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Full Length Research Paper

Shea butter processing as an engine of poverty reduction in Northern Ghana: Case study of four communities in the Bolgatanga Municipality

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Peasant farming had been seen for many years as a means of fighting rural poverty in the Sub-Saharan zone of Africa. With the passing of time, new researches had shown that the notion is fading off since studies have established that only a small percentage of those farms have seen expansion and intensification leaving the rest stagnated with lowering productivity, decrease in size and low output. Alternative sources of rural income are therefore important to determine for specific locations. This paper looks at the effects of shea butter processing on rural household income in four: communities in the Sumbrungu area of the Bolgatanga Municipality of the Upper East Region of Ghana. Regression analysis performed indicated that shea butter processing activity in the selected communities is a signification source of income as compared to the official minimum daily wage in Ghana. The main factors that influence income of shea producer households are the size of the household, quantity of shea butter produced, farming activity and number of employed members of the household. The location of a community with respect to Atolesum community also has effect on shea butter producer household income. Notwithstanding the potential of the shea industry in poverty reduction, challenges like lack of financial support, lack of ready market, high cost of machinery and others are making the women not fully utilizing the potential of the industry. Governmental as well as Non-Governmental support is therefore needed to put the shea industry in its right place in poverty reduction efforts.

Key words: Shea butter producers, households, communities, household income, Ghana, poverty.

INTRODUCTION

Researchers in recent times have established that non-farm income is on the ascendency and becoming important, accounting for between 35 and 50% of rural household income in SSA (Reardon, 1997; Haggblade et al., 2010). Diversification of source of household income had been identified in SSA of recent times as a means of sustaining livelihood (Losch et al., 2011; Winters et al., 2010; Ellis, 2005; De Janvry et al., 2002). Chalfin (2004)

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recognised the potential of the shea trees as one of the major income generating sources for the people of Northern Ghana since the colonial days. The potential of the shea till date has not been effectively tapped due to the socio-economic conditions and lack of proper policy and governmental backing as in the case of cocoa. It is therefore important that research is carried out to unfold the potential of shea. In this respect, the Upper East Region had been selected for this research work since little or no information could be found in existing literature.

Interestingly, the shea tree which grows in the wild is mainly found in areas of immense poverty. Yidana (1994) states that involvement of all stakeholders in the industry is needed in order to sustain the shea tree. Shea pickers, butter producers and communities of shea growing areas need to strengthen and modify the existing practices in order to make the industry an effective engine for poverty alleviation.

As mentioned in literature (Grigsby and Force, 1993) and also confirmed through a field interview conducted in April, 2012 by the researcher, shea fruit picking, processing of fruits into nuts as well as processing the nuts into shea butter had been the reserve for women. It is also stated by TechnoServe Ghana (2004), 90% of the world's shea nuts as raw material in the world for shea butter processors and marketers can be produced by Ghana. Although the shea industry can effectively alleviate poverty among women, financial constraint and inadequate technical support has made them to remain in poverty.

Kanlisi et al. (2014) also states that shea butter production has the potential to increase income generation to improve the living standard of local women and their households and also create jobs there by slowing down rural-urban drift in Ghana.

At the Sagnarigu Shea Butter Processing Centre, women generally admitted that shea butter processing is the main livelihood strategy that they undertake and has reduced their vulnerability as they have derived some benefits from shea butter processing (Dauda et al., 2014). Daniel et al. (2005), also writes that in Nigeria, shea butter extraction is a lucrative business especially in rural areas where the shea trees thrives. It was realized by Kanlisi et al. (2014) that on an average, each woman in the Wa Municipality earns about 31 Ghana cedis 46 pesewas, which falls below the minimum wage of 104 Ghana cedis 80 pesewas (5 Ghana cedis 24 pesewas per day) of the national level minimum wage rate indicated by the Ghana Trade Union Congress in 2013. An estimated number of about 600.000 women of the Ghanaian northern decent live on the income they acquire through processing and marketing of shea related products (Stichting, 2006). This paper examines the ability of the shea industry to alleviate poverty, the main factors of income generation among shea butter producer households in four communities in the Bolgatanga Municipality namely: Kulbia Bokom, Kulbia Atolesum Kulbia Amolgoduni and Kulbia Anateem.

The main objective of this research is to identify determinants of household income in four communities in the research area. The study's specific objectives are therefore:

1. To verify possible determinants of household income, such as location, household size, gender of household head, number of children, education of household head and shea producer, other income activities other than shea, age of producer and quantity of nuts processed among others.
2. Project household income assuming all other income generating determinants are constant apart from shea activity.
3. Make comparison of projected income as against the minimum daily average wage in Ghana.

The theoretical underpinning of the study is based on the theory of Leedy and Ormrod (2005), which defines a case study as an in depth examination of an individual, program or event.

The study area

The study area comprises of four communities in the Sumbrungu area of the Bolgatanga Municipality of the Upper East Region. The Region is one of the three northern regions of Ghana and shares borders with Northern and Upper West Regions of Ghana, Burkina Faso and Togo. Like all others northern regions Upper East Region is located in the Guinea savannah agro-ecological zone. It is blessed with multipurpose wild trees like shea and locust bean that have economic values and yet it is one of the poorest and less developed regions of Ghana with her population mainly engaged in rain-fed peasant farming as the primary source of livelihood. Like all indigenous rural communities of the Northern Ghana, the households of the four communities are scattered giving room to farming activities around their houses. Historically, men are engage mostly in the farming activities leaving the women to engage in other income generating activities such as petty trading, basket weaving, shea fruit picking and shea butter processing as well as assisting on the farms.

The region is one of the poorest for several decades in terms of living standards, literacy levels, health and nutritional status which are all extremely low and well below the national average (Whitehead, 2006).

MATERIALS AND METHODS

In this research, the case study was focused on purposefully selected sites and individuals were conducted. Although findings were reported on more than one group, a single case study approach was used to collect data and report results. This is because the case study was focused on shea butter producers in the Upper East Region, precisely the Sumbrungu area. The study

Table 1. Variable identification.

Variable identification	Name of variable
X_1	Size of household
X_2	Age of shea butter producer
X_3	No. of unemployed in household
X_4	No. of children in household
X_5	No. of employed in household
X_6	Shea butter quantity produced
D_1	Gender of household head
D_2	Education of household head
D_3	Education of shea butter producer
D_4	Farming
D_5	Craft (basket weaving)
D_9	Bokom community
D_8	Amolgoduni community
D_6	Anateem community

covered the four aspects of case study namely:

1. The setting (where the research took place);
2. The actors or participants (who was observed or interviewed);
3. The events (what the actor was doing);
4. The process (the evolving nature of events undertaken by the actors within the setting).

The study objective as mentioned earlier seeks to find out the impact of the shea industry in alleviating poverty in the study area. Based on this objective the hypothesis stating that: the socio-economic characteristics of households do not affect household income was verified.

After the step-by-step regression, fourteen (14) explanatory variables (Table 1) out of nineteen making up of six (6) quantitative and eight (8) qualitative were selected to be used to create the maximum multi-variable regression model. The initial set of seemingly significant variables were put into regression and results tested on assumptions in linear regression, thus linearity, independency, normality and homoscedasticity, a final regression model was then obtained.

Data collection and preparation

Household income data were collected from four communities in the Sumbrungu area of the Bolgatanga District Assembly. In all, data from 33 out of 45 known shea butter producer households were taken with the break down as: Kulbia Atolesum 6, Kulbia Amolgoduni 1, Kulbia Anateem 12 and Kulbia Bokom 24. Thus data from 73% of shea butter producers in the four communities were taken. To prepare the field data for the multiple regression analysis, the explanatory variables were first grouped into quantitative and qualitative variables.

Analytical model

A regression model can be expressed in econometric terms as:

$$y_{(t)} = \sum_k \beta_{(k)} X_{(k,t)} + \sum_m \phi_{(m)} D_{(m,t)} + \varepsilon_t \quad (1)$$

Where y is the observed per head household income, t - the time of study, ß- estimated coefficient associated with a given independent quantitative variable $X_{(k,t)}$, Ø - estimated coefficient associated with a given independent qualitative variable $D_{(k,t)}$, ε is the error term and k and m - number of quantitative and qualitative variables respectively. Having a change in time (t+1) and associated changes in condition, the new predicted per head household income could be expressed as:

$$\hat{y}_{(t\_1)} = \sum_k \hat{\beta}_{(k)} X_{(k,t+1)} + \sum_m \hat{\phi}_{(m)} D_{(m,t)} + \varepsilon_t \quad (2)$$

In this work the dependent variable is the total household income over the four months period of farming, collection of weaving material and shea butter processing activity. Household based factors approach was employed to develop a regression model for the prediction of per head household income taken into consideration the most relevance indicators.

Proxy indicators

The foundation of an income prediction model is the proxy indicators used which forms the conceptual framework. The selection of the proxy variable is therefore of great importance. Although such models are not suitable for determining any cause-effect relationship, proxy variable that have proved to be of strong logical and empirical links with household income will lead to a more concise prediction. The variables linking household income can be grouped into two main categories: namely the internal household dependant and external variables. Over the period of more than four decades, literature on the determinates of household income had established that the main internal household determinates include household size, age and gender distribution of the household, education, employment, health status, assets, capital among others (Schultz, 1961; Welch, 1970; Hassan and Badu, 1991; Lanjouw and Ravallion, 1995; Simler et al., 2004; Otsuka and Yamano, 2006). Similarly, the external determinants are recognised to be infrastructure, climate, prices, Governmental policies, geographical location, etc. Adebayo (1985) suggested that income levels of the rural poor may be attributed to some crucial determinants, hence understanding these determinants could result in developing effective polices aimed at alleviating rural poverty. There exist several potential variables that can be used, but it is

important to minimize the size of variables in other to minimize the error associated with the model. A combination of the forward and backward approach as well as variable transformation strategy was used to determine the most optimal model (Greene, 1993). Hastie et al. (2001) indicates that the error associated with a model is dependent on two factors (variance and square bias) which oppose each other, it is therefore important to have a trade-off between them. Limiting the number of variables will lead to reduction of variance but increases the square bias thus overall R-square value will be reduced. The overall R-square can be increased by transforming some variables and including some interaction terms between the variables but that will also lead to increase in variance since more complex models turns to have some statistically insignificant variables not withstanding that they may have high R-square values. Trading-off is therefore necessary to arrive at a model that in-cooperates variables that will lead to an R-square value close to 1 and also having all coefficients statistically significant.

Based on the motive of this work which seeks to develop a per head household income predictive model, socio-economic variable with close link to household characteristics were used. Among these variables are: Household size, gender of household head, income generating activities of household, education status, number of children in household, age, etc.

Selection of model

When there is no pre-knowledge as to the factors that determine the respondent variable in a regression problem, there appears to be so many probable independent variables which make the regression equation complex. The independent variables may include interaction terms, qualitative and quantitative variables which may or may not be relevant. It is therefore necessary to reduce the model to contain only the variables which provide important information about the dependant variable. There are a number of methods to arrive at the best simple model which explains the independent variable to the best possible level and making the regression statistically meaningful. In doing so, two main issues must be taken into consideration thus: Selection criterion and selection procedure.

Selection criterion

Selection criterion deals with the selection of explanatory variables to be included in the possible reduced model and also grade all possible reduced models from best to worst. There are different criteria for reducing a regression model. The econometrical expressions of three of them namely: R^2or adjustable R_a^2, F-test and Mallow's C_m criteria are given as:

Adjustable R^2 statistic - $$R_a^2 = 1 - \frac{n-1}{n-k-1}\left(1-R^2\right) \quad (3)$$

Based on this criterion, the model with the highest R_a^2 or R^2 is chosen.

F-test criterion- $$F_m = \frac{\left(RSS_m - RSS_k\right)/\left(k-m\right)}{RSS_k/\left(n-k-1\right)} \quad (4)$$

Where *RSS* is defined as:

$$RSS_j = \sum_{i=1}^{n}\left(Y_i - \hat{\beta}_{j,0} - \hat{\beta}_{j,1}x_i,_1 - \hat{\beta}_{j,2}x_i,_2 - \ldots\ldots - \hat{\beta}_{j,j}\ x_i,_j\right) \quad (5)$$

Whre $\hat{\beta}_{j,1}$ denotes the least squares estimator for the regression parameter β_i in the model with *j* explanatory variables.

Mallow's C_m statistic - $$C_m = \frac{RSS_m}{RSS_k/\left(n-k-1\right)} + 2\left(m+1\right) - n \quad (6)$$

In using C_m criterion the reduced model with the smallest value of C_m is chosen.

For the purpose of this work the R^2 criterion was used. All explanatory variables were correlated with the dependent variable and their R^2 values observed. The criterion set was that the explanatory variable should have a relation with the dependable variables.

Selection procedure

In literature, three strategies are used in selection of best model after a chosen selection criterion is used to select the relevant explanatory variables. The selection strategies are the traditional forward and backward selection, stepwise regression and the most recent all possible model procedure.

The forward and the backward selection procedures determine whether each of the explanatory variables should or should not be included in the model and it is quick to run but do not always lead to the best final model.

The stepwise regression strategy is a modification of the forward or backward selection procedure. The removal and re-addition of explanatory variables as at when necessary, enhances the possibility of arriving at a best model.

The recently introduced, all possible model is the most efficient strategy but suffers from huge calculation and time consuming especially if the number of explanatory variable is huge. The number of regressions to run is equal to the factorial of the number of explanatory variables thus a set of 5 explanatory variables will demand over 30 regressions. Due to the possible huge size of the set of explanatory variables and its associated number of regressions, interpretation of the results could be quite difficult.

For the purpose of this work, the stepwise regression strategy which is a combination of the forward and backward selection strategy was used and as such a brief description of the procedure is given here subsequently.

The procedure starts with the most relevant explanatory variable as determined by the selection criterion. Each time a new variable is added to the regression model, the significance of individual variables incorporated are re-examined. The variable with the highest P-value is removed from the model and the model re-fitted before the next new variable is added. The procedure so continue until there is no more variables to be added or removed. In this work the threshold was set at P-value ≤ 0.1.

RESULTS AND DISCUSSION

The result of the regression analysis indicates that the explanatory variables: size of household and quantity of shea butter produced are the most significant independent variables with P-values virtually zero. The location indicators are also very significant with P-values virtually zero. Farming activity is less significant with a P-value of 0.018. The values are far below the predetermined accepted significance level of 0.05. From the result it

Table 2. Predicted household monthly income with variation in shea butter produced for different locations and family employment status.

Community	Shea butter produced per month (kg)								
	With employed member of the family								
	20	30	40	50	60	70	80	90	100
Bokom	216.50	303.66	390.83	477.99	565.16	652.32	739.49	826.66	913.82
Amolgoduni	203.17	290.33	377.50	464.66	551.83	638.99	726.16	813.32	900.49
Anateem	214.98	302.15	389.31	476.48	563.64	650.81	737.97	825.14	912.30
Atolesum	160.31	247.47	334.64	421.80	508.97	596.13	683.30	770.46	857.63
	Without employed member of the family								
Bokom	200.74	287.90	375.07	462.23	549.40	636.56	723.73	810.89	898.06
Amolgoduni	187.40	274.57	361.73	448.90	536.07	623.23	710.40	797.56	884.73
Anateem	199.22	286.38	373.55	460.72	547.88	635.05	722.21	809.38	896.54
Atolesum	144.55	231.71	318.88	406.04	493.21	580.37	667.54	754.70	841.87

could be said that the seven explanatory variables in cooperated in the reduce model do explain the dependant variable of household income at 99.9% leaving only 0.1% of the factors of the household income missing. The overall regression equation's accuracy which is expressed in terms of R^2 and adjusted R^2 is estimated to be above 99% which could be considered to be quite significant. This is an indication of how accurate the regression line approximates the real data. It also gives an indication that the dependent variable's variance is determined by the explanatory variables' variance at a level of 99%. Significance F of 5.25E-32 obtained indicates that the probability that the regression output is by chance.

From the regression model, household annual income of shea butter producing families in the research area can therefore be estimated by the expression:

$$Y = -367.50 - 26.22X_1 + 189.14X_5 + 104.60X_6 + 167.37D_4 + 656.09D_6 + 514.30D_8 + 674.29D_9 \quad (7)$$

The result indicates that producers in Anateem community stand to earn more than their counterparts in the Atolesum community followed by Bokom and Amolgoduni.

Prediction of household income of shea butter producing families in the research area was done two scenarios: Families with employed member and families without employed member. The predictions were made on the following assumption that the families are of the same size and also have the same level of income from farming activity. The monthly income in Ghana cedis obtained with quantity of butter ranging between 20 and 100 kg per month as presented in Table 2.

From Table 2, it is clear that a producer should produce at least 20 kg of shea butter per month in order to earn up to the average wage of 150 Ghana cedis for unskilled labour. It therefore indicates that producers who are able to produce more than the 20 kg of butter per month do earn more than their collages employed. It can also be induced that the effect of the salary of the employed member of the family does not significantly affect the income of the shea butter producer.

Challenges involved in shea butter processing

Notwithstanding the fact that the study results indicate the potential of shea butter processing as effective poverty alleviation machinery, therefore exist some challenges that do prevent the women from coming out of their poverty situation. Lack of financial support was identified as a major challenge that lead to the women not able to buy enough shea nuts during the main season for all year round production. Ready market for their butter was also identified as a challenge. Their products are sold basically on the local market with few bulk purchasers sometimes coming round to buy from them at their own prices. It was also found out the high cost and unavailability of machinery was another challenge. Some producers have to travel distances in order to mill their roasted shea nuts thus increasing their production cost and also limiting their production capacity. Though the machines are locally produced by the GRATIS Foundation the women cannot afford them.

