objectives of the study were to assess the adoption pattern of 'T&D' pig innovation and its diffusion in the study area, identify the factors influencing adoption of 'T&D' pig and analyze the socio-economic consequences associated with 'T&D' pig adoption.

MATERIALS AND METHODS

Sampling

The study employed a combination of multistage random and purposive sampling technique to select the ultimate sampling units. 'T&D' pig was developed at Birsa Agricultural University, Ranchi, Jharkhand in 1989 and gradually spread within the Jharkhand State (23° 23' N and 85° 23' E) and in adjoining States, viz. West Bengal (23° 14' N and 87° 07' E), Bihar (42° 49' N and 85° 01' E) and Chhattisgarh (22° 53' N and 84° 12' E). One district was selected from each State, viz. Ranchi district from Jharkhand, Bankura district from West Bengal, Jashpur district from Chhattisgarh and Gaya district from Bihar. These districts were selected on account of having highest concentration of pig farmers among all the districts in the respective States. Most of the farmers in these selected districts were tribals and pork consumption was comparably very high among these communities. Surveys for the study were purposely targeted at farmers who own pigs. Only those farmers were considered who were engaged in pig husbandry for a minimum period of 5 years so as to have proper and reliable response on different variables. A semi-structured questionnaire was administered to 60 randomly selected farmers in each State, thus, making a sample size of 240 farmers.

Data

The socioeconomic variables selected were farm experience, education, communication profile, landholding, size of pig stock, income generation from piggery, economic motivation for rearing pigs, attributes of innovation, need perception, constraints in piggery and degree of adoption of improved pig husbandry practices.

Descriptive analyses

Descriptive statistics in the form of means and proportions were used to analyse farm and farmer-specific characteristics and information pertaining to different aspects regarding adoption of 'T&D' pig innovation.

Explaining likelihood of adoption of 'T&D' pig

Binary Choice Regression model (Logit) was formulated in an attempt to explain the factors influencing adoption of 'T&D' pig. Logit analysis is a mathematical modelling approach which describes the relationship of one or several explanatory variables (X's) to a binary response variable (Y) coded to take the value of 1 or 0 for success or failure, respectively. The dependent variable in this study was dichotomous in nature (dependent variable assumes a value of 1 in case a respondent has adopted 'T&D' pig and 0 if the respondent has not adopted). The Logit model is of the form:

$$P_i = \frac{1}{(1 + e^{zi})}$$

Where, P_i is the probability that the dependent variable assumes a value of 1

$$1-P_i = 1- \frac{1}{(1 + e^{zi})}$$

is the probability that the dependent variable assumes a value of 0, where

$$Z_i = \alpha + \sum \beta_i X_i$$

$$\text{Odd's Ratio (OR)} = \frac{Pi}{1 - Pi} = e^{Zi}$$

Taking log on both sides,

$$\text{Ln} \frac{Pi}{1 - Pi} = Z_i = \alpha + \sum \beta_i X_i + e_i$$

Where X_i is a vector of independent variables and β_i's are the coefficients to be estimated. These coefficients represent change in log of odds of T & D pig innovation adoption. A positive estimated coefficient implies an increase in likelihood that the respondent will be adopter of 'T&D' pig with a unit increase in the concerned explanatory variable. e^{β} gives the Odd's Ratio associated with change in independent variable. The Odd's Ratio means the ratio of probability of happening of an event to probability of not happening of that event. The odds are expressed as single number to the ratio to 1. Odds of 2, for example, mean that likelihood of adoption of 'T&D' pig is twice that of non-adoption. The above econometric model was estimated using the iterative Maximum Likelihood Estimation (MLE) procedure due to the nonlinearity of the logistic regression model.

RESULTS AND DICUSSION

Profile of pig farmers

Table 1 elicits the socioeconomic profile of pig farmers surveyed in the study area. Vast majority of pig farmers surveyed in this study belonged to Scheduled Castes/Scheduled Tribe caste category (81%). Religion-wise profiling of the respondents revealed that highest proportion of pig farmers in all the states except Bihar belonged to Sarna religion of tribes (38% in Jharkhand, 53% in West Bengal and 45% in Chhattisgarh). There are as many as 30 different tribes in this region (http://tribes-ofj-harkhand.blogspot.in/). In Bihar, Hinduism was the predominant religion as 90% of the pig farmers belonged to this religion in the State. Findings regarding education of respondents revealed good educational status in all the four states as highest proportions of pig farmers in these states were educated up to high school level (38%).

Jini (2008) and Kumar (2012) had also reported that tribal community has good level of education. Pandey (1996) on the other hand reported that tribals have low literacy rate. Fifty-three percent of the farmers across all the States had 31 to 45 years of experience in pig farming which is considered as high experience level. Crop cultivation was the primary occupation for majority of the pig farmers (65%) while animal husbandry was the main source of income for only 12% of households. Animal husbandry was pursued mainly as a subsidiary occupation by majority of respondents (84%).

Subsistence nature of crop farming was revealed by the preponderance of marginal farmers (66%) followed by landless (17%) and large land holders (4%) (Table 2). Highest proportion of respondents in all the states owned small herd size (up to 3 animals) in all the States (80% in Jharkhand, 83% in West Bengal, 82% in Chhattisgarh and 87% in Bihar).

Size of pig stock and reasons for pig keeping

Majority of the pig farmers (65%) had small size of pig stock while 24% owned medium size pig stocks followed by large size of pig stock (11%) (Table 3). Overall, average size of pig stock was 14 in Jharkhand, 10 each in West Bengal and Chhattisgarh and 8 in Bihar.

Across all States, source of extra income and cultural and religious reasons were reported as the most important reasons for rearing pigs by the highest proportion of pig farmers (82%) while 62% pig farmers reared pigs as their main source of income (Table 4). Source of employment and utilization of waste materials were reported as reasons for keeping pigs by relatively lesser proportion of respondents (40% and 38%, respectively). The findings are in line with the results of Mahli (2004) and Jini (2008).

Source of information about 'T&D' pigs

Table 5 presents the findings regarding sources from which the pig farmers obtained information about 'T&D' pigs. Pooled data from all the four States revealed that majority of farmers obtained information on 'T&D' pig through personal localite channels viz. relatives (85%), fellow farmers (82%), neighbors (76%), village leaders (61%) and friends (61%). On the other hand, relatively lesser proportions of farmers received information about 'T&D' pig through personal cosmopolite channel, viz. Agricultural University/Krishi Vigyan Kendra (KVK) personnel (48%), Department of Animal Husbandry officials (49%) and pig grower society (14%). *Gram Sewak* (61%) was the only personal cosmopolite channel through which relatively higher proportion of farmers (61%) received information about 'T&D' pig. Since 'T&D' breed was developed in the State Agricultural University in Jharkhand, Pig Grower Society, Agricultural University and its associated Farm Science Centers played a major role in promotion of new breed. Higher proportion of respondents obtained information from Department of Animal Husbandry in Bihar (50%) and Chhattisgarh (58%) while State Agricultural University and associated institutes (28 and 17%, respectively) were the major source of information.

Pooled data from all the four States revealed that majority of farmers obtained information on 'T&D' pig through personal localite channels followed by personal cosmopolite channels. This indicates that cosmopolites channels are relatively more important at the knowledge stage and localize channels are relatively more important at the persuasion stage. Cosmopolite communication channel are those linking an individual with source

Table 1. Distribution of sample households on the basis of their socio-economic characteristics.

Category	Jharkhand		West Bengal		Chhattisgarh		Bihar		Pooled	
	f	%	f	%	F	%	f	%	f	%
Caste										
SC	05	8.3	12	20.0	07	11.7	44	73.4	68	28.3
ST	37	61.7	42	70.0	45	75.0	02	03.3	126	52.5
OBC	10	16.7	04	06.7	05	08.3	09	15.0	28	11.7
General	08	13.3	02	03.3	03	05.0	05	08.3	18	07.5
Religion										
Hindu	23	38.0	18	30.0	15	25.0	54	90.0	110	45.8
Christian	15	25.0	10	16.7	18	30.0	4	06.7	47	19.6
Sarna	22	36.7	32	53.3	27	45.0	2	03.3	83	34.6
Education										
Illiterate	00	00	00	00	00	00	00	00	00	00
Primary	00	00	08	13.3	10	16.7	17	28.3	35	14.6
Middle	13	21.7	18	30.0	15	25.0	12	20.0	58	24.2
High School	27	45.0	25	41.7	22	36.7	18	30.0	92	38.3
Intermediate	12	20.0	06	10.0	09	15.0	10	16.7	37	15.4
Graduate and above	08	13.3	03	05.0	04	6.6	03	05.0	18	07.5
Farm experience										
< 30 years	18	30.0	15	25.0	21	35.0	19	31.7	72	40.0
31-45 years	39	65.0	40	66.7	36	06.0	37	61.7	152	53.2
> 45 years	03	05.0	05	08.3	03	05.0	04	06.7	15	06.8
Annual household income										
Low (< Rs. 50, 000)	10	16.7	09	15.0	12	20.0	22	36.7	53	22.1
Medium (Rs. 50, 000-Rs. 60, 000)	42	70.0	45	75.0	43	71.7	35	58.3	165	68.7
High (> Rs. 60, 000)	08	13.3	06	10.0	05	08.3	03	05.0	22	09.2
Occupation (Primary)										
Crop Cultivation	38	63.3	32	53.3	48	80.0	38	63.3	156	65.0
Animal Husbandry	12	20.0	04	06.7	05	08.3	07	11.7	28	11.6
Agricultural Labour	00	00	19	31.7	00	00	08	13.3	27	11.3
Non-agricultural Labour	03	05.0	00	00	01	01.7	02	03.3	06	02.5
Trade and Commerce	03	05.0	02	03.3	02	03.3	03	05.0	10	04.2

Table 1. Contd.

Service	04	06.7	03	05.0	04	06.7	02	03.3	13	05.4
Occupation (Secondary)										
Crop Cultivation	02	03.3	03	05.0	02	03.3	02	03.3	09	03.7
Animal Husbandry	52	86.7	48	80.0	52	86.7	49	81.7	201	83.7
Agricultural Labour	03	05.0	04	06.7	02	03.3	04	06.7	13	05.4
Non-agricultural Labour	02	03.3	03	05.0	03	05.0	02	03.3	10	04.2
Trade and Commerce	01	01.7	02	03.3	01	01.7	03	05.0	07	02.9
Service	00	00	00	00	00	00	00	00	00	00

Table 2. Distribution of sample households on the basis of their farm characteristics.

Category	Jharkhand		West Bengal		Chhattisgarh		Bihar		Pooled	
	f	%	f	%	F	%	F	%	f	%
Size of landholding										
Landless (No land)	06	10.0	22	36.7	04	06.7	08	13.3	40	16.7
Marginal (0.1-2.5 acres)	43	71.6	28	46.7	43	71.6	44	73.4	158	65.8
Small (2.6-5.0 acres)	04	06.7	06	10.0	06	10.0	05	08.3	21	08.7
Medium (5.1-10.0 acres)	04	06.7	02	03.3	03	05.0	02	03.3	11	04.6
Large (>10 acres)	03	05.0	02	03.3	04	06.7	01	01.7	10	04.2
Mean±SE	2.06±0.26		1.41±0.30		2.05±0.32		1.40±0.25		1.73±0.14	
Herd Size										
Small (<3 animals)	48	80.00	50	83.3	49	81.7	52	86.7	199	82.9
Medium (4-6 animals)	12	20.00	10	16.7	11	18.3	08	13.3	41	17.1
Large (>6 animals	00	00	00	00	00	00	00	00	00	00
Mean±SE	2.90±0.16		2.50±0.10		2.80±0.13		2.93±0.13		2.78±0.07	

Table 3. Distribution of sample households according to the size of pig stock.