Conclusion

From the study it is made clear that income from shea butter production as compared with the wage of an unskilled labour is quite significant hence, shea butter production can be an engine of poverty reduction. To fully utilize the potential of shea butter processing a means of income poverty alleviation for the rural northern women it requires the use of inputs in the form of technology

such as grinding mill, oil filters, toasters, dryers as well as special storage facilities. These inputs though locally produced are quite expensive for the women as they do not have adequate financial support to purchase them. There is the need to buy enough shea nuts during the main season and store for an all year round production. This requires some capital which is not available to the women. Taking into consideration the fact that unemployment, season unemployment and under employment in the study area is phenomenal as against the relatively high financial requirement of the shea butter processing industry in order to produce quality butter and make the process profitable, it is necessary that both Governmental and Non-Governmental support is rendered to the women to facilitate all stages of shea butter production. This will empower them to effectively alleviate their poverty.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

Preliminary study on the prevalence and risk factors associated with gastrointestinal parasites of Camel in Yabello district, Southern rangelands of Ethiopia

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A cross sectional study design was used to determine the prevalence and species spectrum of major gastrointestinal parasites affecting camels; and to find out risk factors associated with this parasitic infestation in Yabello district, southern rangelands of Ethiopia. A total of 412 camels of all age and sex were examined between August, 2011 and March, 2012. Collected faecal samples were processed by standard floatation methods and then examined for helminth eggs. Coprological examination revealed that 73.8% (n=304) of the camels excreted helminth eggs/protozoan oocyst in their faeces. Six types of helminth/protozoan parasites eggs/oocyst encountered in descending order of prevalence were, Strongylus species 55.59%, Strongyloides species 13.82%, Trichostrongylus species 10.19%, Monezia species 6.91%, Coccidia and Trichuris species each encountered 1.32%. Single and concurrent infections with two or more parasites were recorded in 89.15% and 10.85% of the cases, respectively. Except for age and treatment factors significantly affected (P<0.05) the prevalence of gastrointestinal parasite infections, all the other factors like origin, sex, body condition score and health status have shown no significant effect on parasitic infestation. The high prevalence and wide spectrum observed in the present study suggests that helminth infection are widespread and may be a constraint to economic camel production, and there is need to institute control measures.

Key words: Camels, gastrointestinal parasites, prevalence, risk factors, Yabello.

INTRODUCTION

Camels are important multipurpose animals of arid and semi-arid parts of the world. Camel is a very hardy animal and anatomically as well as physiologically well adapted to harsh climatic conditions of desert areas of the world, including Ethiopia. Camel is the most important livestock that can live and produce in poor farms, and can be compared with high-yield animals of the same weight, like cattle, in productivity under manual feeding. Hence, there is a need to improve management of camels considering its prospect in the semiarid and arid regions where

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livestock production is becoming more difficult due to climate changes (Sazmand, 2011).

Camels suffer from various internal and external parasitic diseases which are major causes of impaired fertility and low calving rates of camels as well as impaired milk and meat production. Moreover, parasitic diseases may also predispose them to other infections, lower the working efficiency or result in death, and sometimes serve as potential danger for public health (Anwar and Khan, 1998). With the introduction of sedentary, semi-intensive camel farming systems, parasites may assume much more significant role in camel husbandry (Parsani et al., 2008).

Camels can acquire helminth infection by grazing on infected pastures or by ingesting infective larvae with drinking water. Signs and symptoms of gastrointestinal helminths in camels are numerous, mainly weight loss along with growth disorders, colic, fever, diarrhoea, anemia, gastritis and enteritis (Fowler, 1996). However, the clinical manifestations of helminthosis may be subclinical or asymptomatic, in which case the animal appears normal but performs below its full potential (Borji et al., 2010).

Despite being usually reared under harsh environments unsuitable for propagation and transmission of helminths, camels are capable of harbouring a fairly large variety of internal parasites. There is paucity of literature as helminthic infections of camels are generally regarded less of a problem than those in other ruminants. Among others, the camel stomach worm *Haemonchus longistipes* is the most pathogenic strongyle nematode of camels. Trichostrongyles are also very common and may contribute to the debilitating effects of gastrointestinal nematodes. Extraintestinal nematodes commonly parasitizing camels include *Onchocerca fasciata*, which characteristically produces subcutaneous nodules in the head and neck regions; the filarial worm *Dipetalonema evansi*, the eye worm *Thelazia* and rarely the lungworms (*Dictyocaulus* or *Protostrongylus* species). Among larval cestodes, hydatid cysts are commonly reported, while *Cysticercus* and *Coenurus* species are infrequent (Chhabra and Gupta, 2006).

Climate plays a dominant role in determining the timing and size of peak larval contamination on pasture (Suolsby, 1982). Various studies have shown a relationship between the onsets of parasitic gastroenteritis and meteorological data (Thomas and Starr, 1978). Accordingly, *Haemonchus* and *Oesophagostomum colombianum* predominate in hot climate while *Trichostrongylus* and *Ostertagia* and *Oesophagostomum venulosum* are predominate in warm climates (Levine, 1978).

Currently, there is growing awareness of the unique role that camel plays in the cultural heritage and socio-economics in Ethiopia. The increasing value of the camel, however, has verified the economic viability of health care. The most important is that, camel can tolerate harsh conditions and thrive better if good control means for the diseases affecting camels are adopted. Recently drought has become increasing and brings great challenges on livestock production in pastoral areas of Borena which increase importance of camel production in the area. Data on gastrointestinal parasites of camel are less available in pastoral area of Borena zone. Hence, the present study is very important to give base line data on gastrointestinal parasites of camel which improve their production and reproduction. Therefore, a questionnaire and parasitological survey was carried out in camel herds in different localities of Yabello district, in order to obtain information on the relationship between various host factors and to estimate the prevalence and identify the species spectrum of major gastrointestinal parasites affecting camels in Yabello district, southern rangelands of Ethiopia.

MATERIALS AND METHODS

Description of study area

The study was conducted in Yabello district of Oromia regional state, which is found at about 575 km south of Addis Ababa. According to data from the district and vaccination survey of zonal veterinary service of 2010/2011, Yabello has a livestock population of 435,553; of which camels are estimated at 22,972. Delivery of the rainfall is bimodal: 56% of the annual rainfall occurs with long rains expected from March to May and 27% the short rains from mid September to mid November (Coppock, 1994). The area has a migratory route of livestock during drought and animal trading from it neighboring country, regions and districts. Hence, huge livestock population and encroachment of bushes in the area brought shortage of livestock feed, increase movement and disease transmission and difficulty of livestock disease control.

Study animal

The study animals consisted of indigenous breeds of camels (one hump camel) reared under extensive management system which allows free grazing, usually mixed with livestock from other villages, and in which the animals move from feed shortage area to those improved with feed intake especially during drought season. During sampling gender, age, body condition, treatment history and the presence of clinical signs were recorded.

Study design and sampling method

A cross sectional study to estimate the prevalence of gastrointestinal parasites infestation and stratified random sampling techniques were used to collect the data between August, 2011 and March, 2012. Risk factors like body condition, gender, sex, history of treatment and clinical health status most probably associated with parasitic disease was collected at the time of sampling using structured (closed) questionnaires. Out of 23 kebeles of Yabello district, six were selected by considering accessibility and our facilities. From the selected localities, households were randomly selected. Camels from each selected household of localities were examined with proportional sample size of the total camel

Table 1. Relative prevalence of gastrointestinal parasites examined in camels.

Species of parasite	Number of camels examined	Test result	
		Number of positive	Prevalence (%)
Strongylus species	412	169	55.59
Strongyles species	412	31	10.19
Strongyloides species	412	42	13.82
Monezia species	412	21	6.91
Trichuris species	412	4	1.32
Coccidian oocyst	412	4	1.32
Mixed infestation	412	33	10.86
Overall	412	304	73.8

population from each kebele. Accordingly, 108, 42, 80, 48, 50 and 84 camels were selected from Surupha, Bake, Dide-Hara, Dherito, Haro-wayu and Areri kebeles, respectively.

Sample size determination

The desired sample size for the study was calculated using the formula given by Thrusfield (2005) with 95% confidence interval, at 5% precision and by assuming maximum 50% expected prevalence of camel gastrointestinal parasite infestation in the area. The calculated sample size was 384, but to increase the precision of sampling in the study, 412 camels were considered.

Study methodology and parasitological examination

The gender, body condition score based on http://www.camelsaust.com.au/livebodycond.htm and further classified as poor (score 1 and 2), medium (score 3) and good (score 4 and 5), age group (<4 years, 4-6 years and >6 years), the health condition (apparently healthy and camels with any signs (emaciation, depression, intermittent diarrhea, milk production and weight losses, coughing and nasal discharge) and deworming history (dewormed and non-dewormed camels) were considered during the study. Fresh fecal samples were collected per rectum from individual camel using plastic gloves, put into faecal pots, labelled and immediately transported to Yabello Regional Veterinary Diagnostic Laboratory. Individual samples were processed by using standard flotation techniques as described by Hansen and Perry (1994). All parasite eggs were identified morphologically as described by Soulsby (1982), Boid et al. (1986), Urquhart et al. (1996) and Max et al. (2006).

Closed type questionnaire survey was also carried out to interview individual owners to obtain general information about camel age, previous anthelmintics administration and appearance of any clinical signs/syndromes.

Data management and statistical analysis

All collected data was entered to MS excel sheet and analyzed by using SPSS version 19. Descriptive statistics was used to determine the prevalence of the parasites and the risk factors associated to the disease (age, sex, body condition, health status and history of deworming) was related using Chi-square test ($\chi 2$) for their significant difference by using confidence level at 95% and $P<0.05$ for significance.

RESULTS

Of the total 412 camels examined, 304 camels (73.8%) were observed to harbor one or more types of gastrointestinal parasites at varying levels. As shown on Table 1, the identified parasite includes different nematode species, cestodes (monezia species) and coccidian oocyst.

Gastrointestinal parasite prevalence variation with host related risk factors

The overall gastrointestinal parasite infestation in different age groups and health status of camel were revealing statistically significant variation among camels in different age groups (X^2=6.73; $P<0.05$) and health status (X^2=4.95; $P<0.05$). However, gastrointestinal parasite infestation in relation to camel sex and body condition showed no statistical significant variation ($P>0.05$) in both cases (Table 2).

Gastrointestinal parasite infestation variation with anthelmintics usage

The analysis of questionnaire survey from camels owner revealed the effect of anthelmintics usage on the prevalence of gastrointestinal parasite infestation and the variation was found to be statistically significant (X^2=47.78; $P<0.05$) (Table 2).

Gastrointestinal parasite prevalence variation with origin of camels

The data analysis conducted during the study indicated no of significant association (X^2=5.58; $P>0.05$) between

Table 2. Prevalence of gastrointestinal parasites infestation in relation to host related risk factors.

Risk factors	No. examined	No. positive	Prevalence (%)	$\chi 2$	P-value
Sex					
Male	88	66	75.00	0.09	0.77
Female	324	238	73.46		
Gender					
<4 years	141	93	65.96		
4-6 years	99	76	76.77	6.73	0.01
>6 years	172	135	78.49		
Body condition					
Good	217	154	70.97	1.89	0.39
Medium	151	116	76.82		
Poor	44	34	77.27		
Health status					
With any sign(s)	42	37	88.09	4.95	0.03
Health	370	267	72.16		
Deworming history					
Yes	79	34	43.04	47.78	0.00
No	333	270	81.08		

Table 3. The prevalence of gastrointestinal parasite in relation to the origin of animals.

Localities	No. Examined	No. positive	Prevalence (%)	$\chi 2$	*P-Value*
Surupha	108	71	65.7		
Bake	42	31	73.8		
Dide-Hara	80	61	70.3	5.58	0.35
Dherito	48	38	79.2		
Haro-wayu	50	37	74		
Areri	84	66	78.6		
Total	**412**	**304**	**73.8**		

camels origin and gastrointestinal parasite infestation (Table 3).

DISCUSSION

It is evident from the results of this study that helminthosis was an important health disease in camels. This finding is in agreement with the results of other researchers, that helminthosis is one of the main problems in camel worldwide (Selim and Rahman, 1972; Fadl et al., 1992; Abdul-Salam and Farah, 1988; Rewatkar et al., 2009; Khan et al., 2010). According to our results, 73.8% (304/412) of camels harboured at least one type of gastrointestinal parasite eggs/oocyst. This finding almost coincides with previous report of overall infection rates of 75% in Eastern Ethiopia (Bekele, 2002), 75.1%, in Iranian camels (Borji et al., 2010), and 76.2% in Bahrain (Abubakr et al., 2000). However, it is lower than prevalence reports of Sharrif et al. (1997) in Jordan; Tekle and Abebe (2001) in Ethiopia; Bamaiyi and Kalu (2011) in Nigeria; Demelash et al. (2014) in Yabello district of Ethiopia, who reported prevalence of 98, 96.92, 92.4 and 80.73%, respectively. In contrast, lower rate of 68.9 and 62.7% reported from dromedaries in Nigeria (Kamani et al., 2008) and in Northern Tanzania (Swai et al., 2011), respectively. The possible explanation for the country to country variation in the infestation rate could be variations in agro-ecological conditions between countries, which favor or disfavor the survival of parasites

eggs or larvae, levels of hygiene and husbandry practices (Allport et al., 2005). Moreover, the occurrence of parasite is associated with nutritional status, level of immunity, rainfall, humidity and temperature differences and season of examination on the respective study areas.

Six different types of gastrointestinal worms and protozoan were identified in camels. They were broadly classified as nematodes (4 species), cestode (1 species) and protozoan (1 species) according to the egg/oocyst structure (Soulsby, 1982; Boid et al., 1986, Urquhart et al., 1996; Max et al., 2006). Mixed parasitism (10.85%) involving two or more helminths and protozoan genera was common in the present study and is in agreements with the results of other researchers (Bekele, 2002; Rewatkar et al., 2009; Swai et al., 2011). Strongylus species occurred in 169 of 412 camels (55.59%) screened and was the most prevalent gastrointestinal parasite encountered during the study. This prevalence was comparable to the prevalence of 41% reported in Ethiopia (Bekele, 2002), but lower than the prevalence's of 100, 89.2 and 75% reported in Kenya, Northern Tanzania and Sudan, respectively (Mukani and Kimani, 1999; Swai et al., 2011; Abdul-Salam and Farah, 1988). The relatively high level of gastrointestinal parasitism recorded in this study is probably related to the number of adult parasites established in the gastrointestinal tract, level of host immunity, stage of parasite infection, and lack of improvement in animal health management programmes or non adoption of the modern animal health care programmes by camel owners.

Eimeria species with prevalence of 1.32% was low compared with prevalence of 9.9, 12.5 and 25% respectively recorded in northern Tanzania and Pakistan (Swai et al., 2011; Anwar and Khan, 1998; Rewatkar et al., 2009). Heavy protozoan infection causes significant impact in young camels resulting into high morbidity and mortality (Chineme, 1980; Boid et al., 1986; Kinne and Wernery, 1997).

Significant factors might influence the prevalence of gastrointestinal parasites infestation. Host age was found to be a significant factor with respect to gastrointestinal parasite infection ($P<0.05$), with eggs/oocyst been detected more frequently in age categories >6 years than 4 to 6 years and <4 years camels. Camels reported to have been treated against helminths in the last one year prior to the study survey were significantly infected ($p<0.05$) by gastrointestinal parasites than untreated camel. Moreover, males were more likely to harbour gastrointestinal parasites eggs/oocyst than female camels, but the variation was not significant ($P>0.05$).

The study further revealed that health status, origin and body condition of the camel did not show significant association ($P>0.05$) with the prevalence of parasite infestation. The absence of association between body condition and prevalence disagrees with previous reports of Swai et al. (2011) and studies in other livestock species (Keyyu et al., 2003). This could be explained by the fact that loss of body condition in the camels could be due to other factors, such as seasonal change of forgeable feed and presence of other concurrent disease conditions, mainly high prevalence of trypanosomosis in some of the lowland areas.

In conclusion, as most of the gastrointestinal helminth species in camels are also common to cattle, sheep and goats, strategic deworming of camel using broad spectrum anthelmintics seems necessary for enhancing productivity of camels as well as other livestock kept near them. Moreover, from the results of this study parasitism is one of the major health problems of camels which need special attention to save the already poor people from poverty who are the main camel keepers in Yabello, Ethiopia. These people use camels for carriage purposes as well as a source of milk and meat in addition to their use as draught animals. For this purpose, it is suggested that livestock disease diagnostic and monitoring centers be strengthened in the area to look after the health, management and breeding aspects of the camels.

Conflict of Interest

The authors have not declared any conflict of interest.

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Review

Alternatives for remediation and decontamination of soils from Brazil

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The aim of this work is to identify the main sources of contamination of soils, their effects on organisms also presenting alternatives for remediation and decontamination of these contaminated environments. The soils have in their composition organisms that are naturally present, as well as the presence of contaminants in increasing proportion when compared to the world industrialization and modernization of agriculture; therefore, increase in evolution brings with it a bigger totality of compounds, resulting in worrying rates in the soils of Brazil, such as trace elements (Cadmium, Lead, Arsenic, Mercury, Copper) and compounds organic (pesticides) and inorganic (waste fossil fuels). In many instances, this contamination can decimate forms of life in the soil. With that, remediation and decontamination of these soils becomes a fundamental need for the current economic models, making bioremediation and phytoremediation techniques consist in a feasible alternative for remediation and decontamination of soil, presenting performances satisfactory in removal and stabilization of contaminants.

Key words: Soil contamination, trace elements, pesticides, removal, stabilization

INTRODUCTION

Seeking to attend to the high demand of food, agricultural production has generated a shortage in the traditional sources of essential nutrients used in agriculture (phosphate rocks and minerals originating from extraction in the soil), resulting in the beginning of the search for alternative sources (industrial residue) Nacke et al. (2013); Gonçalves Jr. and Pessoa (2002), in some cases of dubious origins, bringing elements that have undesirable substances in its composition. Thus, there was an increase in the content of harmful substances and compounds in the soil (Coutinho and Barbosa, 2007). For the same authors (Coutinho and Barbosa, 2007), the

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search by the authorities on strategies and economically viable approaches to restoration of polluted areas and biodiversity conservation occurs in the same proportion as these contaminations.

The metal contamination usually occurs because of human activities, whether through waste from mining, steel, cosmetics industry, automobile scrap, agricultural activities, among others. Such factors generally expose the commercial crops to adverse situation of contamination (Tarley and Arruda, 2003). The contamination that affects the agricultural areas is now a major problem because many pollutants somehow exert essential roles in important economic activities, such as pesticides and fertilizers, and the most of those products there are characteristics of concern due to its composition and persistence in soil, water and food (Pires et al., 2003).