Category	Jharkhand		West Bengal		Chhattisgarh		Bihar		Pooled	
	f	%	f	%	F	%	F	%	f	%
Small (<10 pigs)	32	53.4	43	71.7	37	61.7	44	73.3	156	65.0
Medium (11-15 pigs)	17	28.3	12	20.0	15	25.0	14	23.3	58	24.2
Large (>15 pigs)	11	18.3	05	08.3	08	13.3	02	03.3	26	10.8
Total	60	100	60	100	60	100	60	100	240	100
Mean±SE	13.98±1.44		10.26±0.79		9.76±0.81		8.35±0.68		10.58±0.50	

Table 4. Distribution of respondents according to rationale for pig farming.

Reason for pig farming	Jharkhand		West Bengal		Chhattisgarh		Bihar		Pooled	
	f	%	f	%	F	%	F	%	f	%
Main source of income	32	53.3	45	75.0	50	83.3	38	63.3	165	68.7
For extra income	49	81.7	52	86.7	45	75.0	50	83.3	196	81.7
To utilize waste	15	25.0	25	41.7	30	50.0	21	35.0	91	27.9
For employment	18	30.0	28	46.7	26	43.3	23	38.3	95	39.6
Cultural and religious reasons	45	80.0	52	86.7	55	91.7	41	68.3	196	81.7
Own consumption	20	33.3	24	40.0	27	45.0	18	30.0	89	37.1

Table 5. Distribution of respondents according to their source of information for 'T&D' pig innovation.

Source	Jharkhand		West Bengal		Chhattisgarh		Bihar		Pooled	
	f	%	f	%	F	%	F	%	f	%
Personal localite channel										
Neighbour	41	68.3	47	78.3	45	75.0	49	81.7	182	75.8
Relatives	49	81.7	51	85.0	55	91.7	50	83.3	205	85.4
Village leader	35	58.3	42	70.0	30	50.0	39	65.0	146	60.8
Fellow farmer	50	83.3	52	86.7	48	80.0	46	76.7	196	81.7
Friends	31	51.7	36	60.0	42	70.0	38	63.3	147	61.2
Personal cosmopolite channel										
Agricultural University/KVK personnel	47	78.3	40	66.7	10	16.7	17	28.3	114	47.5
DAH officials	28	46.7	25	41.7	35	58.3	30	50.0	118	49.2
Gram Sewak	32	53.3	38	63.3	36	60.0	40	66.7	146	60.8
Pig Grower Society Personnel	34	56.7	00	00	00	00	00	00	34	14.2

outside the social system

Reasons for adopting T&D pigs

Farmers' motivation to convert from traditional (local pig) to 'T&D' pig (crossbred) farming were categorized into farming related motivation, financial motivation, personal motivation and general concerns motivation (Table 6). Majority of the farmers (91.70%) reported low yield problem (litter size) with traditional piggery followed by problems relating to husbandry and technical aspects (78%) and animal health problems (65%) under farming related motivation to adopt 'T&D' pig innovation. Under financial motivation category, need for solving existing financial problems (88%) was the reason for adopting 'T&D' pig innovation by highest proportion of farmers followed by need for cost saving (81.70%) and securing future of farm (72%). It was interesting to note that majority of the farmers (91.25%) reported black colour of 'T&D' pigs as the reason for its adoption, followed by cultural reasons (76.25%), custom reasons (69.20%), religious reasons (63.75%) and ancestral or traditional reasons (57.10%) under the personal motivation category of 'T&D' pig innovation adoption. All the sample farmers reported that meat quality had motivated them to adopt 'T&D' pig, while 86% of the farmers were motivated to adopt 'T&D' pig for self employment reasons. Environmental concerns and (75.00%) and stewardship (71.25%) were the reasons for adoption of 'T&D' pig under general concerns motivations.

Characteristics of different adopter categories of 'T&D' innovation

The 'T&D' pig adopters were categorized into five adopter categories (Rogers, 2003) by using mean and standard deviation, viz. innovators (2.50%), early adopters (13.75%), early majority (33.7%), late majority (31.70%) and laggards (18.30%). The detailed characteristics of each adopter categories are depicted in Table 7. Innovator farmers adopted 'T&D' pig early in the study area due to more contact with research personnel of Birsa Agricultural University, Ranchi and also accessed 'T&D' piglets free from scientists of Birsa Agricultural University as on trial basis. Further, few farmers had good interaction with the personnel of KVK, Bankura

Table 6. Distribution of respondents on the basis of motivation to convert from traditional to 'T&D' pig farming.

Motivation	Jharkhand		West Bengal		Chhattisgarh		Bihar		Pooled	
	f	%	F	%	F	%	F	%	f	%
Farming related motivation										
A. Husbandry and technical reasons	50	83.0	48	80.0	52	86.6	38	63.3	188	78.3
B. Animal health problems	42	70.0	38	63.3	40	66.6	36	60.0	156	65.0
C. Yield problem (litter size)	58	96.6	56	93.3	52	86.6	54	90.0	220	91.7
Financial motivation										
A. Solve existing financial problems	56	93.3	52	86.6	50	83.0	54	90.0	212	88.3
B. Secure future of farm	46	76.6	42	70.0	44	73.3	40	66.6	172	71.7
C. Cost saving	52	86.6	50	83.0	48	80.0	46	76.6	196	81.7
D. Premium marketing	58	96.6	54	90.0	50	83.0	52	86.6	214	89.2
Personal motivation										
A. Ancestry/Tradition	30	50.0	40	66.6	42	70.0	25	41.6	137	57.1
B. Choice of black colour pigs	58	96.6	56	93.3	57	95.0	48	80.0	219	91.2
C. Custom reasons	42	70.0	45	75.0	44	73.3	35	58.3	166	69.2
D. Cultural reasons	48	80.0	49	81.6	46	76.6	40	66.6	183	76.2
E. Religious reasons	35	58.3	40	66.6	42	70.0	36	60.0	153	63.7
General concerns										
A. Stewardship	42	70.0	45	75.0	44	73.3	40	66.6	171	71.2
B. Meat quality	60	100.0	60	100.0	60	100.0	60	100.0	240	100.0
C. Rural development	56	93.3	50	83.0	48	80.0	52	86.6	206	85.8
D. Environment	48	80.0	42	70.0	46	76.6	44	73.3	180	75.0

Table 7. Characteristics of adopter categories in 'T&D' pig innovation (N=240).

Characteristic	Innovators n=06	Early adopters n=33	Early majority n=81	Late majority n=76	Laggards n=44
Age	Young to middle	Middle	Middle	Middle	Middle
Education	Above high school	High school	High school	High school	High school
Family size	Small	Small	Medium	Medium	Medium
Herd size	Small	Small	Small	Small	Small
Land size	Marginal to small	Landless	Marginal	Marginal	Marginal
Social participation	High	High	Medium	Low	Low
Extension contact	High	Medium	Medium	Medium	Low
Cosmo-politeness	High	Medium	Medium	Medium	Low
Innovation proneness	High	Medium	Medium	Medium	Medium
Economic motivation	High	Medium	Medium	Low	Medium
Risk orientation	High	High	Medium	Medium	Low

which made them to adopt the innovation. Interestingly, majority of the characteristics of adopter categories were similar to the findings of Rogers (2003).

Time lag in adoption of T& D pigs

A small proportion of farmers first became aware in Jharkhand about 'T&D' pig in the year 1994 (Table 8). Thereafter, awareness spread amongst other farmers and majority of them (18.30, 21.70 and 25.00%) became aware about the 'T&D' pig by the year 1998, 1999 and 2000, respectively. Most of the farmers (16.70, 18.30 and 30.00%) of West Bengal became aware about the 'T&D' pig in the year 2004, 2005 and 2006, respectively. Majority of the farmers (15.00, 21.70 and 28.30%) of Chhattisgarh first became aware about 'T&D' pig in year 2003, 2004 and 2005, respectively. Majority of the farmers (15.00, 20.00 and 16.70%) of Bihar became aware about the 'T&D' pig innovation in the year 2002,

Table 8. Pattern of adoption of T& D pig innovation.

Adoption year	Jharkhand		West Bengal		Chhattisgarh		Bihar		Pooled		Cumulative No.
	f	%	f	%	f	%	f	%	f	%	
1994	01	01.70							01	00.42	01
1995	01	01.70							01	00.42	02
1996	02	03.30							02	00.83	04
1997	03	05.00							03	01.25	07
1998	04	06.70							04	01.70	11
1999	06	10.00			01	01.70			07	02.90	18
2000	09	15.00			02	03.30	02	3.30	13	05.40	31
2001	12	20.00	01	01.70	02	03.30	02	3.30	17	07.10	48
2002	08	13.30	02	03.30	04	06.70	04	6.70	18	07.50	66
2003	06	10.00	03	05.00	05	08.83	06	10.00	20	08.30	86
2004	03	05.00	06	10.00	07	11.70	07	11.70	23	09.60	109
2005	01	01.70	08	13.3	10	16.70	11	18.30	30	12.50	139
2006			14	23.3	07	11.70	07	11.70	28	11.70	167
2007			07	11.70	06	10.00	05	8.30	18	7.50	185
2008			05	08.30	04	04.70	04	6.70	13	5.40	198
2009			04	06.70	02	3.30	03	5.00	09	3.75	207
2010			03	05.00			01	1.70	04	1.70	211

2003 and 2004, respectively. Overall, awareness to adopt 'T&D' pig was perceived in 1994 (1.25%) and majority of the farmers became aware about T&D pig first during the year 2000 to 2005.

Majority of the respondents (35.00%) had high adoption level and 25.0% of respondents had full adoption level of 'T&D' pig innovation (Table 9). However, 17.1% of respondents had partial adoption level and 10.8% of the respondents had low adoption level of innovation. Only 12.1% of the respondents reported non-adoption of 'T&D' pig innovation. The above findings thus depict a high rate of adoption of 'T&D' pig innovation.

The major reason for non-adoption of 'T&D' pig innovation was poor supply of 'T&D' piglets as reported by 80% of non-adopters, followed by expensive investment (72%), and lack in conviction (72%) across all the states under study (Table 10). Discouraging results in trial (47.10%), government substitute (39.20%) and local substitute (38.75%) were other reasons for non adoption of 'T&D' pig innovation.

Sources of procurement of 'T&D' innovation

The T&D pig could be diffused rapidly in these states due to various interventions by the government agencies through various schemes, NGOs, Agricultural University, apart from the breeding policy (mega seed production) supporting T&D pig multiplication and mission mode projects on pigs.

Majority of the respondents (33.75%) identified Agricultural University/KVK pig farm as source for easy access of 'T&D' piglet, followed by progressive pig farmers (15.0%), relatives (11.25%), neighbours/villager (10.80%) and private farms (10.0%) and government pig farms (10%). Relatively lesser proportion (5%) of respondents procured 'T&D' piglets from middlemen, friends (3%) and pig grower society (2%).

Constraints in 'T&D' pig production

Non-remunerative price for pork emerged as the most important constraint in pig production as reported by all the respondents (Table 11). Lack of financial support for purchase of improved pigs and construction of sty were identified as the next most severe constraints as reported by 98% of pig farmers, followed by high cost of concentrate mixture (95%), lack of subsidies on purchase of improved pigs (93%), procedural complications in getting support from banks (88%), non-availability of veterinary services (78%) and high cost of vaccines and medicines (70%).

Factors influencing adoption of 'T&D' pig innovation (Logit results)

The results of the logit analysis revealed significant and positive influence of education ($P<0.05$), extension contact ($P<0.05$), cosmopoliteness source ($P<0.05$), innovation proneness ($P<0.05$) and farm experience $P<0.01$) on likelihood of adoption of 'T&D' pig technology (Table 12). Size of land holding ($P<0.05$), annual

Table 9. Constraints perceived by pig farmers in adoption of piggery development intervention.

Constraint	Respondents		
	f	%	Rank
Non remunerative price for pork	240	100.00	I
Lack of financial support for construction of sty	234	97.50	II
Lack of subsidies on purchase of improved T&D pigs	228	95.00	III
High cost of concentrate mixture	222	92.50	IV
Procedural complications in getting support from banks	210	87.50	V
Non- availability of veterinary services	185	77.80	VI
Cost of vaccines and modern medicines are high	168	70.00	VII
Lack of irrigation facilities for fodder production	160	66.70	VIII
Lack of transportation of pigs to other market places	156	65.00	IX
Lack of market facilities	137	57.08	X
Lack of guidance about the management of improved pigs	108	45.00	XI
Charging exorbitant amount by veterinarian treat/ vaccinate pigs	80	33.00	XII
Distant location of veterinary hospital	72	30.00	XIII
Inadequate input supply	60	25.00	XIV

Table 10. Binary logit estimates for factors affecting `T&D' pig innovation.

Variable	Coefficient	S.E.	Wald χ^2	P-Value	Odds ratio
Constant	3.863	1.857	4.326	0.038**	47.606
Age	-0.912	0.882	1.069	0.301	0.402
Education	1.354	0.535	6.410	0.011**	3.871
Land holding	0.510	0.564	0.818	0.366	1.665
Size of pig stock	-1.186	0.779	2.318	0.128	0.305
Farming experiences	-1.402	0.825	2.888	0.089*	0.246
Economic motivation	-0.265	1.069	0.061	0.804	0.767
Scientific orientation	0.285	0.822	0.120	0.729	1.329
Risk orientation	0.396	1.082	0.134	0.714	1.486
Extension contact	1.375	1.098	1.568	0.010**	3.957
Mass media Exposure	-0.515	1.105	0.217	0.641	0.597
Cosmopoliteness source	2.227	1.103	4.079	0.043**	9.274
Localiteness source	-0.958	0.979	0.958	0.328	0.384
Innovation proneness	-2.163	1.089	3.948	0.047*	0.115

-2 log likelihood ratio = 152.031, % Correct Predictions = 89.20, Significant at ***1%, ** 5% and *10% level of significance.

income ($P<0.05$), scientific orientation ($P<0.05$) and risk orientation ($P<0.05$) also exerted significant and positive influence on probability of 'T&D' innovation adoption. On the other hand, size of pig stock ($P<0.05$), mass media exposure ($P<0.05$), economic motivation ($P<0.05$), social participation ($P<0.05$) and localiteness source ($P<0.05$) were negatively associated with likelihood of adoption of 'T&D' pig innovation.

The estimated model was used to predict probability of 'T&D' pig adoption across all four states. The probability that a pig farmer will adopt the 'T&D' pig technology was 84%, implying that there was 84 % chance that a pig farmer would adopt 'T&D' pig innovation, all other things being equal/same.

Perceived benefits of T&D pigs over local breed

The respondents in the study typically received 100% price premium on adoption of 'T&D' pig and increased profitability was another important economic advantage of 'T&D' pig as reported by all the sample pig farmers, followed by reduction in marketing uncertainty (75%) and decreased input cost (72%). Majority of the respondents perceived that adoption of 'T&D' innovation increased their comfort level (75%) and decreased the amount of time spent on performing farming activities (72%) of farmers. Further, 89% of farmers perceived immediacy of reward from social organizations and government officials as a benefit of adoption of ‘T&D’ pig innovation. High yielding characteristic of ‘T&D’ pigs (100%) and sustainability of pig production system with the innovation (86%) were major benefits as perceived by the pig farmers.

Majority of the respondents (76.25%) mentioned their previous experience was compatible with ‘T&D’ pig farming. Most of the respondents had experience in conventional grazing and kitchen waste based piggery while 18% of pig farmers had practiced it on a small scale before finally implementing in their farms. Majority of the pig farmers used pig during festival, ceremony and marriage (100.00%), *Gram Devta pooja or Kuldevi pooja* (77.00%), offering of sacrifice during sowing and harvesting of paddy (64.60%), bride dowry (67.10%), gift to daughters after marriage (65.4%) and exchange of pig among relatives and or kinship (61.70%). Few previous studies (Kosgey et al., 2006; Ndumu et al., 2008) have referred it as less tangible objectives of livestock rearing. Nidup et al. (2011) also stated that, in Bhutanese society, pigs were a very important medium by which social significance was measured. He further depicted that white pigs were unpopular because of practice complexity, since white pigs required good feed, shade, plenty of water and access to wallow.

Farmers’ perceived less complexity, high knowledge level of pig farming (83%), confidence in actual ‘T&D’ pig farming (90%) and high information accessibility (61%). However, there were some disadvantages/disincentives in keeping ‘T&D’ pigs in terms of obtaining technical skills in rearing ‘T&D’ pigs (94%), maintenance of detailed records (91%) and difficulty in finding ‘T&D’ piglets (87%). Interestingly, marketing of ‘T&D’ pigs was not a major problem as only 37% of farmers reported about difficulty in marketing. In the study area, the adoption of innovation had very good observability which was previously reported by Singh (2009).

Conclusion

‘T&D’ breed of pig with its black colour has found wide acceptance among tribal communities in Eastern India by fulfilling majority of the favourable attributes and depicts the success of cross breeding in pig husbandry. Interestingly, role of personal localite channels in information dissemination was more prominent than personal cosmopolite channels on account of the breed’s successful adaptability and better performance in the existing production system. Though, high yield of ‘T&D’ pig, low per unit cost of production and black colour were the key reasons for wide adoption, non-remunerative price for pork, lack of financial support in the form of credit and subsidies and lack of adequate supply of ‘T&D’ piglets were the potential bottlenecks in diffusion and adoption of innovation. In this context, institutional arrangements and enabling policies are critical for the success in identifying and applying appropriate technologies, improving access to input services and facilitating access to markets in order to translate productivity gains into incomes. Livestock technologies, crossbreeding technologies in particular, like in the case of ‘T&D’ innovation, have the potential to bring poor livestock keepers out of poverty and also to prevent progressive but vulnerable farmers fall back into the clutches of poverty.

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Rural households' awareness and preceptions to variability in climatic conditions in rural South Africa

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Understanding climate variability is key to the reduction of human foot print and communal farming production. This study evaluates climate change awareness and perceptions of climate variability among the Eastern Cape communal farmers. A multi-stage sampling technique was used to select 130 heads of households across Ntabankulu local municipality for participation in the study. Data were collected through a pre-tested questionnaire. The study revealed that about 70% of the interviewed households knew about climate change. On the other hand, 80% agreed that the climate is changing, 70% were defiant that the change is caused by human beings and approximately 25% were convinced that the climate change is as a result of natural causes. The respondents fail to construe the causes of climate change and past trends climate. Factor analysis findsage, gender and years of education as having a positive significant effect on understanding climate change. The paper recommended for an extension service that would encourage the elderly and the educated to transfer information on climate change. South African weather services, extension workers, councilors, civil societies and other development agencies have a lot to learn from the investigated households.

Key words: Awareness, perceived changes, climate change, seasonal changes.

INTRODUCTION

Climate change refers to changes that alter the composition of the global atmosphere and which are in addition to natural climate variability observed over comparable time periods (United Nations, 1992). This phenomenon is undermining the achievement of the millennium development goals (MDGs) and the international communities' efforts to reduce extreme hunger and poverty. Climate change is a big threat to livelihoods, environment and biodiversity resource base. For rain fed agriculture, a 1% change in rainfall is likely to reduce South Africa's maize output by approximately 1% (Blignaut et al., 2009). The largest losses are predicted to occur among rural households and smallholder farmers in Eastern Cape. These are more vulnerable due to predominance of rain fed agriculture, wide ignorance of the phenomenon, low adoption rate of adaptation measures and because of the low adaptive capacity. The losses will range from crop failure, livestock death, floods and other associated changes.

The broader public understanding of climate change is an essential ingredient for informed adaptation and mitigation strategies (Anderson et al., 2010). A critical element to climate vulnerability in rural South Africa is the the issue of awareness and adaptation strategies (Thomas

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et al., 2007). The level of awareness of climate change, particularly causes, climatic trends and adapta-tion issues, is varied among the South African public (Madzwamuse, 2010). Less knowledgeable communities are more vulnerable to climate change (Thomas et al., 2007). The vulnerability of most communities is exasperated by high dependence on rain fed agriculture, low literacy rates and proximity to the ocean which heighten the propensity of climate variability. Climatic risks, variable and sometimes agricultural output remains a daunting challenge in the Eastern Cape Province. Adding on to low purchasing power, a significant number households are faced with a challenge of providing their families through food purchasing only as crop failure, livestock death and lack of water make agriculture unreliable (van der Merwe, 2011). An estimated 25% of South African households have inadequate or severe inadequate food access (Du Toit, 2011).

The Eastern Cape habitats the highest proportion of unutilized land and the area is known for land degradation and food insecurity (Bank and Minkley, 2005). The proportion of land lying fallow could even increase if the environmental and social consequences of climate change continue to put agriculture at risk. Awareness about the climate change phenomenon is assumed to reduce the rate of climate change and improve adaptation, thus building a resilient agricultural community in the face of climatic risks (Anderson et al., 2010; Madzwamuse, 2010; Mandleni and Anim, 2011). Human activities and ignorance of the climate change phenomenon have been in most circumstances blamed for intensifying climate change in South Africa (Madzwamuse, 2010). These important linkages and the reported impacts of the phenomenon on agriculture in Eastern Cape by Blignaut et al. (2009) has fueled the urge to study the level of climate change awareness in the province.

The objectives of this study were to establish the extent of awareness of climate change in the area of study. Firstly, the study examines households' awareness of the climate change phenomenon. Secondly, the study seeks understand farmers' experiences and own perceptions of changes in climate over the past 20 years. The level of understanding of the climate change phenomenon by the resource-poor smallholder farmers and livestock farmers is an important area of concern. With the livelihoods at risk, it is important to understand how climate change is understood by farmers.

Conceptual framework

The conceptual basis of this study considers understanding climate change as important to communal farmers. It is important for climate to be recognized, understood and appropriately reacted to (Thomas et al., 2007). This study is set on the premise that farmers should understand the magnitude of climate variability, frequency of event occurrence and rate of change within climate systems. These are important attributes as they can affect farmers' ability to respond, cope and to adapt to climate change. Acquah (2011) posits that climate change is a challenge to farmers and further remarks that awareness and quality of knowledge on existence and issues relating to it could reduce its impact. This can be through several channels. The first channel assumes that the broader public understanding of climate change by the citizens is an essential ingredient for reducing human foot print. Secondly, public understanding of climate change has a significant role to play in preparing adaptation strategies and addressing the challenges it poses. Informed responses can significantly reduce yield loss. Awareness of the phenomenon increases households' risk bearing capacity and helps households in adopting and altering coping strategies. The third pathway is that public understanding of climate variability increases households' willingness to take action to mitigate the anticipated conditions (Anderson et al., 2010). People cannot accurately predict the next season and this is largely a factor of climate change (Molua, 2002).