Heavy metals often accumulate in the surface soil layer (0 to 20 cm), also called arable layer, thus becoming present in the soil solution and available for plant absorption included in the food chain (Carvalho et al., 2008).

There is great interest in the study of heavy metals, having in mind that in relation to chemical action, these elements have no character of rapid biodegradation, remaining in the environment over time. Residuals of these global biogeochemical cycles are those with natural waters as their main means of conduction (Cotta et al., 2006).

In this scenario, Gonçalves Jr et al. (2014) presented several papers and case studies demonstrating the increasing number of cases of contamination in Brazilian soils. Also, one must take into account the toxic effects of these metals representing risks to living organisms, reducing plant growth, causing disturbing various metabolic processes that leads to yield losses, absorption and loss of commercial products quality (Silva et al., 2007; Gonçalves Jr. et al., 2014).

According to findings by Pandey et al. (2009), abiotic stresses in plants exposed to excessive levels of heavy metals produce oxidative stress and stimulate antioxidative responses in different efficiencies. Also, according to Pandey et al. (2009), the damage by oxidative action can be evaluated by external visual expression of toxicity of the elements in the order Ni> Co> Cd> Cu> Zn.

To regulate these events, the National Environmental Council (CONAMA) has drafted a resolution (Resolution 420) that briefly defines criteria and guiding values of soil quality. The explicit forms of prevention and control of soil quality provides guidelines for management of contaminated areas. It should be noted that, for the decontamination and remediation of contaminated soils there are several methods using variable principles (Gerhardt et al., 2009). Between them stands bioremediation and phytoremediation, which uses microorganisms and plants with the objective of removing, transferring, stabilize or destroy harmful elements. Having these high potential of removal or degradation of pollutants, its efficiency depends on the structure of the molecule, because the chemical formation of organic pollutants, have direct influence on the ability to break these substances (Mariano et al., 2007).

With that in mind, the use of phytoremediation appears promising as it is used in heavy metal contaminated soils, taking into consideration the dangers of this contamination for both soils like products from contaminated areas. Besides the soil-plant-water, taking into consideration the need to maintain soil fertility and ensure the health of food produced, the aim of this paper is to address the major sources of contamination of soils, their effects on organisms and presents alternatives for remediation and decontamination of these contaminated environments.

LITERATURE REVIEW

Contaminating sources

In the current production, both industrial and agricultural systems, generates by-products or waste, and when there are no practices of sustainable production, it can become contaminants to the soil. Five activities are known as sources of residues contaminants to soil, which are originated from industry, domestic, hospital, commercial and agricultural activity. Included in this are steelworks, leadworks, mining, leather, cosmetics industries and fertilizer industries, as well as cemeteries, cars cemeteries, agricultural activities and excessive use of pesticides (Tarley and Arruda, 2003).

The term heavy metal comprises chemical elements that have atomic number greater than 20 or specific mass greater than 5 g cm^{-3} and are potentially toxic to living beings (Malavolta, 1994). There are also essential elements that allow the development of metabolic pathways, which can represent risks and toxicity at high levels, such as Manganese, Zinc, Chromium and Cobalt (Gonçalves Jr. et al., 2009).

About this, Ribas (2007) made a research on the composition of fertilizers in 2006, where technicians of the Department of Supervision of the Secretary of Agriculture of the State of Paraná, obtained in their analysis of fertilizers positive results for 70% of the material analyzed, meaning that 30% of the analyzed fertilizers were below the rates specified on their labels. The author also gives a warning about the need of evaluation of the materials due to the possibility of contamination by heavy metals (Ribas 2007).

Causes and impacts of contamination

Heavy metals like, Copper (Cu), Zinc (Zn) and Cobalt (Co), play an important role in the nutrition of plants and animals (Silva et al., 2007). The metals occur naturally in the soil, however, elements such as Cadmium (Cd), Lead (Pb), Arsenic (As) and Selenium (Se) have unhealthy effects on various components of the biosphere (Kabata-Pendias and Pendias, 2001); among these effects, the bioaccumulation and biomagnification is worth mentioning due to the risks they present to living organisms, being ways to concentrate the contaminants over time and even the food chain. For example, organisms presented in a contaminated soil can be exposed to various contaminants absorbing them slowly, reaching levels up to 100,000 higher in their tissues, as in aquatic organisms, leading these levels along the food chain (Souza et al., 2014; Gonçalves Jr. et al., 2014).

For Arora et al. (2008) stemmed from ingesting contaminated with heavy metals is to be avoided, so that these can transfer these metals, and accumulate in the body areas food. In order to prevent excessive accumulation of heavy metals in the food chain, the use of wastewater in soil fertilization should be monitored.

In the case of soils, contamination comes from the high concentrations of heavy metals, often occurring where there is large concentration of industries that destines their waste to landfills, which suffers burials and sedimentation (Carvalho et al., 2008). The metals can be accumulated in these wastes and sediments that generate great concern, as they become potential sources of contamination and important indicators of environmental contamination. Positively, this capacity of sediment makes the environmental matrix one of the most important to evaluate levels of contamination. (Cotta et al., 2006).

The mobility of these elements in soils depends essentially on chemical reactions of adsorption and desorption occurring between the metal and the solid components of the mineral system. The reactions are influenced by several factors, with emphasis on the presence of organic and inorganic ligands and cation exchange capacity (CEC) of soils (Carvalho et al., 2008). Moreover, changes in environmental conditions, like acidification, changes in redox potential or increasing in the concentration of organic ligands, can affect the bioavailability of metals, favoring the contamination of plants that developed in the soil (Cotta et al., 2006).

Current legislation related to soil contamination

On the juridical context, the National Council on the Environment (CONAMA) N.420 treats the issue of contamination by heavy metals (Brasil, 2009). This legal letter, published on 28 December 2009, from the National Environmental Council, provides criteria and guiding values of soil quality on the presence of chemicals, and establishes guidelines for environmental management of areas contaminated by exogenous substances due to anthropogenic activities.

For the above-mentioned resolution, the Council exposes the need to prevent contamination of soil, aiming to maintain its functionality and protection of the quality of surface and underground water. It considers that the existence of contaminated areas can configure serious risk to public health and to the environment. It also states the need to establish criteria for setting guidance values for the prevention of soil contamination and to define guidelines for the management of contaminated areas.

The resolution determines that in the presence of chemical substances, the evaluation of the quality of the soil should be based on the Reference Values Guiding Quality (RVGQs), Prevention (VPs) and Investigation (VIs) described in Table 1, the RVGQs of the soil for chemical substance naturally present will be established by environmental agencies of the states and the Federal District. The VPs were based on tests of phytotoxicity or in evaluation of ecological risks, according to the resolution.

With regard to the VIs, the figures presented in the resolution are also adopted, which were derived based on evaluation of risk to human health according to exposure standardized scenarios for different uses and occupation of the soils. The soil classification is performed based on the concentration of chemical substances, as follows:

Class 1: Soils that have concentrations of chemical substances less than or equal to VRQ.
Class 2: Soils that have concentrations of at least one chemical substance greater than the chemical VRQ and less than or equal to VP.
Class 3: Soils where there is concentration of at least one chemical substance greater than VP and less than or equal to chemical VI.
Class 4: Soils which have concentrations of at least one chemical substance greater than the VI.

Highlight that the resolution lays down that the generation and availability of information, the joint, cooperation and integration of interagency between government agencies, owners, users and other beneficiaries or affected are basic principles (Di Giulio et al., 2010). The authors also emphasize that risk communication constitutes a key element for the environment's preservation. And in this case "should be created by the government, suited mechanisms to the different publics involved, providing easy understanding and access to information for the social group and environmentally vulnerable, targeting

Table 1. Values guiding of substances for soils and underground water.

Substance	Soil (mg kg^{-1} of dry weight)				Underground water (µg L^{-1})
	Prevention	Investigation			Investigation
		Agricultural area	Residential	Industrial	
Aluminum	-	-	-	-	3.500**
Arsenic	15	35	55	150	10*
Cadmium	1.3	3	8	20	5*
Lead	72	180	300	900	10*
Cobalt	25	35	65	90	70
Copper	60	200	400	600	2.000*
Mercury	0.5	12	36	70	1*
Zinc	300	450	1.000	2.000	1.050**
Lindane	0.001	0.02	0.07	1.5	2*
Aldrin	0.015	0.003	0.01	0.03	-

Source: Resolution 420/2009-CONAMA - Organized by the authors. * Standards portability of chemical substances that pose a health risk as defined in Ordinance N°. 518/2004 of the Ministry of Health; ** Calculated based on risk to human health, according to the scope of this resolution. Differ from the standards for acceptance for human consumption defined in regulation 518/2004 of the Ministry of Health and the maximum value allowed for human consumption defined in CONAMA Resolution N°. 396/2008.

the communication of risk to the population (Di Giulio et al., 2010).

A concern regarding the resolution is the fact that it allows the contamination of the soil until the concentrations of elements or substances of environmental interest are above a limit called intervention value. Understanding the resolution, according to Article 26, only at this time the area is declared Contaminated Area under Intervention (ACI), by the competent environmental agency. Thus ACI will be the one area in which is found the presence of chemicals in free phase or is proven, after detailed investigation and risk assessment, the existence of risk to human health.

It is understood that a soil in which the concentration of an element or substance of environmental interest is less than or equal to the naturally occurring, can be contaminated until the intervention values. The parameters of the values of prevention and investigation are variable between agricultural, residential and industrial area. This elasticity in the parameters demanding a detailed investigation can be crucial for the soil contamination with harmful consequences to the environment.

It is not about prohibition of the use or handling of heavy metals, it is about seeing the precautionary principle with the proper intensity, which in environmental law is invaluable for environmental preservation. The permittivity of Resolution 420/CONAMA comes against the environmental law, needing to be more careful with the matter of contamination, demanding an adequate monitoring and immediate intervention in areas that verify an increase in the concentration of heavy metals in soils already in their levels of prevention.

Alternative of remediation and decontamination

Out of the known methods of soil remediation, phytoremediation is distinguished by its applicability. Considering this, the use of phytoremediation was verified as an output decontamination for water bodies, since these resources are rarely reused due to the presence of contaminants. Concerned about the destination of this water, alternatives for treatment and recovery of waste and effluents, as the use of macrophyte plants for decontamination and reuse of these have been tested (Pires et al., 2003). In soils, the use of filamentous fungi and their metabolites in bioremediation processes has increased, due to the high potential for degradative and biossorption for metals and dyes and mechanisms of resistance to adverse environmental conditions (Conceição et al., 2005).

Phytoremediation, aside using processes that occur naturally by plants and their root systems, kidnapping and degrading organic pollutants and inorganics of the soil, appear as an excellent corrective strategy and its development is propagated for *in situ* remediation of contaminated environments (Pilon-Smits, 2005). Bioremediation is a viable and environmentally friendly alternative for the treatment of contaminated soils by organic compounds and metals that are potentially toxic. It is essentially the awakening of human consciousness to the need for development and application of these technologies in favor of the environment.

Also, as a decontamination method, adsorption is considered an effective procedure for removal of contaminants. It works through the binding of the interested compounds in the binding sites present on the adsorbent, making it unavailable to these plants or organisms (Dhankhar and Hooda, 2011).

PHYTOREMEDIATION

Phytoremediation is a viable technique for sustainable systems, characterized by the use of plants for remediation, mitigation and decontamination of resources that have the presence of contaminants. This technique presents a satisfactory cost-benefit, without spending the carbon credits, therefore is a practice energetically clean and sustainable (Dowling and Doty, 2009).

For the choosing of phytoremediator species, plants that show a set of specific characteristics must be considered for phytoremediation, as a potential to produce high amounts of biomass, fast growth rate, extensive root system, tolerance to the metal (contaminant) and accumulate in the aerial part high amounts of the elements in question. Considering all these characteristics, it is difficult to obtain ideal species, so the one with the greatest phytoremediation potential, or techniques that enable the associated cultivation of various species should be selected (Marques et al., 2009). In phytoremediation, processes of phytoextraction and phytostabilization are the most frequently performed in areas of contamination; however, the choice of the most appropriated method depends on the characteristics of the place, the concentration, the kinds of pollutants to be removed and the final use of the contaminated place (Xiang-Yan et al., 2005).

Phytoextraction is mainly applied to metals (Cd, Ni, Cu, Zn, Pb) and other inorganic and organic compounds. The process consists in the use of plants, especially hyperaccumulators and transgenic, through root uptake, transport and accumulation of contaminants in shoot, which will subsequently be sent to outside the place of contamination (Marques et al., 2009). The destination of the plant material obtained after extraction will depend on its constitution and the possibility of their use or not. Depending on the case, the plant tissue can be incinerated, deposited into landfill, co-processed in cement manufacture. In case of use, it can be used for the production of fibers and mobile (Eapen and D'Souza, 2005).

In turn, phytostabilization consists of the use of plants in order to immobilize the contaminants in the soil, preventing their dispersal to other locations and changing its bio-availability in the soil. The plants used must be able to tolerate high levels of metals and immobilize them in the soil by precipitation, complexation or reducing valencies (Schnoor, 1997).

For Alvarenga et al. (2011), the physical phytostabilization is due to the effect caused by vegetation in the processes of surface erosion and leaching of pollutants through the reduction of direct incidence of rain or by lignification of humification or contaminant in the soil. The chemical fraction of phytostabilization can occur by chemical modification of the contaminant due to the change in the soil's pH by the production and release of exudates and other substances through the roots, or by the production of CO_2.

Phytodegradation is the process in which plants are capable of degrading organic pollutants. It makes them undergo bioconversion, turning them into simple molecules which in some cases may be used for the growth and development of the plant (anabolism or catabolism) (Procópio et al., 2009).

Another possibility is phytostimulation, in which due to the release of root exudates metabolites, there is the stimulation of the microbial activity. Furthermore, plants may also secrete biodegradatives enzymes, in which both compounds act by degrading the contaminants in the soil (Santos et al., 2007). This mechanism of phytoremediation has as main target substances like non-chlorinated organic pesticides and herbicides (Pires et al., 2005).

In respect to phytovolatilization, it can be stated as the process in which plants perform the removal of pollutants by biodegradation in the rhizosphere or after the passage in the plant itself, performing the volatilization on the surface of the leaves. Thus, depending on the physiological state of the plant, the release of contaminants to the atmosphere can occur naturally or with energy expenditure (Procópio et al., 2009).

Rhizofiltration is defined as the use of terrestrial plants in order to absorb, filter and reduce the concentrations of undesirable elements in the soil solution, mainly heavy metals and pesticides, using basically the root system (Rai, 2009).

About the use of transgenic plants that carry out these processes, considering that those plants are accumulators of heavy metals, one should take into account that the use of transgenic plants for phytoremediation introduces an additional risk of horizontal transference of their modified genes to the next generation, and even its introduction into wild species. Yet an increasing number of studies have been performed to obtain plants that are tolerant to high concentrations of toxic metals and, in this way, can be used for phytoremediation of soils. There are already results showing a higher efficiency of removal of metal from the soils when compared to the wild plants (Kawahigashi et al., 2006).

Several species of phytoremediator plants are known, highlighting the gender *Brassicaceae* as the most

Table 2. Main phytoremediator species and compounds removed from soil.

Species	Compounds removed from soil	Reference
Thlaspi caerulescens	Cd, Ni, Pb, Zn	Cosio et al. (2004)
Rye grass	Cu, Cd, As	O'Connor et al. (2003)
Thlaspi ochroleucum	Ni , Zn	Prasad and Freitas (2003)
Thlaspi rotundifolium	Ni, Pb , Zn.	Prasad and Freitas (2003)
Brassica juncea	Cd, Cr, Cu, Ni, Pb, Zn	Schmidt (2003)
Arabidopsis halleri	Zn , Cd	Cosio et al. (2004)
Solanum tuberosum	Herbicides	Doty et al. (2000)
Nicotiana tabacum	H. halogenate	Yamada et al. (2002)
Euphorbia cheiradenia	Pb	Chehregani and Malayeri (2007)
S. photeinocarpum	Cd	Zhang et al. (2011)
A. rusticana P.	Phenols	Kotyza et al. (2010)

important hyperaccumulators of heavy metals and organic compounds, presenting several species that are able to accumulate more than one element (Prasad and Freitas, 2003). As for phytoremediation and removal of Copper using various cultures, among the main results, we can highlight the performance with the cultivation of perennial peanut, where it was observed that the concentration of Cu in the aerial part of the plants were between 50 to 60 mg kg^{-1} (Andreazza et al., 2010). A high tolerance of the species *Elsholtzia haichowensis Sun* was observed in soils with Copper in excess and its presence in plant tissues was also verified (Xia and Chen, 2007). The *Canavalia ensiformis* also showed high levels of copper in their root system and aerial part (Zancheta et al., 2011).

Between those species, the *Gentiana pennelliana* (Wire grass) is considered promising for phytoextraction of contaminated areas by Cd, Cr and Pb in tropical and sub tropical locations (Yoon et al., 2006). Indian mustard (*Brassica juncea*) is one of the most studied species and the one that presents great success in phytoextraction of contaminated areas with more than one metal, as well as the sunflower (*Helianthus annuus*) that accumulate high amount of Pb in its tissues, reaching up to 5 g kg^{-1} of Pb in dry matter (Prassad and Freitas, 2003).

A species with several phytoremediator characteristics, the *Crotalaria spectabilis*, has great capacity to store Lead (Lindino et al., 2012), as well as the Vetiver Grass (*Vetiveria zizanioides* L.) which showed high tolerance and efficiency of absorption and translocation of Pb in its roots tissues and aerial parts, attributing to these species phytoextraction potential and providing great importance in the programs for phytoremediation of contaminated areas with this metal (Alves et al., 2008).