After referring to a large body of literature, Anderson et al. (2010) posit that socio-economic factor shave a differential influence on households understanding of climate change. As a sequential decision process, the household or its members should have to understand climate change before adopting different mitigation measures. Households' understanding of climate phenomenon will be determined by a number of factors. This study aims at investigating the level of awareness as well as the determinants. A better understanding of the determinants of awareness of climate change is important to inform policies aimed at promoting successful awareness campaigns. Therefore, this framework proves relevant to this study.

METHODOLOGY

Study area and sampling procedure

This study was carried out in Ntabankulu municipality of the former homelands. Ntabankulu stretches for about 122 km^2 and is an undulating area with very limited flat surfaces. The area lays approximately, 32°10′S 28°35′E. Ntabankulu is a dry area with mean monthly relative humidity and average rainfall of 92% and 730 mm, respectively. The area is endowed with natural resources ranging from abundant grazing land, thick landscape and many seasonal rivers and one perennial river. Less than 50% of households have access to tape water. These encourage people into animal husbandry, smallholder farming and gardening. Due to its location from the economic hubs of the province, substantial number of the inhabitants engages farming as the main economic activity for living and some are recipients of government's social grants.

A survey was conducted through a well-structured interview schedule which targeted households in Ntabankulu local municipality. A multi-stage random sampling procedure was used to select 150 communal farmers to be used for this study. To select the above sample, 5 wards were randomly selected from a total of 18 wards. Following which 30 communal farmers were randomly selected from each ward for the interview. A pre-tested structured questionnaire was the main instrument used for data collection.

Table 1. Description of variables.

	Variable name	Variable description
Yi	Climate change awareness	0 = Unaware of climate change 2 = Aware of climate change
X_{1i}	Age	1 = <30 years; 2 = 30 to 60 years; 3 = >60 years
X_{2i}	Gender	0 = Female 1 = Male
X_{3i}	Level of education	0 = No education, 1 = Primary education, 2 = Secondary education and 3 = Tertiary education
$X_{4i:}$	Religion	0 = Other or none 1 = Christianity
X_{5i}	Faming as main occupation	0 = None farming household 1 = Farming household

Following data cleaning, a total of 130 responses were however found to be suitable for this study. The questionnaire encompassed demographic, households' socioeconomic information as well as information on climate change awareness.

Method of data analysis

The method of data analysis were based on the intend objectives. Descriptive statistics such as frequency, percentage, means and standard deviation were used to analyze important variables like household socioeconomic characteristics and knowledge on climate change. Data analysis also comprised of a comparative analysis of recorded patterns in climate data and the changes as perceived by respondents. Multivariate analysis was used to analyze the determinants of climate change awareness. The adopted model dichotomized the depended variable into 2 categories, those that are aware of climate change and those that are not aware of the phenomenon. A dummy variable representing the households that are aware of climate change is thus labeled 1, otherwise = 0. The model therefore identifies the important variables that best characterize understanding of climate change by households at the same time determining the marginal contributions and elasticities of some hypothesized variables on the dependent variable.

The model adopted in this study was used to identify those variables that best explain climate change awareness. In order to examine the relative importance of each independent variable, by controlling all the confounding factors, multivariate analysis in the form of binary regression was used. The binary regression analysis is commonly used for the purpose of predicting values of binary response variables from one or more predictor variables. The dependent variables for the study was awareness of that there is climate change, variable ranging from 0 (no aware) and one (aware of climate change).

Let Y_i represent the propensity of a farmer being aware of climate change rather than not. Then the relationship between the observed outcome Y_i and the response propensity can be written as:

$$Y_i = B_0 + B_1 X_{1i} + B_2 X_{2i} + - - - - BKX_{ik} + e$$

Where B stands for the coefficients, K denotes the number of predictor variables (factors explaining the dependent variables) and i denote 0 or 1. The variables (Table 1) were taken into account for the determination of climate change awareness.

Multivariate or univariate analysis estimates the marginal effects of household characteristics on whether the head of household is aware of climate change or not.

RESULTS AND DISCUSSION

Table 2 provides the socio demographic characteristics of the total sample and stratified according to whether the households 'owned, managed, or contributed to any farming operations or not. Of the participants surveyed, 62% indicated that they practise farming either in the form of livestock husbandry, crop farming or operating a garden. This group was under-represented in the survey population when compared to Statistics South Africa (2012) data, which indicated people participating in agriculture to be 37% of Eastern Cape's rural provincial population. The over-representation of this group in the research could be attributed to the nature of the investigated communities and the economic structure of the Ntabankulu local municipality, which is highly orientated towards the agricultural sector and the service sector. In this regard, the research results are more appropriately generalized to the rural community and not necessarily the broader rural community as a whole.

The majority of survey participants were males (60.7%). This proportion was higher than recent estimates by Statistics South Africa (2012) of 44.7%. Male household members attend to surveys more than their female counterparts (Evans et al., 2011). As for the non-farming households, the males were slightly more than females. The representation of women involved in farming (38.5%) in the survey was much lower than the 61% reported by Altman et al. (2009). The results also conflicts with STATS SA (2012)'s finding that female headed households are more likely than male headed households to be involved in agriculture in rural areas.

The distribution of household size given on Table 2 reveals that both the farming households and none farming households have an equal mean household size of 7. The computed mean household size for all the respondents is 6, which is well above the mean at municipality level (4.4) (Statistics South Africa, 2012). This observation is supported by the finding that traditional communities favor large families than the modern societies.

The age distribution of all the household head indicates that majority of them are in the age group 30 to 60 years (63.4%). The aged, (+60 years) accounts for 27% and the youth account for insignificant proportion (6%) of the respondents. Similar proportions are also observed for the farming and non-farming households. The sample population's age distribution shows vast experience with both farming and climate change as experience is

Table 2. Household characteristics of the farming and non-farming households.

Characteristics	All respondents	Farmer households	Non farming households
Households size*			
Maximum	21	15	21
Mean (SD)	6 (3.2)	6.47 (2.7)	7.2(3.7)
Age of head of household			
<30 years	8 (6)	3 (2.3)	5 (3.8)
30-50 years	83 (63.4)	53 (40.7)	28 (21.5)
>50 years	35 (27)	24 (18.5)	13 (8.5)
Gender			
Male	79 (60.7)	30 (23)	27 (20.8)
Female	47 (36.2)	50 (38.5)	19 (13.1)
Education			
Not educated	49 (37.7)	37 (28.5)	10 (7.7)
Primary education	45 (34.7)	23 (17.7)	22 (16.9)
Secondary education	24 (18.5)	14 (10.8)	10 (7.70
Tertiary education	8 (6.2)	6 (4.6)	4 (1.5)
Marital status			
Married	64 (49.2)	40 (30.7)	24 (18.5)
Single	33 (24.6)	20 (15.4)	13 (7.7)
Divorced	4 (3.1)	4 (3.1)	0 (0)
Widowed	25 (19.2)	16 (12.3)	9 (6.9)

Source: Result of data analysis * Actual figures and not measured in percentage.

approximated by age (Falco and Veronesi, 2012).

The distribution on educational status of the respondents indicates that 37.7 of the respondents are found to be illiterate, and of the illiterate, 75.5% are farmers and only 20.5 are not farmers. However, the remaining 62.3% achieved a certain level of education. Out of the 62.3%, 26.8% are farmers. The educated households are more likely to be aware of climate change and understand its impact on farming activities than the illiterate (Mandleni and Anim, 2011).

Past studies have drawn linkages between climate change awareness and marital status (Mandleni and Anim, 2011; Acquah, 2011). The majority of the respondents (75.2%) are married followed by single (9.3%), widowed (4.7%) and the rest divorced and they contribute smaller proportion of the respondents. The higher percentage distribution of the married households is not commensurate to the country's picture where about 40% of the rural households in South Africa are reported to be legally married (Statistics South Africa, 2012).

Households' awareness and understanding of climate change

The level of respondents' understanding of climate change and its causes is the first question examined. Figure 1 presents the percentages of all households who have knowledge about climate and the perceived causes.

Results of the household questionnaire survey indicate that a high proportion of the respondents (70%) know about climate change but few understand the phenomenon. In a study in Ghana, 87.2% were aware of the climate change (Acquah, 2011) and proportion of 28% for a community in South Africa is not encouraging after understanding that the COP17 was held in that same country and the investigated community is located less than 400 km from Durban. An important outcome emerged as 80% agree that the climate is changing, and the difference of 10% generate an impression that they have seen the changes but remain unknowledgeable of the phenomenon. Evans et al. (2011) and Mandleni and Anim (2011) posits that people remain unaware of climate change but recognize some changes in climate. The prominent feature of many people's attitude towards climate change is uncertainty, disbelief, ignorance and some believe climate change will not affect them. This finding illustrates that generally the respondents have little concerns about climate change which probably imply that they do not consider it as a major threat to their livelihood. The outcome suggests the need to promote greater public awareness of climate change. Further efforts should be on familiarizing farmers with the trends in climate and assist farmers in developing and adopting measures best suited

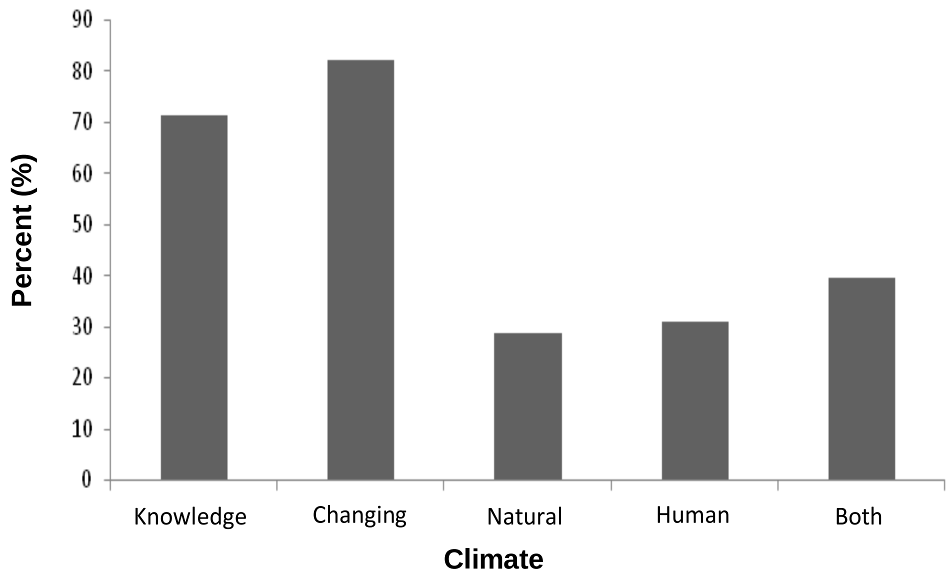

Figure 1. Levels of understanding of climate change.

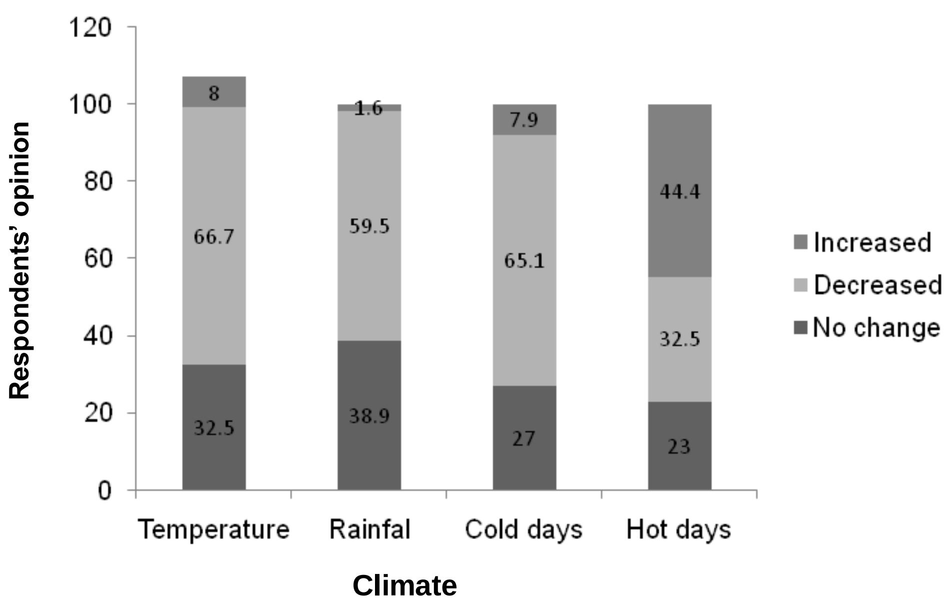

Figure 2. Respondents' opinion of climate over the past 20 years.

for reducing its adverse effects.

Further enquiry however; show that very few understand the causes as 28% stated that climate change is due to natural causes, 30% stated that it is caused by human beings and 40% stating that climate change is caused by both human and natural causes. In another critical level of conceptualization, one of the respondents perceives the changes to be a result of God's punishment to the human race for disobedience. The respondent even quoted a section in the Bible (Amos 2). The data presented illustrate unwarranted misunderstanding of climate change by rural folks. Most of the respondents were unsure whether human activities are responsible for climate change.

Knowledge on past trends in climate could help in more formal assessments of climate. After understanding that 80% of the households agree that they have seen some changes in climate, the study went on to sort to understand the respondents' perceived changes. Figure 2 shows the summarized statistics of the respondents' opinion of the past trends in temperature, rainfall, cold days and hot days. Remarks by Acquah (2011) substantiate knowledge on past changes in climate and uphold that information on past knowledge on changes in

Table 3. Binary logistic regression of the factors influencing household climate change awareness.

Variable of interests	Odds ratio	P value
Age		
<30 years [c]	-	-
30 to 60 years	1.1730	0.084*
>60 years	1.348	0.023**
Gender 0[c] = Female, 1 = Male	1.024	0.025**
Education		
0=No education[c]	-	.
1=Primary education	0.069	0.042**
2=Secondary education	1.45	0.168
3=Tertiary education	1.339	0.0943*
R Squared	0.45	

*, **, Significant at 0.10 and 0.05, respectively; [c]Reference category of the categorical variable.

local climate contribute to better understanding of present weather and climate variability.

The majority (66.7%) indicated that temperature had declined, 59.5% indicated that rainfall has decreased, 65.1% believe that cold days have decreased and 44.4% were convinced that that the number of hot days have increased. According to Blignaut (2009), Eastern Cape's temperature has increased by 3% and rainfall has decreased by 6% over the past twenty years. The perceptions of 66.7% of the respondents and 44.4% of the respondents on temperature and rainfall, respectively, are in line with the finding by Blignaut et al. (2009) in Eastern Cape Province. The local understanding of temperature and rainfall trends over the past 20 years indicate that 55% are misinformed about trends in temperature and 33% are misinformed about the trends in rainfall. A significant proportion, 30% remain adamant that there have not been any changes in any of the 4 conditions. This result implies that communal farmers are unsure of the trend in important climate aspects. This probably illustrate that rural farmers are not benefiting from their past understanding of trends in climate, therefore are not in a position to respond to current variability in climate. However, this finding is against the standard understanding from all over the world showing that local resource users usually hold a great deal of climate relevant knowledge of a depth and detail (Marin and Berkes, 2013). This therefore implies that local and indigenous understanding of climate change in rural South Africa should always be treated with skepticism.

The respondents' level of understanding of past trends in climatic conditions is lower than that reported in other studies where a much higher percentage of respondents identified the correct trends in climatic variability. In a study in Limpopo, Gbetibouo (2009) found that 91% perceive an increase in temperature and 81% perceive a decrease in rainfall. However, Gbetibouo (2009) posits that farmers' reports on climate variability over the past years are not necessarily correct as they are influenced by recent climate trends. The current research indicates various level of understanding of climate change and high degree of households' misinterpretation of the trends in important climatic aspects that occurred over the past 20 years. Despite the assumed knowledge on climate change by a higher proportion of the respondents, the level of understanding of the causes and past trends in climatic variability remains low among the investigated households.

Table 3 shows the results of the binary logistic regression of the factors influencing household climate change awareness. The coefficient for the variables age, gender and education was significant for climate change awareness. All the age group categories show a positive significant relationship with climate change awareness. The older age groups (30 to 60 years and > 60 years) were more likely more aware of climate change than the younger age group (<30 years). The possible reason was that the middle age group had individuals who are recent school leavers who had acquired knowledge on climate change through past experiences with climate variability and/or at school; which is currently part of their curriculum. The old age group has individuals who had stayed in the area of study for a reasonable amount of time to observe climate change. A study by Mongi et al. (2010) posits that households understanding of climate change depend on age and the level of education among other variables. Previous research Mandleni and Anim (2011) indicated similar results whereby education significantly affected awareness to climate change.

Also, respondents with tertiary education are more likely to have knowledge on climate change than respondents with no education and primary education. However chances are high that better among those with primary education that those without education at all. These results emphasize the importance of literacy.

The study showed that male headed households were more likely to be aware of climate change than their female counterparts. Asimilar study that was conducted by Mandleni and Anim (2011) conflict this results and however posits that male farmers are more responsive to adaptation to climate change.

The unwarranted misinterpretation of climate change calls for climate change awareness campaigns. Improving knowledge on climate change is a vital step towards reducing human foot-print and the adverse effects of climate change on agricultural production.

Conclusions

The paper provides important insights into the level of understanding of climate change by communal farmers and their perceived trends in important aspects of climate.

The results shed light on the importance of promoting community understanding of climate change. A large proportion of the respondents showed that they are not fully aware of the phenomenon threatening their farming livelihood. Local understanding of climate change is too general and inappropriate to positively influence adaptation. The study provide a case based evidence that extension workers, councilors, civil societies and other development agencies can use in enhancing public understanding of the climate change phenomenon. The importance of the elderly people in the community, education and the value of male was noted from this limited analysis of factors explaining climate change awareness. Improving knowledge on climatechange through financing education, carrying out some awareness campaigns and timely provision of scientific and instrumental data households could help.

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Full Length Research Paper

Relative performance of oat (*Avena sativa* L.) varieties for their growth and seed yield

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Deficit of the feed and fodder availability of the desired quality has been considered as the major bottleneck in harnessing the potential of the livestock sector in India. With the objective to find out the suitable variety of oat for getting maximum seed yield, a field experiment was conducted during rabi season of 2007 to 2008 at JNKVV, Jabalpur (MP). The treatments consisted of six varieties of oat (Kent, UPO 2005-1, NDO-1, JO 2003-78, OS-6 and JHO-822). The results showed that the variety NDO-1 produced the highest number of tillers/m^2, panicle weight and 1000 grain weight which resulted into higher seed yield (3.64 t/ha) than other varieties followed by Kent (3.52 t/ha) whereas, the variety OS-6 recorded lowest (2.86 t/ha) but its variation with JO 2003-78 (2.95 t/ha), UPO 2005-1 (3.10 t/ha) and JHO-822 (3.18 t/ha) was not significant. The straw yield was higher under variety OS-6 (10.62 t/ha) compared to other varieties. Growth parameters such as crop growth rate, relative growth rate and leaf area index were superior for variety NDO-1. NDO-1 recorded highest benefit-cost ratio (2.84), which was due to high gross as well as net monetary returns obtained.

Key words: *Avena sativa* L., benefit-cost ratio, forage dry matter, oat varieties, net monetary returns, yield.

INTRODUCTION

Livestock production is the backbone of Indian agriculture contributing 7% to national GDP and source of employment and ultimate livelihood for 70% population in rural areas. India is having the largest livestock population of 520 million heads, which is about 15% of the world's livestock population (Neelar, 2011). The animal products make a larger contribution to dietary energy in the developed countries than developing ones. There is tremendous pressure of livestock on the available total feed and fodder, as land available for fodder production has been decreasing. At present, the country faces a net deficit of 63% green fodder, 24% dry crop residues and 64% feeds (Kumar et al. 2012). The scenario of food security for a huge cattle population of the country is quite different. The crop residues mainly constitute the major feed material for the animals. The national effort towards ensuring adequate availability of livestock products like milk, meat and wool is hampered, to a greater extent by the shortage of nutritive forage from grasslands and fodder crops. The productivity of our livestock often remains low due to inadequate and nutritionally unbalanced supply of feed and fodder. Half of the total losses in livestock productivity are contributed to by the inadequacy in supply of feed and fodder (DARE, 2013). Thus emerging shortage of adequate and qualitative fodders and feeds to livestock is posing severe threats in maintaining the sustainable productivity of milk and other livestock products. The success of

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livestock industry depends upon availability of the quality fodder to meet out their nutritional requirement for maintenance and production. Recently, there has been a rapid change in the way agricultural scenario is shifting. There is need to meet the demand of increasing number of livestock and also enhance their productivity for which availability of feed resources have to be increased.

Oat is one of the important fodder crops widely grown during winter season for green fodder as well as grain purpose in different parts of the world. It ranks sixth in world cereal production following wheat, maize, rice, barley and sorghum. It was produced in 10212 million ha area with an annual production of 233 million tons in the world (Anonymous, 2009). In India, cultivated fodder is limited to 4.9% of the total cropped area (Kumar et al., 2012). The total area under cultivated fodders is 8.6 million ha on individual crop basis. Sorghum amongst the kharif crops (2.6 million ha) and berseem (Egyptian clover) amongst the rabi crops (1.9 million ha) occupy about 54% of the total cultivated fodder cropped area. The total area covered under oat cultivation in the country is about 1.0 million ha with 35-50 t/ha green fodder productivity (IGFRI, 2011). In India, it is grown in Punjab, Haryana, Jammu & Kashmir, Himachal Pradesh, Uttar Pradesh, Madhya Pradesh, Rajasthan, Maharashtra and West Bengal. The crop occupies maximum area in Uttar Pradesh (34%), followed by Punjab (20%), Bihar (16%), Haryana (9%) and Madhya Pradesh (6%) (Agricultural Statistics, 2006-2007). In Madhya Pradesh, it is cultivated in about 790 ha area under irrigated and rainfed conditions (Argil. Statistics, 2006 to 2007). It constitutes 30% of the Indian market in terms of volume for breakfast foods next only to Cornflakes and 18% in value terms (Government of Western Australia, 2012). High grain yield is the most desired characteristic of oat cultivars. Most of the fodder crops are grown under irrigated situations except in areas, which receive adequate winter rains. Under such situations where water supply is limited and the farmers are not in a position to grow the crops having high water requirement such as lucerne and berseem, oat can grow successfully, which provides energy rich nutritious and palatable fodder for livestock. The livestock grain feed is still the primary use of oat crops, accounting for an average of around 74% of the world's total usage (Welch, 1995). It can be fed in any form like green forage or silage to the animals covering the scarcity period of the year.