Working with leguminous crops in soils contaminated with herbicides, revealed that *Crotalaria juncea* showed high phytoremediation capacity of the contaminated soils at levels up to 400 g ha^{-1} of active ingredient (Madalão et al., 2012), in a general aspect related to the removal of heavy metals, some plant species have high efficiency, as mustard (*Brassica hirta*), peanuts (*Arachis hypogaea*), broccoli (*Brassica oleracea*), buckwheat (*Fagopyrum esculentum* Moench), vetiver grass or smell (*Chrysopogon zizanioides* L.), among others (Accioly and Siqueira, 2000). These data are presented in Table 2.

The phytoremediation has as main advantages the low cost, landscape improvement, little environmental impact, public acceptance, economical recovery of the plant from the recycling of metals after harvesting, easier control process with plants than using microorganisms, plants production of their own energy (through photosynthesis) and ready availability of technologies to harvest these plants (Lamego and Vidal, 2007).

BIOREMEDIATION

Bioremediation is a technique that involves the use of natural occurrence or cultivated microorganisms that, through metabolic routes, promote physical-chemical reactions, transforming compounds of hard degradation into simple compounds, making degradation an easy process, being used in the removal of contaminants in surface water, groundwater and soils (Andrade et al., 2010). Some studies report that most microorganisms used in this technique are bacteria and fungi, in reason of the ability to degrade a wide range of organic substances (Pereira and Freitas, 2012).

There are two methods of bioremediation when referring to the place of work: *in situ* bioremediation, also known as natural remediation. In this technique, the contaminant remains in place and decontamination occurs through physical, chemical and biological processes. In general, it occurs slowly, requiring

monitoring of the site in long term, aiming to restore the environmental equilibrium (Fogh, 2008). And *ex situ* bioremediation, that requires the removal of the contaminated soil from the place so that it can be treated in another location. Removal may be required when there is possible contamination of people and of the environment near the soil to be bioremediated, or the presence of high concentrations of contaminants requires the use of techniques such as: composting, bioreactor, among others (Jacques et al., 2007).

Microorganisms are considered efficient biodegradation promoters, because of its abundance, diversity of species and catabolic and anabolic versatilities, as well as its capacity of adaptation to adverse environmental conditions (Moraes and Tornisielo, 2009). Several metabolic pathways of degradation of PHA's have been identified in various microorganisms. The possibility of the use of some biochemical pathways allows the bacteria to grow using PHA's as the only source of Carbon and energy for growth, degrading these compounds and eliminating them from the environment. The same author said that bacteria of the genus *Pseudomonas*, degraded on average 51% of the anthracene present in middle mineral culture. In the case of lignolyticus fungi, they oxidize lignin extracellularly by the action of lignin peroxidases, manganese and laccases dependent peroxidases (Jacques, 2007).

In studies conducted with *Fusarium moliniforme,* it was concluded that it is a good indicator for consumption of contaminants, acting in the elimination of glyphosate molecules, lixiated and diesel oil. It can also be used in the treatment of contaminated soils (Silva and Rondon, 2013). Satisfactory results were found in the substitution of a chemical surfactant for the biosurfactant produced by *Corynebacterium aquaticum*, aimed at bioremediation of benzene, toluene and xylene (BTX) in sandy soil (Zilio et al., 2012).

The information obtained in this work makes it possible to understand the importance of using microorganisms in biotechnology for remediation of contaminated soils, considering that they use toxic substances as a Carbon source, resulting in an effective and safe method to human and environmental health.

CONCLUSIONS

Activities of agriculture and industry are one of the mains sources of soil contamination, depositing contaminants like toxic metals and pesticides, affecting the development of plants and humans that depend on it.

Both bioremediation and phytoremediation consist of viable alternatives techniques for soil decontamination and remediation with satisfactory performance on stabilization and removal of contaminants.

Conflict of Interest

The authors have not declared any conflict of interest.

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Towards a theoretical framework for sustainable smallholder irrigation farming: A case study of Lusip smallholder sugar-cane farmers in Swaziland

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The government of Swaziland has fully recognized the role of smallholder irrigation development in poverty reduction hence intensive investments have been made to empower rural smallholder farmers through irrigation. The Lower Usuthu Irrigation Project (LUSIP) is one of the projects which strive to empower 2600 rural poor households to attain an improved quality of life and be able to sustain it. The study sought to interrogate the development model used at LUSIP and determine whether it guarantees sustainability of the development as well as to inform policy makers on the social and economic issues associated with the project. This was a case study using a qualitative research design where a purposive sample of the total operational farmers companies was selected for interviews. It can be concluded that the smallholder development under LUSIP has a potential to contribute to the overall agricultural contribution to the Swazi economy. The study unfolded issues around the farmer companies remaining in business and not being properly corporatized as well as uncertainty surrounding the land ownership and user rights though. Three broad recommendations include; corporatization of the farmer companies in a true sense, reviewing the participation-for-all model that is currently being used and the finalization of the National Land Policy by the government.

Key words: Sustainable agriculture, smallholder irrigation, productivity, poverty reduction.

INTRODUCTION

Agriculture is the backbone of the Swazi economy and is critical for achieving the overall development objectives of the country. The agriculture sector of Swaziland is acutely dualistic. A dynamic commercial sub-sector established on Title Deed Land (TDL) that occupies 26% of the land, holds an estimated 90% of available irrigation infrastructures, and uses modern technologies to produce mainly cash crops. A traditional sub-sector based on communal tenure in the Swazi Nation Land (SNL) involves semi-subsistence smallholder agriculture with

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communal grazing. Majority of the population in Swaziland live in farm households located on communal Swazi Nation Land (SNL) and most of them (70%) are engaged in low-productivity subsistence agriculture and animal husbandry (GoS, 2005a). Agriculture sector accounts for about 9% of the GDP and employs about 70% of the population.

Agriculture is far more important for Swaziland's population and for national economic development than its contribution to Gross Domestic Product (GDP) suggests. Crucially, agriculture plays a key role in the lives of the majority of the population, since most households rely on agricultural output as a major source of income and food security, either as small-scale producers or as recipients of income from employment on medium and large-scale farms and estates (GoS, 2005b).

The Government of Swaziland (GoS) has recognized the role of smallholder irrigation development as a key poverty reduction intervention. The Swaziland Water and Agricultural Development Enterprise (SWADE) was established to empower rural smallholder farmers to realize poverty reduction through irrigation. SWADE helps farmers establish irrigation schemes that use water as a catalyst for developmental change. The schemes are what farmer managed with sugarcane being the main cash crop and other crops include field crops such as maize, sweet potatoes and vegetables.

The schemes employ labour from members, non-members and from other contract sources especially for specialized jobs which require special skills and equipment such as harvesting and haulage.

The Lower Usuthu Small Holder Irrigation Project (LUSIP) is one of Swaziland Water and Agricultural Development Enterprise (SWADE) projects. The physical implementation of the Project started in the year 2005 following the social mobilization activities which started earlier. The Project objective is the empowering of 2600 rural poor households within the project area at Siphofaneni to attain an improved quality of life and be able to sustain it. This is to be achieved through commercial irrigated agriculture. The project is founded on sound environment, social and business principles (IFAD, 2001a).

Within seven years of existence, the project has developed an environment compliant bulk water infrastructure capable of irrigating 11 500 ha. The project has, through a sound social system, mobilized the community into business groups ready to take advantage of the harnessed water for the betterment of their lives. As a result forty-one business groups have formed in the project development area (PDA) with a total of 1065 households currently participating. These groups combined have an area ownership of about 2000 ha and individually, they significantly vary in size, with the smallest farm being 19ha and the biggest being 119ha. Their core business is sugar cane production which is market driven (ADEMU, unpublished). Swaziland's sugar industry is a very robust and highly organized in terms of technology, research and support. As such Swaziland has a good track record of being among the top 10 low cost producers of sugar globally.

The development of these businesses is based on a sound technical system aimed at ensuring financial viability. They are premised on an excellent funding structure which is 70% grant funding (European Union and Swaziland government) and 30% loan funding. The 70% grant funding covers the whole of farm construction and the 30% constitutes operational cost. The 30% is amortized over the payback period and that allows the business a good cash-flow. The payback period of these businesses is 6 years and that is favorable to loan funders (ADEMU, unpublished).

There has been much debate within the country concerning the long term sustainability of the new smallholder irrigation schemes, looking at the recent changes in the world sugar prices and the escalating developmental and operational costs. Studies have shown that too often, after a seemingly successful take-off period, declining yields, diminishing returns, the growing indebtedness of the farmers, and hence their loss of interest, lead to the failure of the schemes. The blame for failure is usually placed on the farmers, but invariably the true cause is an overall lack of viability of the project design itself, a design that did not permit farmers to adopt irrigated cropping as an integral component of a new, self-sustaining, balanced farming system despite all the huge investments by the national and international stakeholders on smallholder irrigation. Manyatsi (2005); Malaza and Myeni (2009) reported that the irrigation schemes are faced with the challenge of ensuring long-term sustainability. As a result, many of the irrigation schemes are not performing up to the expected performance hence the continued decline in agricultural productivity especially in the rural areas. The challenges range from technical level, economic level, social level to ecological level.

On the other hand, the beneficiaries are of the opinion that SWADE implementing strategies or processes do not empower them to a level that they can carry on after the support of the SWADE comes to an end. SWADE has laid down sets of policies and procedures to be followed in terms of project development which the farmers have got to adopt. Most of the policies are adapted from government policies and procedures. There is a notion that the project was conceived from outside with little or no participation of the local communities prior to implementation.

Botes and van Rensburg (2000) reported that in some instances, community participation is not a genuine attempt to empower communities to choose develop options freely, but rather an attempt to sell preconceived proposals. They also state that the participation processes often begin only after projects have already been designed with the attempt not to ascertain the

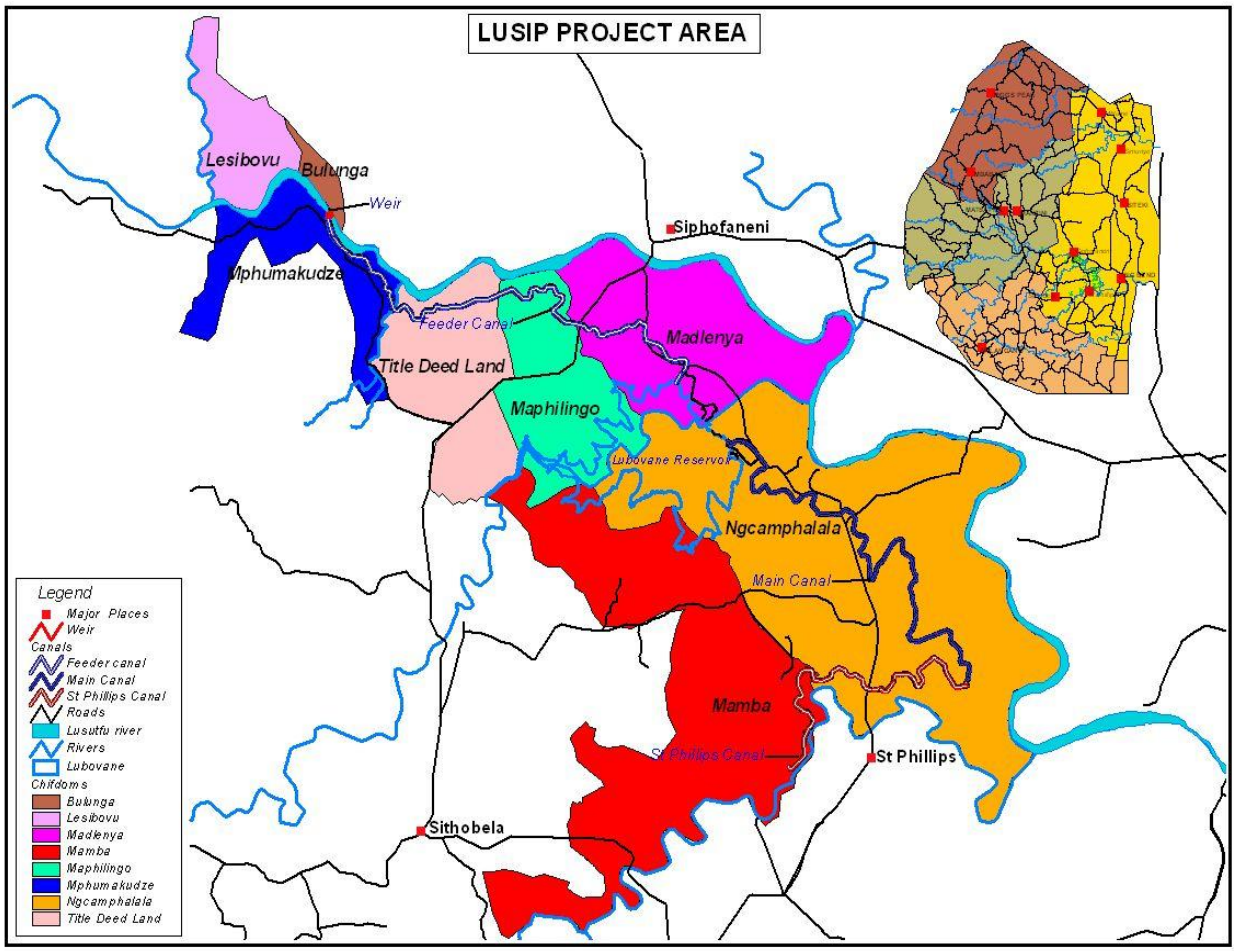

Figure 1. Map of Project Development Area – LUSIP.

outcome and priorities but rather to gain acceptance for an already assembled package. The study seeks to determine whether the development models/strategies used in LUSIP will ensure sustainability of the smallholder farmers post LUSIP support as a basis for policy and strategy improvement.

METHODOLOGY

Study area

The study was conducted in LUSIP area which is located in the Western Lowveld of Swaziland. The project was built on the successes of achieved smallholder irrigators in the Lower Usuthu Basin and is planned to take advantage of the strong market linkages in the sugar industry, while further developing available linkages in the cotton, food crop and livestock sub-sectors. LUSIP involves the diversion, storage and delivery of surplus summer flows from the Usuthu river to permit smallholders to irrigate a total of 11 500 ha of land. This took the construction of a low weir at Bulungapoort, a 23 km feeder canal leading to the 155 m^3 Lubovane Reservoir, a North Canal designed to serve 2000 ha, and a South Main Canal to irrigate some 4 500 ha making the total irrigable area of 6 500 ha (Phase I) in the Lubovane block (Figure 1). Phase II will consist of an extension of the South Main Canal into the Matata block to irrigate a further 5000 ha (IFAD, 2001a).

The total gross irrigable area for this study is 6 500 ha. This area is bordered to the north by the Usuthu River and to the south, west and east approximately by the 220 m contour line (Figure 1), the project development area (PDA) covers seven chiefdoms namely; Dlamini, Mamba, Ngcamphalala, Gamedze and Shongwe, Lesibovu and Mphumakudze but to-date only two have been have been developed and these are Ngcamphalala and Gamedze hence this study covered only farmer companies (FCs) in the Ngcamphalala and Gamedze chiefdoms that had already started receiving proceeds from the first sugarcane crop that was planted in 2010. The thirteen FCs are discussed briefly in Table 1.

Sampling technique and size

A purposive sampling was used because the thirteen (13) companies were considered to be typical and representative of the population since they had already harvested once and they were being considered to be weaned-off from the LUSIP guidance (technical support on farm and business management and extension). The targeted sample size was at least 38% of population. The population was 34 operational FCs with the 62% only just harvesting or waiting to harvest their first crop. The

Table 1. A Summary of the Thirteen FCs.

Farmer company	Sugar planted Ha.	No. of members	Chiefdom	EU Funding 'as built' E	Govt. funding E (Design not 'as built'?)	Total devt. Cost E	Loan amount E	Loan period years	Cost / ha. of 'as built' area E
Setamiphilo eNgonini	36.20	26	Madlenya	2 026 552.00	1 054 755.00	3 081 307.00	719 752.00	6	83 959.32
Mganyaneni	59.50	30	Madlenya	3 949 825.00	808 266.00	4 758 091.00	1 331 545.00	6	79 301.52
Sibhotela Investment	55.03	35	Madlenya	3 001 449.00	859 492.00	3 860 941.00	1 300 294.00	6	74 248.87
Nyoni Khalakahle	49.80	25	Madlenya	2 828 749.00	946 496.00	3 775 245.00	1 178 698.00	6	72 740.75
Kuselangeni	54.39	36	Madlenya	2 848 692.00	985 524.00	3 834 216.00	1 031 023.00	6	69 460.43
Sukumani Ngonini	46.20	24	Madlenya	2 422 607.00	922 582.00	3 345 189.00	928 758.00	6	68 548.95
Imbali YaMadlenya	55.98	29	Madlenya	2 463 813.00	927 306.00	3 391 119.00	1 109 278.00	6	57 282.42
Bamoyamunye	58.70	57	Ngcamphalala	-	3 892 646.00	3 892 646.00	1 571 422.00	6	66 314.24
Ngcwaleni Farmers Limited	111.10	64	Ngcamphalala	-	6 446 742.00	6 446 742.00	1 878 149.00	6	58 026.48
Matimavu	85.70	86	Ngcamphalala	-	4 542 838.00	4 542 838.00	1 655 131.00	6	53 008.61
Mpondweni Investment	84.00	72	Ngcamphalala	-	4 290 941.00	4 290 941.00	1 723 177.00	6	51 082.63
Kuhle Kutentela	54.00	82	Ngcamphalala	-	2 662 576.00	2 662 576.00	1 167 708.00	6	49 306.96
Mgulugulu and Sihlase (M&S)	81.60	43	Ngcamphalala	-	3 403 555.00	3 403 555.00	1 482 107.00	6	41 710.23

following types of people participated in the study: Executive Board Member (18), Ordinary Board Members (4), Shareholders (8) and Supervisors (6).