The availability of good quality seed of forage crops in sufficient quantity is one of the major constraints, though improved varieties of various fodder crops have been evolved and the agro-techniques have also been developed to obtain their high yield potential. Secondly, the forage crops are usually harvested for fodder purpose before the seed setting. Thus, the opportunity for seed production is limited. The attraction of farmers for seed production of forage crops, particularly oat can be made possible by introducing the varieties, which are having the potential of producing higher seed yield. Increased nutritional demand for optimal animal performance has challenged oat producers to select superior oat variety, and to combine good management practices to produce crops with high yield and favorable quality characteristics (Kim et al., 2006). Oat continues to be an important fodder crop because of their high yield potential and very good feed quality. Recently some new varieties of oat have been developed, which are having capacity to produce higher seed yield. The performance of these varieties is to be compared for their seed production with the existing improved varieties. Therefore, keeping all the above facts in view, the present investigation was undertaken with the objective to identify oat varieties with superior seed yield for livestock production.

MATERIALS AND METHODS

A field experiment was conducted during *rabi* (winter) season of 2007 to 2008 at the Research farm, Department of Agronomy, JNKVV, Jabalpur, India. The geographical location of the site is situated between 23˚09' North latitude and 79˚58' East longitudes with an altitude of 411.78 m above the mean sea level. The climate is sub-tropical with hot dry summer and cool dry winter. The location falls under the rice-wheat crop zone of Madhya Pradesh, India; which lies in the "Kymore plateau and Satpura hills" agro-climatic zone. The average annual rainfall is nearly 1358 mm, which mainly received between mid June to September with maximum concentration in the month of July and August. There are nominal rain (less than 70 mm) occasionally received during the remaining months of the year. The mean relative humidity (RH) varies from 15% in summer to 90% during rainy season. In the region, the temperature rises as high as up to 45.3°C during May to June months, while the minimum temperature goes down up to 4°C during the winter followed by occasional frost.

The soil of experimental site is classified as 'Vertisol'. It swells by wetting and shrinks when dries. The soil was sandy clay loam in texture, neutral in reaction (p^H 7.2) with low organic carbon (0.44 g/kg) and available nitrogen (228 kg/ha) and medium in available phosphorus (16.2 kg/ha) and potassium (297 kg/ha). The electrical conductivity of the soil (0.34 d/Sm) was normal. The experiment consisted of six treatments of oat varieties namely Kent, UPO 2005-1, NDO-1, JO 2003-78, OS-6 and JHO-822 were laid out in randomized block design with four replications on well prepared and leveled field. All the treatments were randomly allocated to different plots in each replication with a plot size of 4.0 x 3.0 m. A uniform dose of 40 kg P_2O_5/ha and 20 kg K_2O/ha was applied as basal to all plots through single super phosphate and muriate of potash, respectively. Nitrogen was applied through urea in two split doses as 40 kg at basal and remaining 40 kg at tillering stage. The basal dose of fertilizers was applied in furrows nearly 2 cm below the seeds. Before sowing, the seeds were treated with thirum at 3 g/kg of seeds. Sowing was done uniformly in all the plots manually by using 100 kg seeds/ha with a row spacing of 25 cm. All the standard agronomic management practices were adopted.

Growth parameters, yield attributes and yield of different varieties were recorded as per the standard procedure at crop maturity. Standard procedures were used for chemical analysis of soil. The economic parameters (gross returns, net returns and B : C ratio) of the treatments were worked out on the basis of prevailing market prices of inputs and outputs. The data were analyzed using the 'Analysis of Variance Technique' as per the standard procedure. The treatment means were compared at 5% level of significance.

Agronomic characteristics of varieties

Kent

This variety is introduced from Australia; plants are semi dwarf (100 to 125 cm) and bear maximum tillers/m^2 (135 to 140). The length of panicle (25 to 30 cm), weight of panicle (3.20 to 3.30 g), seeds/panicle (90 to 100) and test weight (37.40 to 37.60 g). It is widely adopted for fodder and seed production.

OS-6

This variety has been developed from Haryana Agricultural University, Hissar, India. It has more growing habit, medium height (120 to 130 cm), tillers/m^2 (125 to 135), length of panicle (3.20 to 3.40 g), seeds/panicle (90 to 100) and test weight (32.10 to 32.30g).

JHO-822

This variety has been developed from IGFRI, Jhansi, India through a cross between IGO-4262 X Indio 6-5-1. It is widely grown in the central part of India. Plants are with medium height (120 to 130 cm) and a good number of tillers/m^2 (130 to 140). The length of panicle, weight of panicle, seeds/panicle and test weight of variety is 25 to 30 cm, 3.30 to 3.50 g, 95 to 105 and 35.75 to 35.95 g respectively.

UPO 2005-1

It has been developed by Pantnagar Agriculture University, Ludhiana, India. The plants are tall in nature (130 to 140 cm) and produces maximum tillers/m^2, length of panicle and the number of seeds/panicle of 125 to 135, 28 to 32 cm and 105 to 115 respectively. Its panicle weight is (3.20 to 3.30 g), test weight (35.20 to 35.40 g).

NDO-1

It was developed by Narendradev Agriculture University, Faizabad, India. The plant height is about 110 cm, tillers/m^2 (135 to 145), weight of panicle (3.80 to 4.15 g) and test weight (41.30 to 41.60 g). The length of the panicle is about 27 cm, seeds/panicle (85 to 95).

JO 2003-78

This variety has been developed from cross between Kent x UPO 130. Plants are tall (120-130 cm) with 125 to 135 tillers/m^2, length of panicle, seeds/panicle, weight of panicle and test weight of 125 to 135, 25 to 30 cm, 100 to 110, 3.20 to 3.40 g and 34.20 to 34.50 g respectively.

RESULTS AND DISCUSSION

Effect on growth parameters

Three newly developed oat varieties (UPO 2005-1, NDO-1 and JO 2003-78) and three recommended high yielding variety (Kent, OS-6 and JHO-822) were compared for their growth performance under this study. The growth parameters *viz.* plant height, tillers/m^2, leaf area index (LAI), crop growth rate (CGR) and relative growth rate (RGR) gradually increased under all varieties with the advancement in growing periods till harvest of the crop. The increase in plant height continued till the final stage because of phase changes in plants from vegetative to reproductive phase. The results showed that the variety UPO 2005-1 had significantly taller plants (135.2 cm) than others, followed by JO 2003-78 (126.4 cm), OS-6 (125.45 cm), Kent (124.35 cm) and JHO-822 (122.45 cm) which had almost similar plant height (Table 1). Differences in plant height among varieties are expected due to genetic make-up of the varieties. The significant effect of variety on plant height in present study is in agreement with previous findings (Kibite et al., 2002b; Chohan et al., 2004; Hussain et al., 2005). It is apparent from the data that the number of tillers/m^2 increased with the advancement in growth period of crop under all varieties. Variety NDO-1 produced maximum number of tillers/m^2 and proved significantly superior over UPO 2005-1, JO 2003-78 and OS-6, but it was non-significant to Kent and JHO-822 at all the growth stages. Variety OS-6 being at par to JO 2003-78 and UPO 2005-1 produced a minimum number of tillers/m^2. Similarly, the LAI showed rapid rate of increment during the growth period under all varieties but it did not indicate marked variations among varieties at any of the growth stages. Variety Kent recorded highest LAI (2.92) at 90 DAS but the differences were not significant among the varieties and OS-6 was the lowest (2.07) in this regard (Figure 1). It is clear from the data that CGR as well as RGR were greatly influenced due to varieties. Data revealed that CGR as well as RGR increased upto 90 DAS under all varieties, but after that it was declined. RGR was highest at 60 DAS for all the varieties and later on declined slowly. Variety Kent recorded higher values of CGR which was non-significant to JO 2003-78 and NDO-1, than OS-6 and JHO-822 at 90 DAS recorded minimum CGR value (Figure 2). Whereas, in case of RGR UPO 2005-1 recorded maximum value which was non-comparable to OS-6, JHO-822 and Kent (Figure 3). Variety OS-6 followed by JHO-88 produced considerably higher dry

Table 1. Influence of different oat varieties on growth parameters, yield attributes and yield at harvest.

Treatment	Plant height (cm)	Tillers/m²	Dry matter production (t/ha)	Panicle length (cm)	Panicle weight (g)	Grains per panicle (No)	1000-grain weight (g)	Seed yield (t/ha)	Straw yield (t/ha)	HI* (%)
Kent	124.3	138.2	9.97	28.3	3.88	92.0	37.5	3.52	9.55	26.9
UPO 2005-1	135.2	130.1	10.13	29.6	3.57	109.0	35.0	3.10	8.22	27.3
NDO-1	111.0	140.2	9.74	27.1	4.12	88.2	41.5	3.64	8.10	31.0
JO 2003-78	126.4	128.2	10.23	27.5	3.33	103.2	34.4	2.95	10.18	22.6
OS-6	125.4	128.1	11.48	26.9	3.34	96.0	32.9	2.86	10.62	21.2
JHO-822	122.4	136.2	10.91	28.3	3.42	100.8	35.8	3.18	9.32	25.4

*HI-Harvest index.

matter at harvest among all the other varieties (Table 1). Dry matter production under variety NDO-1 was minimum (9.74 t/ha) at harvest but it was comparable to Kent, UPO 2005-1 and JO 2003-78 (9.97, 10.13 and 10.23 t/ha). These parameters are generally expression of the varieties. The variation in various growth parameters among the varieties may be due to their genetic constitution during crop growth period. Similar patterns of growth in oat have been also reported by Kumar et al. (1992); Lupingan et al. (1999) and Naeem et al. (2002).

Effect on yield attributes and yield

The yield attributing characters *viz.* panicle length, panicle weight, grains per panicle and 1000-grain weight was significantly affected due to different varieties. Higher values of LAI under Kent and NDO-1 attributed to better interception, absorption and utilization of radiation energy leading to higher photosynthetic rate and finally more accumulation of dry matter by the plants, which helped to improve the accumulation of dry matter by the plants and ultimately resulted in higher seed yield (3.52 and 3.64 t/ha) under these varieties. However, variety UPO 2005-1 was noted to be appreciably superior in producing longer panicles and more number of grains per panicle (29.65 cm and 109.03), whereas variety NDO-1 recorded significantly higher weight of panicle and test weight (4.12 and 41.50 g) (Table 1). This variability in different yield attributing characters was mainly due to their genetical behavior. These results are in close conformity with the findings of Lupingan et al. (1999); Naeem et al. (2002) and Singh and Singh (1992). The overall improvement of crop growth reflected into better source-sink relationship, which in turn enhanced the yield attributes.

Based on the results, variety NDO-1 produced higher seed yield (3.64 t/ha) followed by Kent (3.52 t/ha) compared to other varieties but do not differ significantly. Variety OS-6 being at par to JO 2003-78, UPO 2005-78 and JHO-822 was noted to be lower among all in seed yield. The improved yield attributing characters *viz*. more number of tillers/m^2, higher panicle weight and 1000 grain weight under variety NDO-1 might have attributed to higher seed yield under this variety. The seed yield of crop had strong possible correlation with number of tillers/m^2, weight of panicle and test weight as reported by Kibite (1997); Lacko-Bortosova et al. (2000) and Villasenor-mir et al. (2001).

The straw yield was differed non-significantly among the varieties. It was remarkably higher under variety OS-6 (10.62 t/ha) followed by JO 2003-78 (10.18 t/ha) next to it, which marked superiority over others. This might be due to its higher dry matter production and lower seed yield, which increased the proportion of straw in the total biomass obtained under this variety. Variety NDO-1 non-comparable to UPO 2005-1 had a considerably lower straw yield as compared to others. The variations in straw yield under different varieties may be due to the differences in plant height and number of tillers/m^2 recorded with them. The straw yield had a strong positive relationship with plant height and number of tillers/m^2. These results are corroborated with the findings of Singh and Nanda (1998) and Nazakat et al. (2004).

While the highest harvest index was

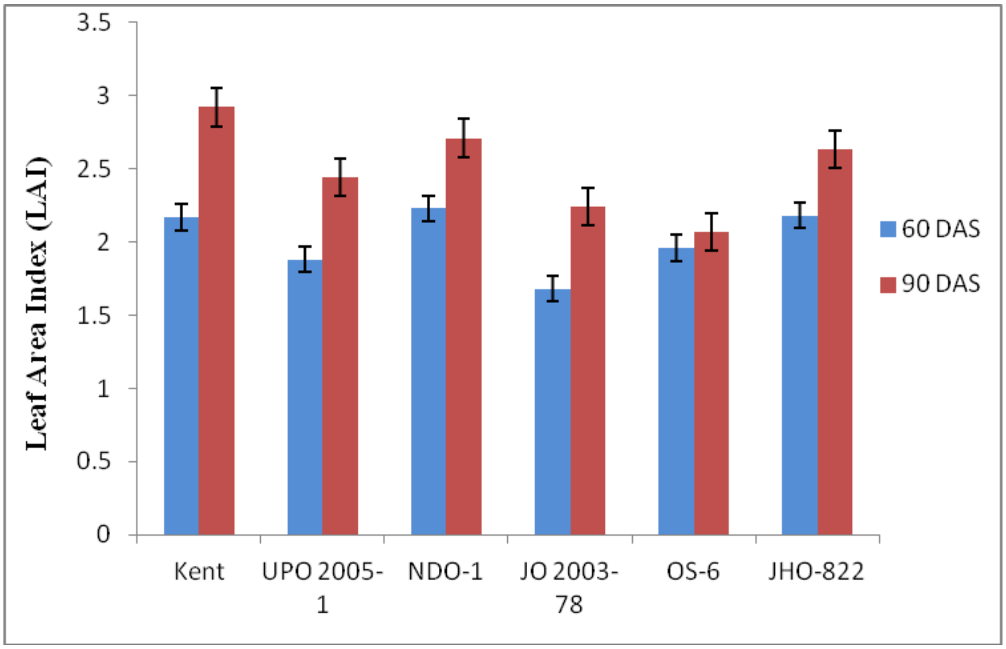

Figure 1. Leaf Area Index (LAI) influenced by different varieties of oat.

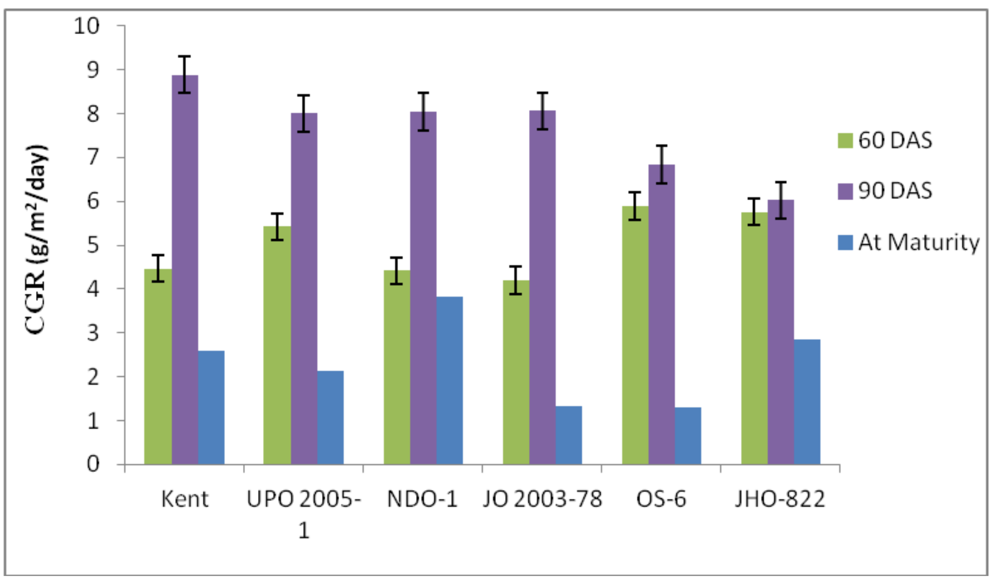

Figure 2. Crop growth rate (CGR) influenced by different varieties of oat.

significantly differed among the varieties and it was maximum (31%) in NDO-1 where as OS-6 had the lowest harvest index (21.2%) as compared to other varieties (Table 1). Differences among varieties with regard to harvest index were due to differences in plant heights. Other researchers also observed significant differences among varieties with regard to harvest index due to variations in total dry matter and assimilate distribution (Dreccer et al. 2009).

Economics

The cost of cultivation was same under all the treatments. It did not vary because all the operations and inputs used in raising the crop were similar under each treatment. The expenditure incurred for each variety was ₹14920.52/ha. The gross monetary return (GMR) is the value of the produce under different treatments. Since the quantity of economic

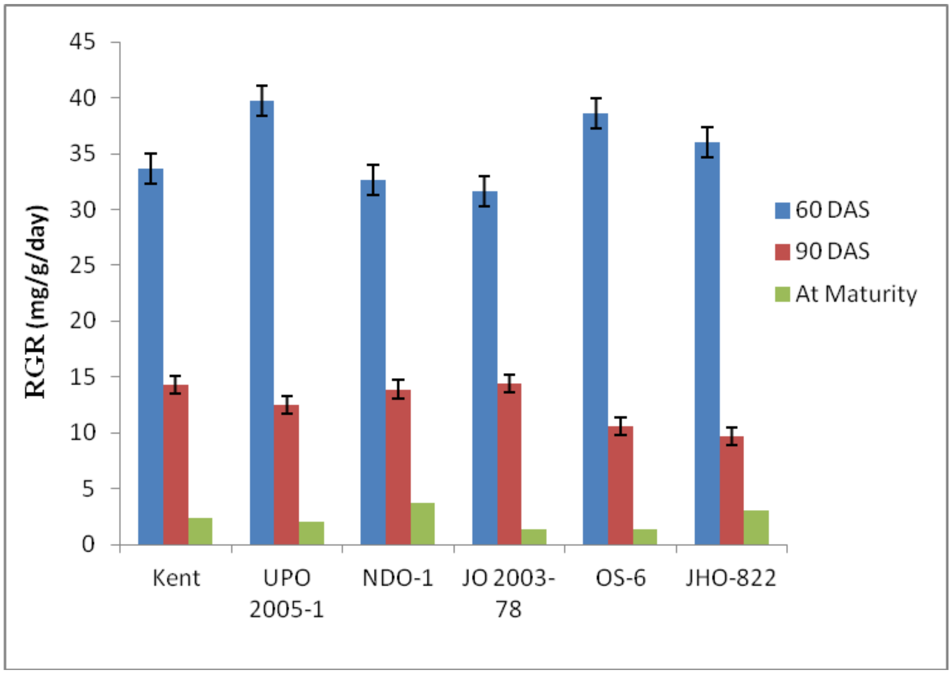

Figure 3. Relative growth rate (RGR) influenced by different varieties of oat.

Table 2. Influence of different oat varieties on economic return.

Treatment	Cost of Cultivation (₹/ha)	GMR (₹/ha)	NMR (₹/ha)	B:C ratio
Kent	14920.52	56143	41222.48	2.76
UPO 2005-1	14920.52	49410	34489.48	2.31
NDO-1	14920.52	57435	42514.48	2.84
JO 2003-78	14920.52	47816	32895.48	2.20
OS-6	14920.52	46619	31698.48	2.12
JHO-822	14920.52	50962	36041.48	2.41

GMR-Gross monetary returns, NMR-Net monetary returns, B:C-Benefit-cost ratio (Selling price of grains- Rs. 1500/q, Straw- Rs. 35/q)

produce (seed and straw yield) was varied due to the different varieties, hence GMR also differed with these treatments. Among the varieties, NDO-1 fetched maximum GMR followed by Kent but not much difference between them (Table 2). All other varieties led to record the lesser GMR because of low seed and straw yield production. Thus, variety NDO-1 fetched highest net returns and B:C ratio (₹42514.48/ha and 2.84) which was closely followed by Kent (₹41222.48/ha and 2.76). But other varieties resulted into lesser net returns and B:C ratio.

Conclusion

Based on the findings of the present investigation, it may be concluded that the NDO-1 proved superior variety with respect to various growth parameters *viz.* number of tillers/m^2, LAI, CGR and RGR as well as yield attributes such as weight of panicle and test weight. It proved to be most suitable and remunerative variety for getting higher seed yield and led to record the highest gross as well as net monetary returns and benefit-cost ratio.

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Review

Rammed earth theory in earth architecture

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Rammed earth is a method of building walls whereby a mixture of earth is compacted in layers between forms. The soil mix needs to be carefully balanced between clay, sand and aggregate. The clay and moisture content of rammed earth is relatively low compared to that used for mud brick or other earth building methods. The use of rammed earth is a fascinating fusion of modern technology, ancient knowledge, and innovative construction techniques, and is increasingly attracting attention. It's a sustainable building materials and natural building methods. Once a building is obsolete, it returns to earth. The paper presents rammed system based on physical and construction characteristics.

Key words: Earth architecture, rammed earth, sustainable, construction.

INTRODUCTION

Rammed earth is a technique for building walls using the raw materials of earth, chalk, lime and gravel. Rammed earth is a structural wall system built of natural mineral soils compacted in thin layers within sturdy formwork. The strength and durability of the wall are results from the densification of a clay, sand and gravel matrix. The mass of the wall provides superior thermal and acoustic properties. It is an ancient building method that has seen a revival in recent years as people seek more sustainable building materials and natural building methods. A natural building involves a range of building systems and materials that place major emphasis on sustainability. Ways of achieving sustainability through natural building focus on durability and the use of minimally processed, plentiful or renewable resources, as well as those that, while recycled or salvaged, produce healthy living environments and maintain indoor air quality. Natural building tends to rely on human labor, more than technology. It depends on "local ecology, geology and climate; on the character of the particular building site, and on the needs and personalities of the builders and users". Rammed-earth walls are simple to construct, incombustible, thermally massive, strong, and durable.

They can be labor-intensive to construct without machinery, however, and they are susceptible to water damage if inadequately protected or maintained. Building a rammed earth wall involves compressing a damp mixture of earth that has suitable proportions of sand, gravel and clay into an externally supported frame or mould, creating either a solid wall of earth or individual blocks. Historically, such additives as lime or animal blood were used to stabilize the material, whilst modern construction uses lime, cement or asphalt emulsions. Some modern builders also add colored oxides or other items, such as bottles or pieces of timber, to add variety to the structure. The construction of an entire wall begins with a temporary frame, usually made of wood or plywood, to act as a mould for the desired shape and dimensions of each wall section. The form must be sturdy and well braced, and the 2 opposing wall faces clamped together, to prevent bulging or deformation from the large compression forces involved. Damp material is poured in to a depth of 10 to 25 cm and then compacted to around 50% of its original height. The material is compressed

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iteratively, in batches, gradually building the wall up to the top of the frame. Tamping was historically done by hand with a long ramming pole, and was very labor-intensive; modern construction can be made more efficient by employing pneumatically powered tampers. Once a wall is complete, it is strong enough that the frames can be removed immediately. This is necessary if a surface texture will be applied, since the walls become too hard to work after about an hour. Construction is best done in warm weather so that the walls can dry and harden. The compression strength of the rammed earth increases as it cures; it takes some time to dry out, as much as 2 years for complete curing. Exposed walls should be sealed to prevent water damage. In modern variations of the method, rammed earth walls are constructed on top of conventional footings or a reinforced concrete slab base. Where blocks made of rammed earth are used, they are generally stacked like regular blocks but are bonded together with thin mud slurry instead of cement. Special machines, usually powered by small engines and often portable, are used to compress the earth into blocks (Figure 1).