Data collection and analysis

This was a case study of the LUSIP farmers. Interviews were conducted by means of questionnaire, focus group discussions (FDGs) and key informants interviews (KII) in thirteen selected smallholder irrigation farmer companies, namely Kuselangeni, Mganyaneni, ImbaliyaMadlenya, Sibhotela, SitamimphiloeNgonini, SukumaniNgonini, NyoniKhalakahle in the Madlenya chiefdom; Ngcwaleni, KuhleKutentela, Matimavu, Mgulugulu and Kuhlase, BaMoyaMunye and Mpondweni in the Ngcamphalala chiefdom all under LUSIP. The thirteen companies were selected because they were the first ones to harvest cane and receive revenue; and they are in the second year of production. Focus group discussions (FDGs) and key informant interviews were conducted with SWADE/SHIP personnel. Secondary data was collected from project documents and reports and evaluation reports.

Data analysis

Data was recorded, transcribed, coded, analyzed and interpreted according to the various dimensions mentioned in the study design. The projects dimensions were demographic characteristics of respondents, socio-economic impact, social acceptability of the project, productivity, risk reduction and the institutional and technical maintenance data was analyzed using the Statistical Package for Social Sciences version 17.0.

RESULTS AND DISCUSSION

Demographic information for farmer groups and respondents

The survey revealed that there are more males (66.7%) than females (33.3%) involved in the project. Secondary data from SWADE reports reveal that only 39% of the shareholders are females. This reflects a gender imbalance in that the males are the majority yet the development model encourages women and youth to form an integral part in the development. Majority (70%) of the people interviewed were between the ages of 26 to 45 years with 22% being older than 45 years and only 8% younger than 25 years. These figures demonstrate that migration to industrial towns and cities for employment is now reduced when you consider that the energetic age group is the majority in the sample.

Socio- economic contribution of the project

Gross revenue

The FCs had budgeted to sell their sucrose to the mill at E1800.00 per ton at project planning stage and yield estimates were pegged at 100 tones

Table 2. FCs' Performance in the first two seasons of harvest.

		2010/2011					2011/2012				
Farmer company	**Hectares**	**Yield TCH**	**% sucrose**	**Yield TSH**	**Price / T**	**Rev / Ha**	**Yield TCH**	**% sucrose**	**Yield TSH**	**Price / T**	**Rev / Ha**
Ngcamphalala FCs					**(E)**	**(E)**				**Est (E)**	**Est (E)**
M&S	81.60	133.63	12.50	16.70	2252	37615	127.28	11.95	15.20	2700	41050
Matimavu	86.30	108.80	13.60	14.80	2252	33321	92.00	12.69	11.67	2700	31515
Kuhle Kutentela	54.00	166.02	13.56	22.51	2252	50695	108.26	12.48	13.51	2700	36476
Ngcwaleni	111.10	118.94	13.32	15.84	2252	35676	102.98	12.45	12.82	2700	34622
Bamoyamunye	58.70	98.82	14.30	14.13	2252	31822	98.94	13.24	13.10	2700	35369
Mpondweini	84.40	115.27	13.10	15.10	2252	34005	101.82	13.71	13.95	2700	37677
Total / Weighted average	**476.10**	**121.83**	**13.36**	**16.28**	**2252**	**36662**	**105.05**	**12.71**	**13.36**	**2700**	**36062**
Madlenya FCs											
Sibhotela	52.20	105.84	12.80	13.55	2252	30508	91.08	12.96	11.81	2700	31876
Imbali	55.98	93.33	12.82	11.96	2252	26944	91.14	13.07	11.91	2700	32162
Nyoni Khalakahle	49.80	103.60	12.80	13.26	2252	29862	98.81	13.41	13.25	2700	35765
Kuselangeni	55.98	105.30	13.60	14.32	2252	32249	103.23	13.45	13.89	2700	37499
Sitamimphilo	36.20	98.50	14.30	14.09	2252	31719	97.76	14.07	13.75	2700	37138
Mganyaneni	59.00	119.20	13.60	16.21	2252	36506	126.79	13.65	17.31	2700	46739
Sukumani	42.08	100.00	14.10	14.10	2252	31752	91.60	13.63	12.48	2700	33707
Total / Weighted average	**351.24**	**104.23**	**13.43**	**14.00**	**2252**	**31529**	**100.87**	**13.49**	**13.61**	**2700**	**36746**

cane per hectare (TCH) at 14% sucrose percentage. Presented in a simpler way the budgeted sucrose production was 14 tones sucrose per hectare (TSH). However the sucrose price at their first harvest was E2252.00 per ton which meant that the gross revenue per hectare was E6328.00 more than budget. The increase in the sucrose price resulted in 61.1% of the respondents saying the gross revenue received was above their expectation with 27.8% saying it was below what they had expected. Possible reason for the dissatisfaction on the revenue received may be the low yields achieved by some of the FCs as three of them recorded yields below the target 14 TSH as shown in Table 2. The second harvest performance is also shown in the same table. The sucrose price rose to E2700 per ton and this compensated for the drop in yields as the gross revenue remained fairly the same as the previous season. The drop in yields could be attributed to the fact that some of the cane was harvested before reaching the recommended 12 months.

Monthly income

Monthly disposable income per household has also improved since the project started as 88.9% of the sampled participants earned less than E900 per month before the start of the project. But after just one year since the start of the project, that earning bracket of E900 has decreased to 58.4% with 41.6% now earning a monthly income of above E901 per month (Figure 2).

Even though the sugarcane crop is not for consumption per se, 27.8% of the respondents reported that the earnings from the sugarcane farming is enough to feed families whilst 88.9% and 77.8% believe that LUSIP has so far contributed to the improved livelihoods and improvement of the standard of living as well respectively. So far the development model is premised on participation for all community members and 100% of the participants believe

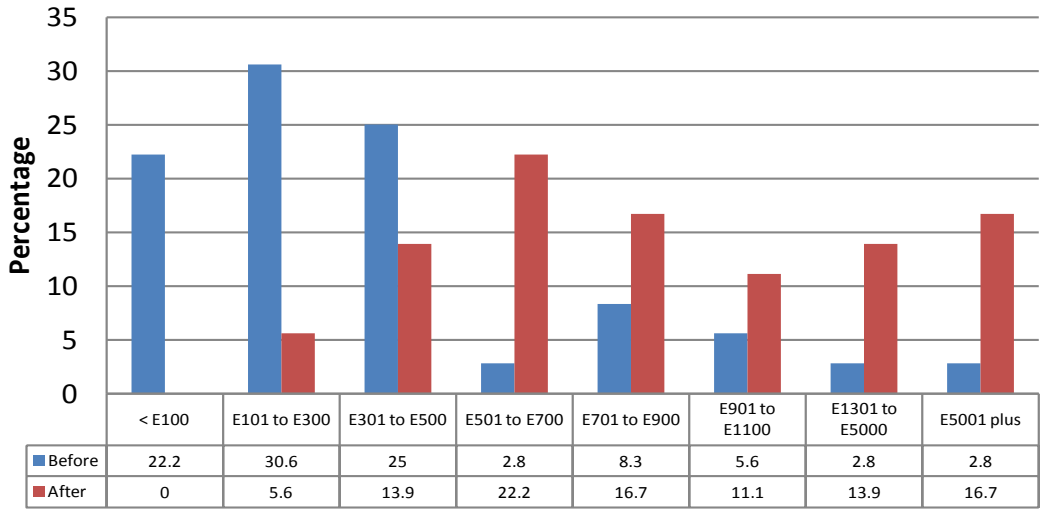

Figure 2. Shareholders' monthly income per participating household.

that everyone is benefitting equitably, albeit for now. It was expressed that the project has contributed positively to enable the beneficiaries to have ability to buy food (45%), build homes (19%), ability to buy luxuries (31%) and 5% indicated that they no longer need to rely on their livestock to survive.

Social acceptability of LUSIP

A socially responsible agriculture development project is one that equitably meets basic human food and fiber needs, provides economic opportunity, supports self-determination, and ensures social equity for both current and future generations. During the upstream development and even before the farm development started, community members have been given job opportunities. The FCs at inception decided that they would give first preference to shareholders with regard to employment on the farms. A total of 86% of the sampled FCs indicated that they have shareholders under their employ with only 13.9% of the FCs not having shareholders on their payroll. All the FCs have employees who are not shareholders but are either from the PDA or outside the PDA, though the numbers are less than ten.

Participation in FCs

On the membership, all the FCs required members to be household representative, resident with or without user rights to land and be from the same locality. A total of 33.3% of the FCs that participated in the survey reported that they have shareholders who are below the age of 18 years and such shareholders are representative of their households. Findings on the groupings were very positive as 69.4% of the respondents rated the groupings as good or very good. However, contrary to the good rating of the groupings 61.1% said they would do the groupings differently if given another chance while 66.7% still said they believed that the farmer groups will remain together in the future.

Land ownership and traditional authorities involvement

All the FCs are situated on SNL and the respondents are aware that paying allegiance to their respective chiefs is very crucial to the sustainability of their projects. Majority (88.9%) of the respondents believed that the land tenure of the country is good and does guarantee sustainability of the development. Reasons for believing in the land tenure were that the chief can fix land disputes quickly, the TAs facilitate better farm management and that tenure systems prevents outsiders (people from outside the PDA) from coming to take their farming business. The chief's interference on the day-to-day operations of the FCs, the demanding of royalties and the fact that the chief has the power to temper with the shareholding or membership are some of the reasons some (11.1%) of the respondents responded negatively to land tenure system in PDA.

Risk reduction

Financial risks

All the FCs received grant finance from either the GoS or the European Union (EU). The availability of the grant finance cannot be guaranteed and signs that these funds dwindling are already starting to show. This is consistent

with the observation made by Wali and Miller (1995) who reported that global indebtedness in the developed countries reduces capital investments in development assistance and technical aid to developing countries. The high interest rates charged by the commercial financial institutions (CFIs) are not helping the farmers. Presently, the CFIs charge 15.5% interest on the loans which is too high when compared to what the big estates/businesses are charged.

Price and market risks

According to Boehlje and Eidman (1984) all factors leading to unpredictable shifts in the supply and demand of inputs and products are sources of prices uncertainty. Movements of a seasonal, cyclical, and trend nature are predictable to some extent, but the inability of the farmer to predict these prices accurately in making decisions represents a business risk. The marketing of sugar in Swaziland is highly centralized since the sugar industry is managed by the Swaziland Sugar Association (SSA) formed by all millers and growers. Once cane is delivered to the mill, it becomes the property of the SSA which owns and markets all sugar and molasses produced in the country. The Swaziland Sugar Industry Quota Board constituted by representatives of millers, growers and government officials, allocates production quotas to growers and assigns them to the respective mills.

Sugarcane produced by each farmer is hauled by contractors from the farm gate to the mill where it is weighed and recorded. A sample of the cane juice is taken from the farmer's produce to determine the sucrose content. Both cane weight and sucrose content are used to determine the price and overall sugar production of each sugarcane grower. After the sale of sugar, the proceeds are shared between the farmers and the mill at a ratio of 67.5% to the farmers and 32.5% to the mill in order to cover its milling cost (ADB, 2003). The farmers are aware that as sugarcane producers, they do not determine the price of their produce instead they are only price takers. Although, they are only price takers, 50% indicated that they are happy with the current sucrose price.

LUSIP has put emphasis on diversifying the crop mix in the irrigated blocks to reduce risks pertaining uncertainty with sugar cane prices. This matches the commitment in government policy to prevent irrigated smallholders from concentrating entirely on sugar. While the crop is currently fetching good prices, its future viability cannot be assured, given continuing uncertainty about access to the European Union market that currently imports half of Swaziland's production. Growing a mix of crops on irrigated land is also advisable for agro-ecological reasons; and for smaller and less prosperous companies it enhances the cash flow if one or two harvests of other crops can be marketed each year in addition to the main sugar harvest.

LUSIP has therefore made commendable progress with two categories of irrigated production and has achieved only 17% of the target for 'alternative cash crops' and 40% for 'commercial gardens'. The former category focuses entirely on the market and has been introduced by three FCs so far. Two are growing bananas, dry maize and beans. The third is producing cassava. The latter category comprises a mix of crops for the market and crops for FC members' home consumption. It should make a good contribution to the food security of those whose FCs engage in it; but the direct impact on the overall quality of household food consumption in the PDA is obviously limited (ADEMU, unpublished).

Production risks

The variation in the production level resulting from factors beyond the farmer's control including weather, pests, genetic variation, changes in the regulations on use of pesticides and timing of production practices represents a major source of business risk. In LUSIP production, risk can be reflected in the variability of yield per hectare as 29% rated failure to follow Best Management Practices (BMPs) top of the list, 26% attributed it to poor extension service, 24% thought that interference in the day-to-day running of the FCs by shareholders and 21% blamed poor services providers or inputs suppliers. The shareholders interference is the result of the FCs failing to separate ownership from management. The shareholders have a notion that since they are the owners of the farming business then they must be involved in the management of the business. The findings in the study are in line with Sunter (2003) observation that in farming the separation of ownership from management does not exist. This indicates that even in the study area, the agri-business has not been corporatized as evidenced by the failure to follow BMPs due to shareholders' to management decisions. This leads to delayed timely execution of farm activities.

Socio-economic risks

At farmer groups' formation stage, shareholding was planned to be 2 ha per shareholding. After renunciation of land by the group members, the chief allocated land to the newly formed farmer group based on the available land (gross) in relation to the members. But as the project progressed to implementation; the turnout of irrigable areas were in most cases smaller than the gross area. This resulted in the decrease in the shareholding ratio. A high proposition (80.6%) of the sampled farmers indicated that they are not happy with the shareholding and would consider buying shares from other FCs given the opportunity. Figure 3 shows that 94.5% of the surveyed FCs had shareholding ratio of at least 2 ha per SH at group formation stage that has since decreased as

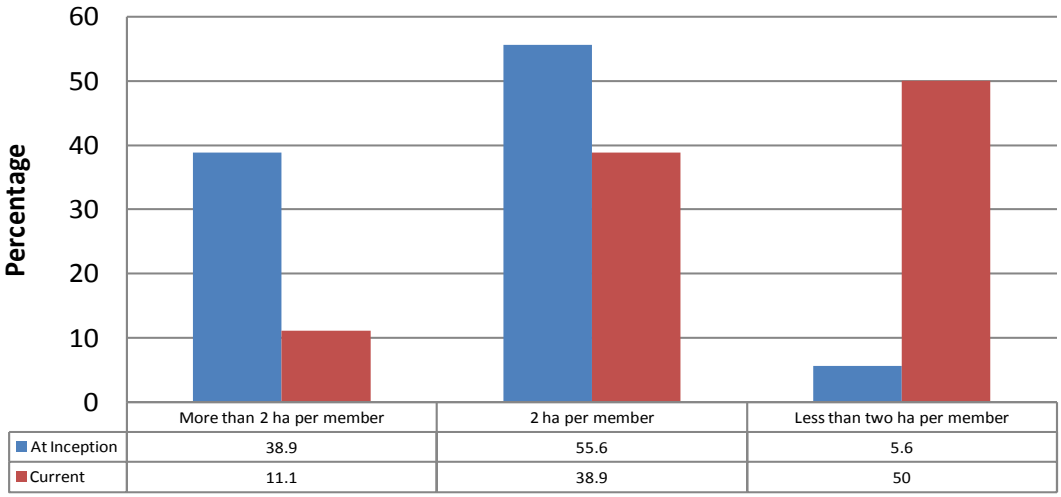

Figure 3. Shareholding (Ha/SH) ratio before and after inception.

Table 3. The list of the institutional structures in the LUSIP.

Institutional structure	Roles in the development
Water Users Associations (WUAs)	Organizing irrigation at farmer level, collection of revenues, and organization of maintenance activities in the command areas below the outlets.
Community Development Committee (CDC)	The Community Development Committee (CDC) coordinates all development initiatives in the section, then report to the Community leadership.
Sigodzi Development Committee (SDC)	The SDC acts a conduit for the expected flows of information between communities and higher planning tiers and represents the interests of their constituents.
Farmers' Federation (FF)	This is an Apex board for the farmers whose mandate is to facilitate and co-ordinate all LUSIP FCs' activities.

the shareholding statistics is now standing at 50% of the surveyed FCs with a ratio that is below 2 ha per SH.

Institutional and technical maintenance

Level of participation

The government of Swaziland assigned the International Fund for Agricultural Development (IFAD) to design and implement the project to ensure that the investment bring about maximum enduring benefit for the rural poor. The model adopted was that smallholders will form groups or associations of about 20 people each and jointly venture into crop and livestock farming sharing the establishment costs, work and income on an equitable basis. Beneficiaries were responsible for the development, preparation and implementation of their work plans after receiving training, skills upgrading and other capacity-building that enable them to manage their enterprises. In addition, they are responsible to take corrective and preventive measures against risks to their health and the health of their family members; and they will participate in the sustained maintenance of flora, fauna, land/soil and other natural resources (IFAD, 2001b). The findings of the study indicates the model promoted participation of the beneficiaries as 58.3% believed that their level of participation was medium with 33.3% accepting that it was high and only 8.3% viewing the participation level as low.