Characteristics

The compressive strength of rammed earth can be up to 4.3 MPa. This is less than that of concrete, but more than strong enough for use in domestic buildings. Indeed, properly built rammed earth can withstand loads for thousands of years, as many still-standing ancient structures around the world attest. Rammed earth using rebar, wood or bamboo reinforcement can prevent failure caused by earthquakes or heavy storms. Adding cement to clay-poor soil mixtures can also increase a structure's load-bearing capacity. Soil is a widely available, low-cost and sustainable resource, and utilizing it in construction has minimal environmental impact. This makes rammed-earth construction highly affordable and viable for low-income builders. Unskilled labor can do most of the necessary work, and today more than 30% of the world's population uses earth as a building material.

Rammed earth has been used around the world in a wide range of climatic conditions, from wet Northern Europe to dry regions in Africa. While the cost of material is low, rammed-earth construction without mechanical tools can be very time-consuming, however, with a mechanical tamper and prefabricated form work, it can take as little as 2 to 3 days to construct the walls for a 200 to 220 m^2 house. One of the significant benefits of rammed earth is its high thermal mass; like brick or concrete construction, it can absorb heat during the day and release it at night. This moderates daily temperature variations and reduces the need for air conditioning and heating. It often requires thermal insulation in colder climates, again like brick and concrete, and must be protected from heavy rain and insulated with vapor barriers. Rammed earth can effectively control humidity where unclad walls containing clay are exposed to an internal space. Humidity is held between 40 and 60%, the ideal range for asthma sufferers and for the storage of such susceptible items as books. The material mass and clay content of rammed earth allows the building to "breathe" more than concrete structures do, avoiding condensation issues without significant heat loss. Surface detail of a rammed earth wall; apart from the patches of damage, the surface shows regular horizontal lines from the wooden formwork used in constructing the wall and subtler horizontal strata from successive layers of compacted earth (Figure 2).

Environmental aspects and sustainability

Sustainable architecture is a general term that describes environmentally conscious design techniques in the field of architecture. Sustainable architecture is framed by the larger discussion of sustainability and the pressing economic and political issues of our world. In the broad context, sustainable architecture seeks to minimize the negative environmental impact of buildings by enhancing efficiency and moderation in the use of materials, energy, and development space (Niroumand et al., 2011). Most simply, the idea of sustainability, or ecological design, is to ensure that our actions and decisions today do not inhibit the opportunities of future generations. Some examples of sustainable building materials include recycled denim or blown-in fiber glass insulation, sustainably harvested wood, Linoleum, sheep wool, concrete, panels made from paper flakes, baked earth, rammed earth, clay, vermiculite, flax linen, sisal, see grass, cork, expanded clay grains, coconut, wood fiber plates, calcium sand stone, locally obtained stone and rock, and bamboo, which is one of the strongest and fastest growing woody plants, and non-toxic glues and paints (Minke, 2006). Because rammed earth structures use locally available materials, they usually have low embodied energy and generate very little waste. The soils used are typically sub soils low in clay (between 5 and 15%), the topsoil being retained for agricultural use. Where soil excavated in preparing the building's foundation can be used, the cost and energy consumption for transportation are minimal.

Rammed earth buildings reduce the need for lumber because the formwork is removable and can be repeatedly reused (Jaquin et al., 2008). When cement is used in the earth mixture, sustainable benefits such as low embodied energy and humidity control will not be realized. Manufacture of the cement itself adds to the global carbon dioxide burden at a rate of 1.25 tons per ton of cement produced. Partial substitution of cement with alternatives such as ground granulated blast furnace slag has not been shown to be effective, and raises further sustainability questions. Rammed earth can contribute to the overall energy-efficiency of buildings. The density, thickness and thermal conductivity of rammed earth make it a particularly suitable material for passive solar heating.

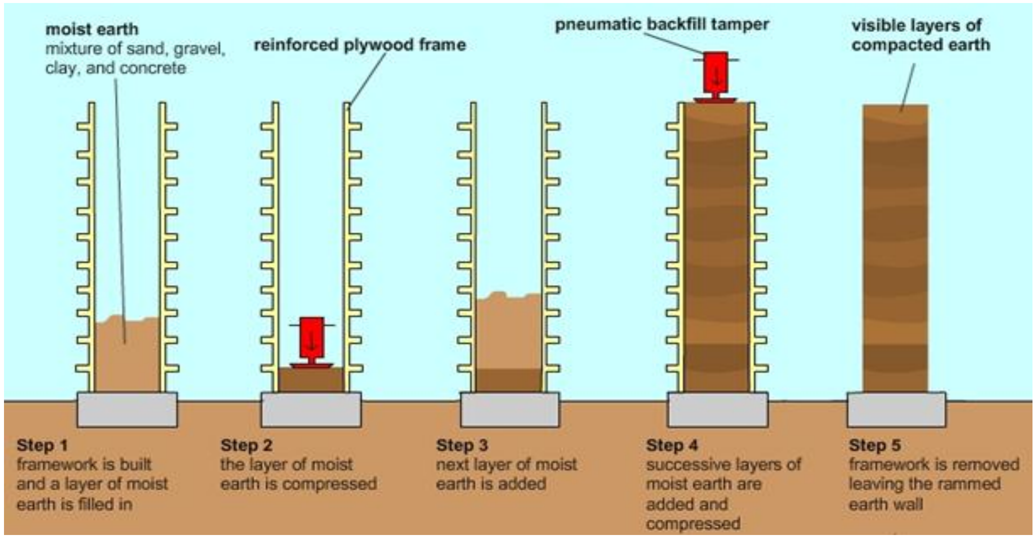

Figure 1. Construction Steps of Rammed Earth (Gunzelmann, 2008).

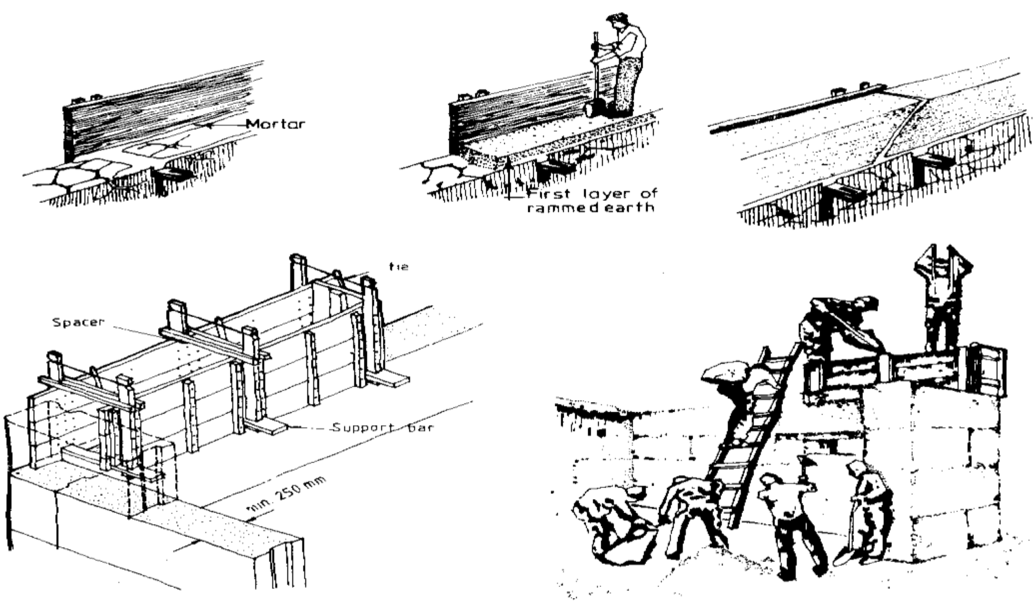

Figure 2. Rammed Earth in Practice (Lennart and James, 1998).

Warmth takes almost 12 h to work its way through a wall 35 cm thick. Rammed earth housing has been shown to resolve problems with homelessness caused by otherwise high building costs, also to help address the ecological impacts of deforestation and the toxicity of building materials associated with conventional construction methods (Figure 3).

CONCLUSION

The many advantages of building with rammed earth include superior insulation, strength and durability, low maintenance; fire proofing, load bearing and pest deterrence (Niroumand et al., 2011). The external walls of rammed earth buildings are a minimum of 300mm thick, providing excellent protection from extremes in climate. The thickness and density of the material means that heat or cold penetration of the wall is very slow and the internal temperature of the building remains relatively stable, with the end result of it feeling warmer in winter and cooler in summer than the outside temperature. Rammed earth is a popular choice for buildings where temperature fluctuations need to be kept to a minimum. The thickness and density of the walls mean that unwanted sounds such as traffic noise are kept out. Internal walls in rammed

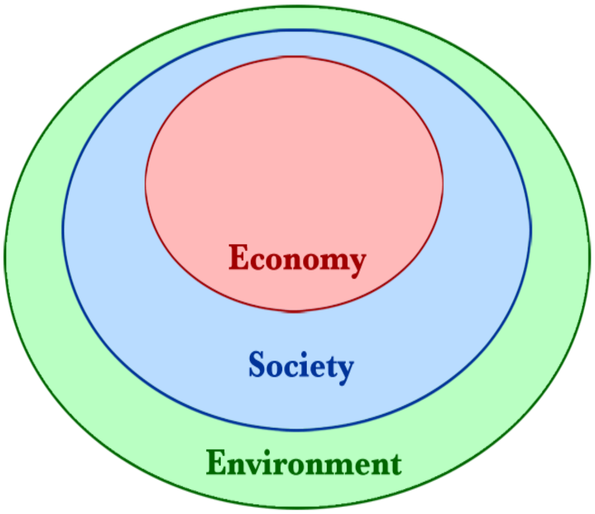

Figure 3. Sustainable development.

earth can also be extremely useful in providing sound insulation between areas with different needs for instance between living and sleeping areas, between a public or family room and a study area, or in party walls between townhouses. Rammed earth walls are maintenance free. They are features that stand alone and don't need finishing with gyprock, render, paint, wallpaper, tiles or anything else. There is no need to ever again spend time and money painting but should you prefer any of these other finishes they can be applied to rammed earth walls in just the same way as to other masonry walls. Rammed earth walls are permanent and require no ongoing maintenance. Earth doesn't burn. This is an ideal material for bush settings and leafy suburbs. Fire tests showed that a 250mm rammed earth block wall achieved a 4 h fire resistance rating. A 150mm wall achieved a rating of 3 h 41 min. Engineers recognize rammed earth as load bearing, so you are unlikely to need other structural framing for your home, cutting costs, fire and pest susceptibility. Rammed earth also provides substantial bracing to buildings; usually well in excess of the minimum requirement achieved by most timber framed homes. It provides a feeling of stability and security in even the worst weather conditions. Rammed earth walls are fast to go up. The walls of an average home can be up and ready for the roof framing in as little as a week. Unlike most types of masonry, rammed earth walls don't need core filling or reinforcing. Nor do they need gyprocking, plastering, painting or wallpapering. This saves money and energy when you build and goes on saving them for years.

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