Institutional structures for management and sustainability

Table 3 indicates the institutional structures that were established in the project to ensure sustainability. The effectiveness of the institutional structures that have been set up to ensure sustainability of the project is in doubt. At the time of the study 50% of the interviewed viewed

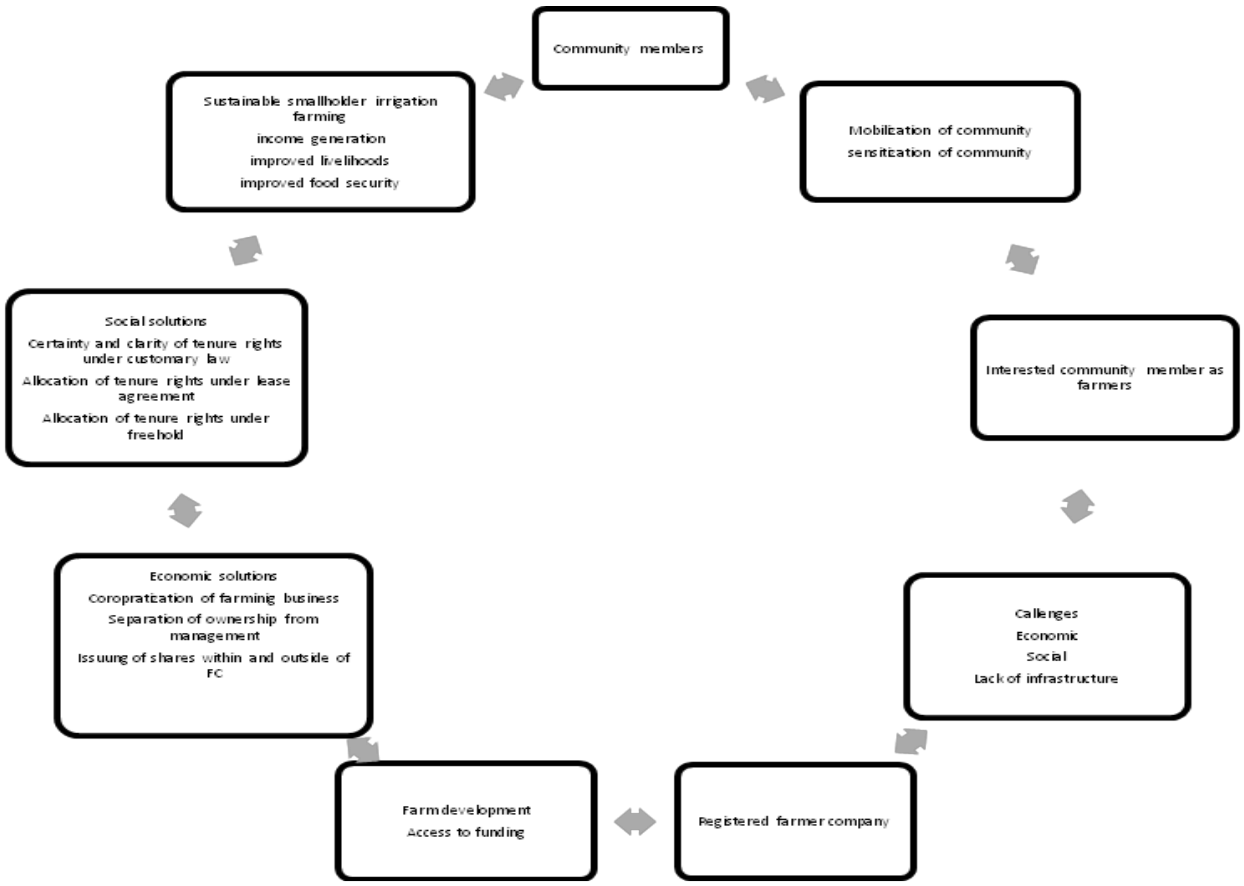

Figure 4. A schematic diagram of the conceptual framework for sustainable smallholder irrigation farming in the PDA.

the institutional structures as ineffective while only 44% thought these are effective. The ineffectiveness was attributed to; (1) the election of unskilled people to serve in these bodies, (2) lack of incentives to motivate the elected members and (3) involvement of people who do not have the interest of the community at heart but only concerned about enriching themselves.

There are other organizations that operate and participate in the project to ensure it achieves its objectives. Among the organizations is Swaziland Development Finance Corporation (FINCORP) and Swaziland Industrial Development Corporation (SIDC) which were identified by GoS as the suitable conduit for channeling credit funds. Also, a memorandum of understanding was signed between SWADE – LUSIP and Ubombo Sugar Limited for provision of comprehensive facilitation and support services to smallholder cane growers from enterprise initiation through to the delivery of cane to the mill.

In the institutional arrangement in the study area a high proportion (75%) of the respondents agreed that SWADE is able to fulfill her mandate of uplifting the standard of living of the people in the PDA. The reasons for the few (5.6%) negative included delays in project implementation, delayed processing of transactions, and inadequate extension support.

CONCLUSION AND RECOMMENDATIONS

The study indicates that smallholder development under LUSIP has a potential to contribute to the overall agricultural contribution to the Swazi economy. However, the question of farmer groups remaining in business in associations cannot be guaranteed as the participation for all community members in the farm business creates some resentment to the diligent when considering that shareholding is on equal basis. In addition, the smallholder farming business remains un-corporatized as ownership is still linked to management and opportunities for wealth creation or addition remain limited. The uncertainties surrounding land ownership and user rights remain one of the major threats on the sustainability of the farming business in SNL.

Farmers should learn from the other sectors and corporatize their businesses to consider issuing more shares as a source of income. Concerning the land ownership and user rights issues the government needs to finalize the National Land Policy to unlock most of the obstacles. Figure 4 summaries the recommendations in a

schematic diagram.

Conflict of Interest

The authors have not declared any conflict of interest.

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A comparative analysis of the agronomic characteristics and economic benefits of using certified seed and farmer saved seed of rice (*Oryza sativa* L.) at different nutrient management regimes: Evidence from on-farm testing in the Guinea Savanna rice growing ecologies of Ghana

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The agronomic performance and economic benefit of rice seed from two sources (farmer-saved and certified seed) at different nutrient management regimes in the Guinea Savanna agro-ecological zone of Ghana were evaluated. A total of 14 on-farm multi-locational trials were established in 2011 and 2012 cropping seasons using Participatory Learning and Action Research (PLAR-IRM) approach to technology dissemination. Regression analysis shows statistically significant differences (P <0.01) of treatment effect in terms of grain yield (kg/ha) for both certified and farmer-saved seed. The highest grain yield of 6,833 kg/ha was recorded for certified seed at full fertilizer recommendation rate for the 2012 growing season while the lowest grain yield of 30 kg/ha was recorded for famer saved seed at zero fertilizer management level for the same cropping season. Returns from cultivating certified rice seed was found to be economically superior to farmer saved seed at all levels of fertilizer management.

Key words: Certified improved rice, farmer learning centres, Guinea Savanna agro-ecological zone, integrated soil fertility management.

INTRODUCTION

The importance of good quality seed in increasing whole farm productivity cannot in anyway be underestimated (Minot, 2008; Kshetri, 2010; Boland et al., 2011; Guei et al., 2011; Thompson and Scoones, 2012; Entwire et al., 2013; Poonia, 2013). The green revolution of the 1960s was a compact of technologies (variety, input, credit, market, etc) yet the role improved seed cultivars/varieties played in its success is a notable fact within the

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agricultural research community and various food policy think tank organizations (Briggs, 2009; Tomita, 2009; IFPRI, 2012; Cassman and Grassini, 2013). Seed is the pivotal point around which various approaches or concepts of increasing agricultural productivity revolve. Whether conventional or organic, starting with a clean, healthy and pure seed or seedling for planting is always the emphasis of farmers, agricultural extension officers, and research workers alike (Kshetri, 2010; Boland et al., 2011). Advances in molecular biology and biotechnological applications of the 21st century have introduced novel approaches such as recombinant DNA technology for precision gene(s) isolation, cloning, and incision at the cellular level. Nevertheless, focus still remains on seed as the fundamental laboratory through which productivity issues in agriculture can be addressed. This is because almost all the products of these technologies such as increased yield (Daoura et al., 2014), pest and disease resistance (Kamthan et al., 2012; Zeller et al., 2013), improved nutrition or bio-fortification (Stein, 2008; Dawe et al., 2002; Bhullar and Gruissem, 2013) and others all rely on seed as the focal point for 'housing' and 'marketing' these technologies.

Against this backdrop, the issue of seed has constantly been one keenly contested, nay controversial, with various groups having their interests to promote and safeguard. Whether it is the introduction of hybrid seed and the accompanying protest by certain interest groups or the more recent sizzling debates on genetically modified (GM) crop seeds/cultivars (Halford and Shewry, 2000; Marchant, 2001; Dibden et al., 2013; Tironi et al., 2013), seed has always caused controversies in agriculture. One aspect to the debate on seed has to do with the issue of certified seed against farmer saved seed. The argument for a long time has been whether the extra costs on certified seed was really worth it? and in particular, for the self-pollinated inbreed lines of crop cultivars where farmers can make seed selection from their farms or at worse just pick lots from the grain harvested and use same as seed the next season.

Researchers and extension workers alike generally stipulate that certified seed is superior to farmer saved seed, given a fundamental understanding that certified seed meets all the requirements of *good seed*. However, empirical evidence generated from on-farm trials to support this claim and use it as proof to convince farmers on the need to use certified seed especially for certain important grain cereals critical to food security in Ghana is lacking (Personal communication).This has often times been demanded during important policy discussions on food security in Ghana (Personal communication). With the world population expected to reach nine billion by 2050 (Falkenmark, 2001; Buhaug and Urdal, 2013), feeding the increasingly urbanized populated world is certainly one of the greatest challenges confronting humanity in this century (Koning and Ittersum, 2009). Globally, the importance of rice to food security is unquestionable to the extent that it has almost become synonymous to food security is certain geographical locations (Dawe and Timmer, 2012; Mariano and Giesecke, 2014). With a per capita consumption ranging from 21-38 kg, a national average of 22.1 kg per annum and a significant continuous increment in annual production, (Kula and Dormon, 2009; SRID, 2012), the significance of rice with respect to food security in Ghana is undisputable. With a population growth rate of 2.5% and an annual rice demand growth rate of 8.9%, a supply of 1.6 million tons of rice will be needed annually in Ghana by 2015 (Ofori et al., 2010). However, rice productivity at the local level is too low to meet this annual national rice demand (Angelucci et al., 2013). Indeed, the Ghana Minister for Food and Agriculture (MoFA) at a recent 'Meet-the-Press' meeting with newsmen in Accra, stated that "the average annual rice import bill stood at US$ 306 million with domestic production accounting for only 46% of total supply and the shortfall of 56% being met by imports". The minister underscored the importance of developing a National Seed road map as an integral component of a national strategy to accelerate the growth of the rice industry (GhanaWeb, 2014).

Years of research breeding programmes (both locally and at international research centres) have resulted in improved genotypes of rice (Hazell, 2010; Peng et al., 2010; Renkow and Byerlee, 2010; Ragasa et al., 2013). Most of these genotypes have been made available to farmers. A great proportion of rice farmers in Ghana use improved genotypes in their cultivation (Ragasa et al., 2013). However, the average yields recorded by rice farmers in Ghana continue to fall far below the potential yields reported by research and experimental stations. In as much these farmers continue to cultivate rice paying little attention to Integrated Rice Management (IRM) recommendations which among others, underscores integrated soil fertility management (ISFM) and the use of certified rice seed planting. Numerous interventions in the rice industry have also taken place in Ghana. These notwithstanding, only about 23% of the total area currently being cropped to rice is under certified seed (Etwire et al., 2013).

Several *yield gap* analysts (Tran, 1996; Duwari et al., 1998; Evans and Fischer, 1999; Ofori et al., 2010) have suggested that this must be one of the factors why rice grain yields are always far below the average achievable yields at farm level. We report here, the results of two year on-farm trials comparing the performances of certified seed against famer saved seed of rice at different fertilizer management regimes in the Guinea-Savanna rice growing ecologies of Ghana.

MATERIALS AND METHODS

Site selection and description

The experiments were conducted in the Guinea Savanna agro-ecological zone (GSZ) of Ghana. Six communities were used as

Table 1. Communities that hosted FLC learning plots.

S/No	District	Community (host)	GPS coordinates of FLC *(GPSmap 60CS$_X$)*
1	Tamale metropolitan	Cheshie	N 09° 21' 18.5" W 000° 55' 18.2"
2	Tolon	Woribogu-kukuo	N 09° 25' 07.9" W 001° 02' 21.6"
3	Karaga	Karaga	N 09° 55' 23.7" W 000° 25' 57.5"
4	East Gonja	Libi	N 09° 10' 43.2" W 000° 37' 32.0"
5	Yendi	Kpatia	N 09° 52' 30.8" W 000° 02' 53.0"
6	West Mamprusi	Katabanawa	N 10° 35' 03.7" W 000° 56' 57.3"

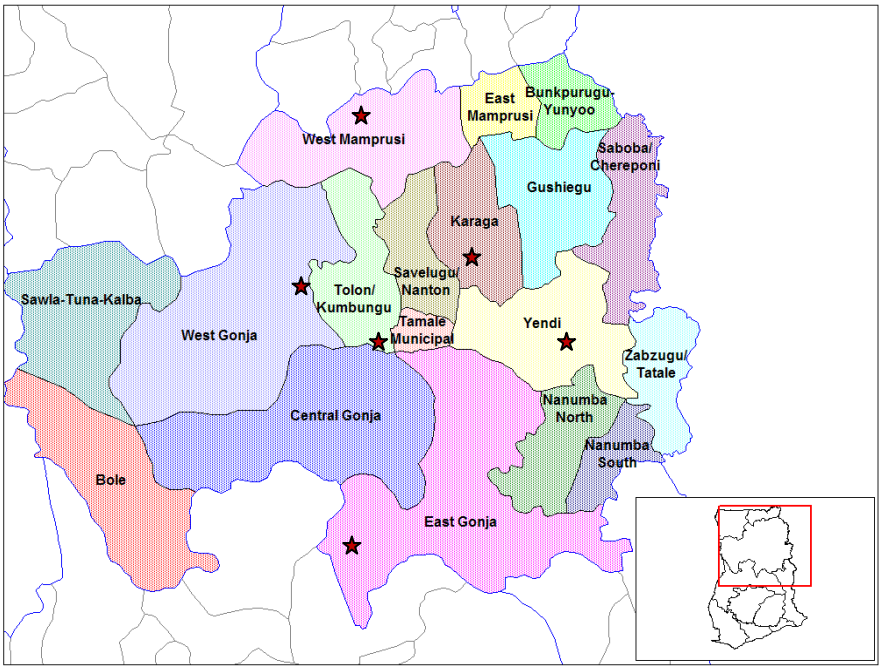

Figure 1. Map of northern Region of Ghana indicating districts where trials were sited (★) (Created by Rarelibra (2014) for public domain use).

sites for the experiments during the two year period (Table 1; Figure 1). The selected sites were representative of the various major rice growing ecologies in the Guinea Savanna zone of Ghana. The soils in Guinea Savanna agro-ecological zone of Ghana are dominated by *Savanna Ochrosols*. These soils are moderately deep to deep and are generally developed over granites and stones. Decomposing rock or hard rock may be encountered within 150 cm depth. The topsoils are generally thin (<20 cm), greyish brown sandy loam, weak granular and friable. They are light, varying in texture from coarse sands to loams. The subsoils range from red in summits to brownish yellow middle slope soils (especially on some sandstone soils). Ironstone concretions and sandstone brashes of about 10 to 40% commonly occur in some of these soils. The subsoils are relatively heavy, varying from coarse sandy loams to clays with varying amounts of gravel (Adu, 1995; Asiamah et al., 1996). According to Owusu-Bennoah et al. (1995), the texture of the soils in the northern part of Ghana varies from loamy sand, sandy loam to loam. The reported pH range of the soils is from 5.4 to 6.1. Majority of the soils in the GSZ occupy gentle undulating to gently rolling topography, yet are more vulnerable to erosion than

Table 2. Treatment combinations used in the study.

Treatment levels (T)	Treatment description	Fertilizer regime explanation
T_0	No fertilizer	No NPK; No compost
T_1	0.5 RRF	Half recommended fertilization rate of NPK
T_2	0.5 RRF + 3 t/ha *Compost	Half recommended fertilization rate plus 3t/ha compost
T_3	RRF	Recommended fertilization rate of NPK
T_4	RRF rate + 3 t/ha Compost	Recommended fertilization rate plus 3t/ha compost

Table 3. Field layout of certified and farmer-saved seed demonstrations. *RF - Recommended fertilization rate of NPK. The recommended chemical fertilization regime for rice in the study area is NPK (60-40-40)/ha; usually provided as 267 kg/ha Compound fertilizer NPK ($_{15\text{-}15\text{-}15}$) as basal manure and 44 kg/ha Urea (N_{46}) or 95 kg/ha Sulphate of ammonia (N_{21}) as top dresser.

Certified seed + No fertilizer	Farmer saved seed + No fertilizer	
Certified seed + 0.5 RF	Farmer saved seed + 0.5 RF	
Certified seed + 0.5 RF + 3t/ha compost	Farmer saved seed + 0.5 RRF + 3 t/ha compost	FARMER'S PRACTICE
Certified seed + RRF	Farmer saved seed + RRF	
Certified seed +RF + 3 t/ha compost	Farmer saved seed +RRF + 3 t/ha compost	

those soils occurring on the more strongly rolling relief of forest agro-ecological zones in the southern parts of Ghana. The GSZ is characterized by a uni-modal rainfall pattern with an annual mean of 1030 mm (May-October) with high degree of variability. The area has an extreme moisture regime relationship with about 5 months of rainy season and 7 months of dry season (NAES, 1993).

A Farmer Learning Centre (FLC) is established in a focal community for 15 to 20 Farmer Based Organisations (FBOs) in a district where CSIR-SARI is implementing several Integrated Soil Fertility Management (ISFM) trials with farmers. Using the concept of FLCs in the catchment area farmers, machinery service providers and agro-input dealers and aggregators are inter-linked to enhance their productivity. Certified seed used for the trials was improved high yielding rice cultivar called *Gbewaa rice*, released by the CSIR-SARI in 2012. *Gbewaa rice* is medium maturing (110 to 115 days) with a yield potential of 6,900 kg/ha. In the case of the farmer-saved seed, each hosting FBO was asked to provide their own seeds. Enquiries were made to ensure that such seed lots had no immediate history of coming from a certified source such as the Seed Inspectorate Unit of the Plant Protection and Regulatory Services Division (SIU/PPRSD) of the Ministry of Food and Agriculture (MoFA) or any seed dealer approved by the MoFA.

Treatment description and application

The experimental design was factorial and comprised two levels of seed (certified seed and farmer saved seed) as main plot and five levels of fertilizer (T_0 -T_4) as sub plot factors (Table 2). A complete demonstration plot at each FLC measured 2000 m^2. Half of the field was used as treatment plots and the remaining was used by the host FBO as 'Farmers' Practice plot. The field layout is shown in Table 3. In the table, five sub plots in each main plot were randomly assigned and labelled as shown. A space of 0.50 m alley was created between two adjacent plots.

The evaluation of certified and farmer-saved seed at different fertilizer management regimes constituted one of five different demonstrations at each FLC The trials were used for the purposes of research and farmer training through learning by doing approaches of Participatory Learning and Action Research (PLAR) (IRRI, 1998; Wopereis et al., 2008) for technology dissemination. The management of the all trial plots was mainly the responsibility of the various famer-based organizations hosting the demonstrations with regular backstopping from the CSIR-SARI researchers and MoFA Agricultural Extension Agents (AEAs). Data was collected for statistical analysis with the assistance of AEAs.

Seeds were dibbled (at three - four per hill) at planting distance of 20 x 20 cm using a seed rate of 50 kg/ha for both the certified seed (CS) and the farmer-saved seed (FSS) plots. CS plots were thinned to one-two plants per stand after first hand weeding just before basal (first) fertilizer application. For all the different fertilizers levels and combinations, the basal fertilizers were applied 3 weeks after planting (WAP) whereas top-dressing fertilization was done at 6 WAP (after second hand weeding), except the compost treatment which was spread and worked into the designated plots before planting. Each treatment plot was enclosed by small bunds or levees to minimise lateral movement of fertilizers from one plot to others. All necessary agronomic practices were carried out as recommended for rice production in the GSZ.

Deco compost

The compost used in the study was *Deco compost*, produced from solid municipal waste and marketed by Deco Co. Ltd., Tamale Ghana. Jordão et al. *(*2006) found that the application of composted urban solid wastes to soils increased the available concentrations of Cu, Pb and Ni in the soil according to the increase in the doses of the compost used. Businelli et al. (2009) found that municipal waste compost amendment resulted in a significant enhancement of the metal loadings in the amended topsoils, particularly for Cu, Zn and Pb. Shulan et al. (2012) have however, indicated that particle size fractionation changed the physical properties and chemical component distribution of compost and that for more environmentally friendly agriculture, it was desirable to separate out fine compost fractions (<0.8 mm) because they have low concentrations of nutrients but more heavy metals. Physico-chemical analysis report of *Deco compost* provided by the producers for this study (Table 4) met required standards of safety and rates of compost used were intended for melioration.

Table 4. *Deco compost* physico-chemical analysis report (Source: Deco Co. Ltd).

Analysis	Weight basis
pH	**7.7**
Bulk density (particle size 1.6-0.8 mm)	0.76 g/cm^3
Solids	41.2%
Moisture	58.8%
Organic matter	21.9%
Total Nitrogen (N)	0.85%
Organic Nitrogen	0.85%
Ammonium Nitrogen (NH_4 -N)	2.7 mg/kg or 0.0003%
Carbon (C)	12.05%
Carbon/Nitrogen (C/N) ratio	14.8
Phosphorus (as P_2O_5)	0.56%
Potassium (as K_2O)	1.39%
Calcium (Ca)	1.71%
Magnesium (Mg)	0.27%
Sulphur (S)	0.18%
Sodium (Na)	471
Aluminium (Al)	2008.5 mg/kg
Iron (Fe)	3592 mg/kg
Manganese (Mn)	200 mg/kg
Copper (Cu)	14.35 mg/kg
Zinc (Zn)	97.55 mg/kg
Nitrite - (N)	630.2 mg/kg

Agronomic data collection and analysis

Data on grain yield and other agronomic important parameters were taken using the standard evaluation system for rice as guideline (IRRI, 2002). Average data of the two years on grain yield for the treatments across all the locations were subjected to regression analysis using the generalized linear model in *Genstat* 9th edition (Lawes Agricultural Trust, 2007).

Economic analysis

In order to identify economically *superior* treatment(s), the study relied on partial budgeting, specifically the marginal rate of return (MRR). Analysis of the on-farm data was based on a hectare of land. A partial budget shows the effect of changes in treatments by comparing changes in net benefits to changes in total variable costs. Mathematically:

$$MRR_i = \frac{\psi_i - \psi_j}{\omega_i - \omega_j}$$

Where MRR_i is the marginal rate of return for the ith treatment, ψ_i is the net benefit of the ith treatment, ψ_j is the net benefit of the jth or preceding treatment, ω_i is the total variable cost for the ith treatment and ω_j is the total variable cost for the jth or preceding treatment.

A treatment is said to be economically *superior* if its marginal rate of return is greater than its acceptable minimum rate of return ($AMRR$). $AMRR$ is the minimum returns that farmers expect to earn from a treatment which is a sum of returns to management and cost of capital or interest. Considering an average interest rate of 30% in northern Ghana and assuming a 100% return to management, the $AMRR$ for this study is estimated to be 130%. A treatment is therefore economically *superior* if;

$$MRR \succ 130\%$$

RESULTS AND DISCUSSION

Table 5 depicts ANOVA results from the regression analysis for mean grain yield for certified and farmer saved seed during the two growing seasons. The analysis shows statistical significant differences (P <0.01) of treatment effect in terms of grain yield (kg/ha) for both certified and farmer saved seed sources (Table 5).

Figure 2 shows results of scatter plot and regression while Table 6 summaries descriptive statistics for mean grain yield (kg/ha) for the two cropping seasons for certified and farmer-saved seed. At the various levels of fertilizer management regimes, the performance of the seed from the certified source proved superior relative to the farmer-save seed (Figure 2; Table 6). The highest grain yield of 6833 kg/ha was recorded for T_4 - certified

Table 5. ANOVA results from the regression analysis for mean grain yield for certified and farmer saved seed during the two growing season.

Variables	Source of variation	Df	MS	F-ratio	P-value
Certified seed	Regression	1	1659748	96.2	0.002
	Residual	3	17254		
	Total	4	427877		
	Change	-1	1659748	96.2	0.002
Farmer saved seed	Regression	1	1060805	57.92	0.005
	Residual	3	18315		
	Total	4	278938		
	Change	-1	1060805	57.92	0.005

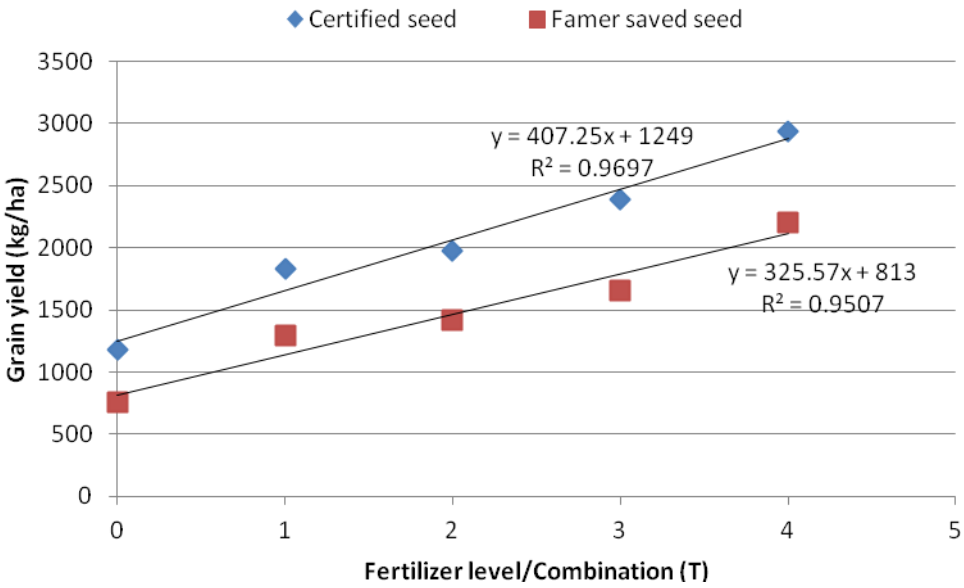

Figure 2. Results of scatter plot and regression for mean grain yield for the two cropping seasons for certified and farmer-saved seed. NB: Fertilizer levels and combination (T) are treatments: $T_1 – T_4$. (x-axis).

seed at full fertilizer recommendation rate for the 2012 growing season whiles the lowest grain yield of 30 kg/ha was recorded for T_0 –famer-saved seed at zero fertilizer management level in the 2012 cropping seasons (Table 6). However, comparing the mean grain yield for the two seed sources (certified and farmer saved seed) at all levels of fertilizer management, the 2011 cropping season gave comparatively higher grain yields (Table 6).

Whenever additional compost was introduced in the fertilizer management regime in the study, the effect proved significant, leading to a corresponding linear increment in grain yield for the various seed sources in both seasons (Table 6; Figure 2). The co-efficients of determination (r^2) from the regression analysis for certified seed and farmer-saved seed are 0.97 and 0.95 respectively (Figure 2). This indicates a very close fit regression plot with above 90% of variation explained by the regression line in both the certified and farmer saved seed analysis.

Certified seed and farmer saved-seed

Figure 3 shows a comparison of the average grain yield for the two year cropping seasons for certified seed and farmer-saved seed. It is evident from the figure that for 2011 and 2012, at all fertilizer management levels, rice yields from certified seed plots were much higher relative to yields from farmer-saved seed fields (Table 6; Figure 3). Duwari et al. (1998); IFPRI (2012); Ragasa et al. (2013) and other workers have demonstrated the superior grain yield advantage of certified seed in

Table 6. Statistical description of grain yield (kg/ha) for certified and farmer saved seed during the two growing seasons

Year	Treatment	Descriptive statistics	No fertilizer	Half- RF	Half RF+ Compost	Full RF	Full RF + Compost
2011	Farmer saved seed	Max	1695	2583	2252	2618	2502
		Min	276	948	1141	1437	2083
		Mean	**923**	**1598**	**1707**	**1852**	**2318**
	Certified seed	Max	2017	2877	2888	3408	3244
		Min	995	1235	1514	1922	2212
		Mean	**1516**	**2325**	**2465**	**2847**	**3152**
2012	Farmer saved seed	Max	2951	3562	3907	4407	6522
		Min	30	250	420	510	580
		Mean	**590**	**982**	**1125**	**1454**	**2090**
	Certified seed	Max	4313	5105	4275	4463	6833
		Min	40	370	410	531	520
		Mean	**850**	**1333**	**1488**	**1934**	**2725**
Average for two years	Farmer saved seed	Max	2323	3073	3080	3513	4512
		Min	153	599	781	974	1332
		Mean	**757**	**1290**	**1416**	**1653**	**2204**
	Certified seed	Max	3165	3991	3582	3936	5039
		Min	518	803	962	1227	1366
		Mean	**1183**	**1829**	**1977**	**2391**	**2939**

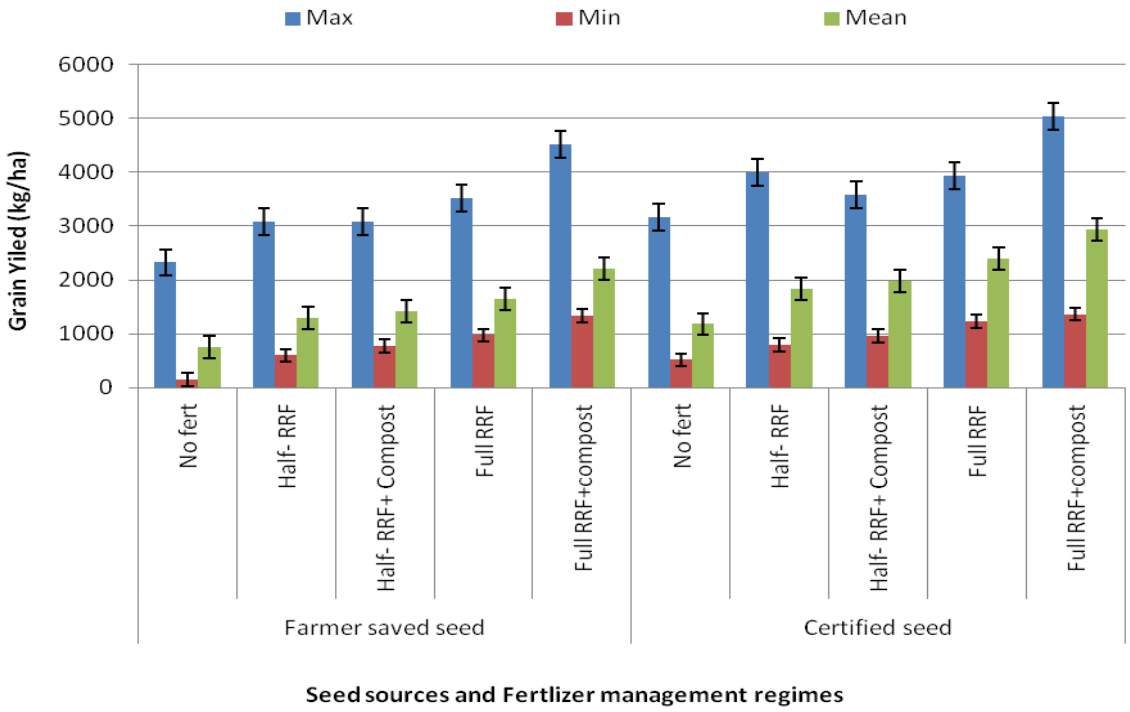

Figure 3. Comparison of the average grain yield for the two year cropping season for certified seed and farmer-saved seed.

Table 7. Average chemical and physical properties of cultivated soils in Northern Region of Ghana (After Dogbe et al., 2012).

Chemical properties					Physical properties		
N (%)	Pmg/kg	Kmg/kg	pH(H_2O)	CEC(Cmol/kg)	Sand (%)	Silt (%)	Clay (%)
0.07	4.2	55.6	5.3	5.05	62.5	27	10.5

contrast to farmers-saved under various conditions. The reasons for the enhanced performance of certified seed are that: 1) it comes with high guarantee of seed viability and purity, healthiness, ensuring optimum plant population and vigorous plant establishment; 2) certified seed by virtue of being (genotypically) true-to-type of improved varieties or cultivars, is better in terms of resources use efficiency (water, radiation, soil nutrients etc.) hence will respond better to application of soil amendments including chemical fertilizers and compost (IRRI, 1998; Boland et al., 2011; Guei et al., 2011; Thompson and Scoones, 2012).

The same cannot be said of farmer-saved seed which more often lacks genetic purity. This was evident in this study as at all the levels of soil amendment regimes, the performance of the certified seed proved superior. Also, farmers and AEAs alike observed during field days that the crops from farmer-saved seed did not look as vigorous and healthy as those from the certified seed and this could have contributed to depressed yields of the FSS compared to the CS plots. The report that farmer-saved seed significantly losses it vigour after a number of years is well established in De Datta (1981); Guei et al. (2011) and Etwire et al. (2013).

Rice farmers in Ghana are unwilling to purchase fresh seed every year and continue to recycle seeds. The phenomenon is very common across Sub-Saharan Africa particular for rice (Dogbe et al., 2012; Etwire et al., 2013). Given the fact that certified seed is so crucial for the success of the rice industry in any rice growing ecology, innovative ideas are required to ensure that good quality seed gets to the rice farmer. One such approach is the concept of Community-based Seed System (CBSS) where farmers are taught and encouraged to use part of their rice farms as 'seed plots' and to apply some basic seed production principles such as, improved land preparation practices to minimize mixtures, eliminating off-types by rogueing and storage in clean bags to ensure seed purity.

With the active involvement of seed inspectors from the SIU/PPRSD/MoFA good quality rice seed can be made available to many farmers at the community level. This is because the seed systems in most sub-Saharan countries are not very strong and vibrant (Etwire et al., 2013). In the interim, while every effort must be made to rapidly overcome challenges in the seed systems, the relatively quite new concept of CBSS in Ghana needs to be nurtured and developed.

Use of deco compost

The importance of organic matter to crop productivity via improvement in soil structure, improved water holding capacity, increase in the bio-availability of soil nutrients etc cannot be overstated. Indeed, Young (1976) observed that "*The agricultural significance of organic matter in tropical soils is greater than that of any other property with the exception of moisture".* On the other hand, the poor health condition of soils in the Guinea Savanna zones of Ghana and West Africa, particularly with respect to organic matter content has been well documented (Vine, 1966; Asiamah et al., 1996). Summarized soil analysis data across 16 districts in Northern region (CSIR- SARI, 2009) are presented in Table 7. The leader of the soil survey team Dr. W. Dogbe made the following insights:

"*because of the low organic matter, low CEC and low clay levels in the soil, the nutrient holding capacity of the soil is significantly reduced. It is imperative for farmers to appreciate that the continuous use of only inorganic fertilizers on their soils cannot sustain production of cereals. There is the need therefore to enhance soil health within the cropping system through organic matter build-up".*

Against this backdrop, the significantly enhanced grain yields obtained at all treatment levels which included compost relative to the preceding treatment without compost is quite well expected.

RESULTS AND DISCUSSION OF ECONOMIC IMPLICATIONS

Results of the partial budget for 2011 and 2012 as well as the average for both years are presented in Table 8a, b, c. In the ensuing analysis a *dominated* treatment was eliminated. A treatment is said to be *dominated* if its net benefit is lower than another. Analysis of the results showed that 0.5RR + 3 t/ha *Deco compost* was a *dominated* treatment hence it was not considered for further analysis. Returns from cultivating certified rice seed was found to be economically superior to farmer-saved seed at all levels of fertilizer management. For instance, whereas farmers who utilize certified rice seed and apply half the recommended rate of fertilizer will

Table 8a. Partial budgets for 2011.

2011/Treatment	Yield		Income		Variable cost		Net benefit		Change in net benefit		Change in variable cost		MRR	
	CS	FS	CS	FS	CS	FS	CS	FS	CS	FS	CS	FS	CS	FS
No Fert	1516	923	758	461.5	833.25	808.25	-75.25	-346.75						
0.5 RR	2325	1598	1162.5	799	928.25	903.25	234.25	-104.25	309.5	242.5	95	95	3.26	2.55
0.5RR + 3 t/ha Deco Compost	2465	1707	1232.5	853.5	1188.25	1163.25	44.25	-309.75						
RR	2847	1852	1423.5	926	1023.25	998.25	400.25	-72.25	166	32	95	95	1.75	0.34
RR + 3 t/ha *Deco* compost	3152	2318	1576	1159	1283.25	1258.25	292.75	-99.25	-107.5	-27	260	260	-0.41	-0.1

Table 8b. Partial budgets 2012.

2012/Treatment	Yield		Income		Variable cost		Net benefit		Change in net benefit		Change in variable cost		MRR	
	CS	FS	CS	FS	CS	FS	CS	FS	CS	FS	CS	FS	CS	FS
No Fert	850	590	637.5	442.5	684.21	634.8	-46.71	-192.3						
0.5 RR	1333	982	999.75	736	803.34	757.3	196.41	-20.8	243.13	171.5	119.13	122.5	2.04	1.4
0.5 RR + 3t/ha Deco Compost	1488	1125	1116	843.75	988.21	941.05	127.79	-97.3						
RR	1934	1454	1450.5	1090.5	932.82	884.41	517.68	206.09	321.27	226.89	129.48	127.11	2.48	1.79
RR + 3 t/ha Deco compost	2725	2090	2043.75	1567.5	1130.88	1076.32	912.88	491.18	395.19	285.09	198.05	191.91	1.99	1.49

Table 8c. Partial budgets – average for 2011 and 2012.

Average for 2011 and 2012/ Treatment	Yield		Income		Variable cost		Net benefit		Change in net benefit		Change in variable cost		MRR	
	CS	FS	CS	FS	CS	FS	CS	FS	CS	FS	CS	FS	CS	FS
No Fert.	1183	756.5	697.75	452	758.73	721.53	-60.98	-269.53						
0.5 RR	1829	1290	1081.13	767.75	865.79	830.28	215.33	-62.53	276.31	207	107.06	108.75	2.65	1.98
0.5 RR + 3 t/ha Deco Compost	1976.5	1416	1174.25	848.63	1088.23	1052.15	86.02	-203.53						
RR	2390.5	1653	1437	1008.2	978.04	941.33	458.96	66.92	243.63	129.45	112.24	111.05	2.11	1.06
RR + 3 t/ha Deco compost	2938.5	2204	1809.88	1363.25	1207.06	1167.29	602.81	195.96	143.85	129.05	229..03	225.96	0.79	0.69

recoup their investment and still gain an additional income of GH¢ 2.65 for every GH¢1.00 invested, their colleagues who utilize farmer-seed will get an additional income of only GH¢1.98 (Table 8c).

Farmers who utilize certified seeds make an incremental income of GH¢0.67 for every GH¢1.00 invested over and above the additional incomes of their counterparts who utilize farmer-saved seed.

A change in management from no fertilizer to half the recommended rate of fertilizer as well as a change from half the recommended fertilizer rate to the full recommended fertilizer rate were both found to be profitable for certified seed and farmer saved seed as shown in Table 8c. The

Table 9. Decision criterion for fertilizer management regimes.

Changing from	MRR (%) CS	MRR (%) FS	AMRR (%)	Decision
No Fert. to 0.5 RR	265	198	>130	Recommended
0.5 RR to RR	211	106	>130	Recommended
RR to RR + 3 t/ha *Deco* compost	79	69	<130	Not recommended

marginal rate of return was however found to be higher when a farmer cultivates certified seed, in fact, in the case of changing from half the recommended rate to the full recommended rate, the returns to certified seed is twice the returns to farmer-saved seed. Adding 3 tons of *Deco compost* per hectare to the full recommended rate of fertilizer was found not be worthwhile for both certified and farmer seed.

Decision criterion for fertilizer management regimes is summarised in Table 9. Clearly, applying half fertilizer rates or full rates in rice cultivation are both viable options compared to No fertilizer or Recommended rates plus 3 t/ha *Deco compost.* Compost application to the soil like mulching, does not perform instant miracles. It may not in the short term translate into enhanced rice yields or profit but as far as certified seed was concerned, there was a significant increase in yield of T_4 (RR + 3 t/ha compost) relative to all the other treatments. Dogbe et al. (2012) have opined that among the various ways (Conservation agriculture, Green manuring, Composting) available for improving soil organic matter, the use of compost in the short term seems to be most appropriate.

Conclusion

Returns from cultivating certified rice seed was found to be economically *superior* to farmer-saved seed at all levels of fertilizer management. Although there often are some concerns about the quality of seed purchased from the agro-input dealers particularly for rice in Ghana, nonetheless the results of this study show that it pays a lot to invest in certified seed. Irrespective of the fertilizer regime adopted by rice producers, they are better off cultivating certified seed as compared to farmer-saved seed. In contrast, farmers are worse off economically if they fail to apply fertilizer or apply a combination of either half or full recommended rates of fertilizer together 3 tons of *Deco compost* per hectare.

Conflict of Interest

The authors have not declared any conflict of interest.

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Comparative performance evaluation of different mechanical equipment for weed control in sugarcane crop in Northern-Western Tarai Region of Uttarakhand

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Manual weeding/ interculture in sugarcane is a common method adopted by the farmers, in *Tarai* region of Uttarakhand, for weed control. However, due to non- availability of labour especially during peak season, the weeding/interculture operation is jeopardized. Also the labour demand in sugarcane weeding is very high compared to other cereal crops making this operation expensive. This study includes comparative performance evaluation of three different types of equipment, namely rotary tiller (T_{1S} -single pass and T_{1D} - two pass of rotary tiller), cultivator (T_2) and rotavator (T_3) for weeding operation in sugarcane. It was also compared with manual method of weed control (T_4) including the cost economics. The result revealed that among the mechanical methods, the highest weeding efficiency (93.20%) was obtained in T_{1D} followed by T_{1S} (88.01%), T_3 (87.97%) and T_2 (83.22%). The plant damage was observed highest (3.67%) in T_2 compared to T_3 (2.63%), T_{1D} (1.83) and T_{1S} (1.11%). Cost of weeding operation was found minimum (INR 374.37 per ha) for treatment T_2 followed by T_3 (INR 507.27 per ha), T_1 (INR 1186.18 per ha) and T_4 (INR 13194.55 per ha). The reduction in cost of weeding over the conventional method was found highest (97.16%) in T_2 followed by T_3 (96.16%) and T_1 (91.01%). The use of rotary tiller can be recommended to the farmer for weed management in sugarcane even at later stage of the crop when plant is tall enough making use of other equipment unfeasible.

Key words: Rotary tiller, intra-row weeder, cultivator, rotavator, manual weeding, mechanical weeding, sugarcane, economics.

INTRODUCTION

Sugarcane, *Saccharum officinarum* L., is grown under diverse agro-climatic conditions around the world. It is a renewable and natural agricultural resource that provides sugar, besides biofuel, fibre and fertilizer. Out of the total white crystal sugar production, approximately 70% comes from sugarcane and 30% from sugar beet. According to FAO, 2011 report, worldwide sugarcane occupies an area of 25.44 million ha with a total production of 1794 million metric tons. Out of 121 sugarcane producing countries, Brazil, India, China, Thailand, Pakistan,

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Table 1. Man-days requirement per hectare in different operations.

Operations	Crops		
	Sugarcane	Rice	Wheat
Planting/sowing	35-40	35-40	10-12
Interculture/weeding	65-70	25-30	22-25
Irrigation	10-12	10-12	8-10
Fertilizer	5-6	5-7	4-5
Harvesting including detrashing	150-200	60-70	35-40
Plant protection	12-15	4-5	4-5
Transport and loading	20-25	6-7	15-20
Total	332	158	106

Mexico, Cuba, Columbia, Australia, USA, Philippines,

South Africa, Argentina, Myanmar and Bangladesh collectively represent 86% of the area and 87% of production. Brazil has the highest area (9.601 million ha), while Australia has the highest productivity (81.7 tons/ha).

India, the second largest sugarcane producing country after Brazil, cultivated sugarcane in 5.09 million ha area, which is much less compared to area under cereals, pulses and oilseeds, with a production of 357.67 Million Tones in the year 2011 to 2012. Sugarcane is grown mainly in the states of Maharashtra, Karnataka, Gujarat, Tamil Nadu, Uttar Pradesh, Punjab, Haryana and Bihar. Among these, Uttar Pradesh alone occupies about 43% of the total area under sugarcane cultivation dominating in production but in terms of productivity, Tamil Nadu leads with 104 tons/ha followed by Karnataka (90 tons/ha) and Maharashtra (83 tons/ha) which is higher than the national average productivity of 68.6 tons/ha. In the state of Uttarakhand it is grown mainly in its *Tarai* region (foot hills) where its production has gone down to 5.05 million tonnes in year 2010 compared to 7.34 million tonnes in year 2001. Highest sugarcane production of 7.68 million tonnes was registered during the year 2008.

It has been observed that the productivity of sugarcane, national average, is stagnating around 65-70 tons/ha for the last about 2 decades. Non implementation of package of practices and shortage of agricultural labour to undertake various cultural practices in time including poor weed management are some of the reasons responsible for low sugarcane yield. Therefore, there is a need to focus on other means including proper weed management for improving the production and productivity. It is reported that the yield loss caused by weeds may range from 15 to 75% depending upon its nature and intensity (Olaoye and Adekanye, 2006; Hasanuzzaman et al., 2009). The initial 90 to 120 days period of crop growth is considered as most critical period of weed competition and therefore weed-free field condition during these days must be ensured for higher yield.

Manual weeding, which is a common practice including in *Tarai* region of Uttarakhand, provides almost a clean weed free field but is highly labour demanding operation. The labour requirement for weeding/ interculture operation alone ranges between 400 to 600 man-h/ha (Tajuddin, 1996; Singh and Panghal, 2012) which is the highest when compared to wheat and rice (Table 1). Also it is a slow, arduous and time consuming process leading to higher cost of production. Scarcity of agricultural labourers during the peak season makes this task more difficult. Because of this reason as well as concern over environmental degradation and a growing demand for organically produced food, mechanical method of weed control is gaining popularity over manual and chemical methods. It is very effective, eliminates drudgery involved in manual weeding, kills the weeds and also keeps the soil surface loose ensuring better soil aeration and water intake capacity. Most of the tractors owning farmers, in Tarai region of Uttarakhand state, are using cultivator and rotavator, by manipulating the tynes/blades spacing, to cope up with the shortage of labour for weeding operation in sugarcane. Also there has been an increasing interest in the use of rotary tillers (mechanical intra-row weeders) due to their availability in the area during the recent years for weeding operation in sugarcane crop. However, systematic data is not available in respect of these equipment for weeding operation in sugarcane. The present study was, therefore, undertaken to compare the field performance of a rotary tiller, cultivator and rotavator for weeding operation in sugarcane crop along with traditional method including their economics.

MATERIALS AND METHODS

Description of equipment used

Three types of equipment namely self propelled rotary tiller (3.5 kW petrol engine operated), tractor drawn cultivator and rotavator were used for this study. The rotary tiller has a working width of 50 cm and only one row was covered during its operation. The second equipment was a tractor mounted type spring loaded 11 tine cultivator with overall width of 230 cm. Out of 11 tines, 5 tines were removed to adjust the cultivator within the row spacing of sugarcane. Three rows of sugarcane were covered at a time during

Table 2. Technical details of equipments used for the experiment.

S/ No	Parameter	Rotary tiller	Cultivator	Rotavator
1	Overall dimensions (length × width × height), mm	1280×620×1140	2600 x700 x103	2100x950x1150
2	Working width, mm	500	2300	2000
3	Weight, kg	42	210	446
4	Number of blades/ shovels in use	16	6	12
5	Number of rows covered in single pass	01	03	03
6	Type of soil working tool	C-type blade	Reversible shovel	L-type blade
7	Power source	Single cylinder, 4-stroke, air cooled, petrol engine with rated engine speed of 3600 rpm	Tractor operated	Tractor operated

single pass of this implement. The third equipment was a tractor mounted type rotavator having a work width of 200 cm. It had 8 flanges arranged on a rotor shaft with four L-shaped blades on each flange. Out of 8 flanges, 5 flanges were removed to adjust the rotavator to operate in between the rows of sugarcane. Three rows of sugarcane were covered at a time during single pass of this rotavator. Table 2 shows the technical details of the equipment used for the experiment. Manual method of weeding, a very common practice, was used as control for this experiment. The common tool used for manual weeding is *Kassi* which is a long handled spade with 20 cm wide blade. It is commonly used in upright posture by the labourers. Figure 1 shows the different equipment in weeding operation.

Experimental field

The performance evaluation of all the three mechanical equipment as well as manual weeding was carried out on University Farm (T-block, Eastern Zone Beni) of G. B. Pant University of Agriculture and Technology, Pantnagar, India during the month of April. The sugarcane crop was planted at a row space of 75 cm. The soil of experimental field is of alluvial origin and classified as silty-clay-loam having 15.1, 55.2 and 29.7% of sand, silt and clay respectively. The weeding operation was performed after 80 days of planting of sugarcane crop. The main field was divided into 20 sub plots each of size 20 × 6 m. Figure 2 shows the layout of the experimental field.

Experimental parameters

The experiment was laid out in Completely Randomized Design (CRD) with five treatments (T_{1S} -single pass of rotary tiller; T_{1D} - two passes of rotary tiller; T_2 -weeding by cultivator; T_3 -weeding by rotavator and T_4 - manual weeding) and four replications of each treatment.

Performance indicators

Weeding efficiency, plant damage and field capacity was taken as performance indicators. Besides these field efficiency, fuel consumption, size of soil aggregate, bulk density and cost of operation were also determined. Weeding efficiency and plant damage were determined as per the standard procedure (RNAM, 1983) using the following equations:

$$\text{Weeding efficiency, \%} = \frac{W_1 - W_2}{W_2} \times 100 \quad (1)$$

$$\text{Plant damage, \%} = \frac{Q_2}{Q_1} \times 100 \quad (2)$$

Where, W_1 and W_2 are the weight of weeds, in grams, before and after weeding operation respectively. Q_1 and Q_2 are the number of plants in 10 m row length before and after tilling operation respectively.

Effective field capacity (F_c), field efficiency (Fe) and work capacity (Wc) were calculated by the following equations (Hunt, 1995).

$$F_c = SWE/10 \quad (3)$$

$$E = (T_e/T_t) \times 100 \quad (4)$$

$$W_c = 1/F_c \quad (5)$$

Where, F_c is the effective field capacity (ha/h), *S* is the speed of operation (km/h), W is the effective width of coverage per run (m), E is the field efficiency (%) of equipment, T_e and T_t are the effective and total working time (h) and W_c is the working capacity (h/ha), respectively.

Cost analysis was performed by determining the fixed and variable cost for all the equipment. Straight line method was used for determining the depreciation cost. Salvage value has been assumed as 10% of the purchase price. Insurance, taxes and shelter has been assumed negligible for the equipment and the same has been taken as 3% for tractor. Rate of interest has been assumed as 10% per annum. Fuel charge has been determined based on actual fuel consumed and its prevailing rate in the market. Lubrication charge has been assumed as 30% of the fuel charge. Repair and maintenance has been assumed as 6% of purchase price per annum. Labour charge has been considered as per the prevailing rate per day (8 h work). Annual operation of the equipment has been considered as 720 h based on maximum 90 days (daily 8 h) of actual use in sugarcane weeding. The following equation was used to determine the cost of operation as suggested by Hunt (1995).

$$C = Fc + Rm + F + O + L \quad (6)$$

Where, C = Cost of operation, INR/h, Fc = Fixed cost, INR/h which includes depreciation, interest on capital, insurance-taxes and shelter cost, RM = Repair and maintenance costs, INR/h, F = Fuel cost, INR/h, O = Lubrication cost, INR/h, L = Labour cost, INR/h (assumed as INR 190/day).

Statistical method

The data collected during the experiment was analyzed for its

Figure 1. Equipments in weeding operation in sugarcane field.

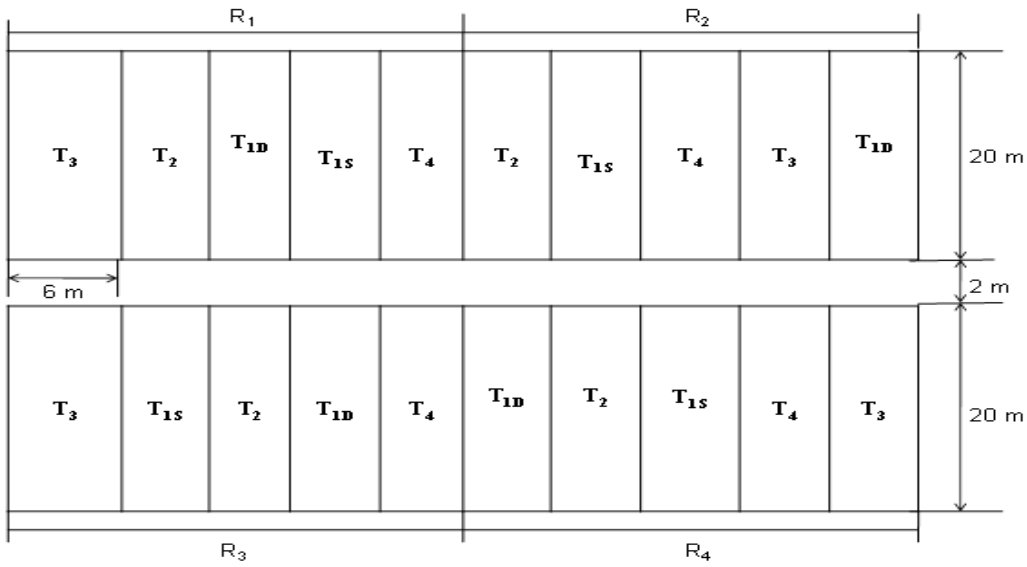

Figure 2: Layout of the experimental field. T1S – Weeding by single pass of rotary tiller, T1D - Weeding by double pass of rotary tiller, T2 – Weeding by cultivator, T3 – Weeding by rotavator T4 – Manual weeding, R1….4 – replications.

significance using Completely Randomized Design (CRD).

RESULTS AND DISCUSSION

Weeding efficiency

The weeding efficiency was determined by considering the weight of weeds before and after weeding operation. The weeding efficiency for single pass and double pass of rotary tiller was found highest followed by treatment T_3 and T_2 (Table 3). Weeding efficiency for double pass of rotary tiller was found higher by 5% than its single pass. The higher soil cutting ability of rotary tiller and rotavator contributed to higher weeding efficiency where as the

Table 3. Machine Parameters as observed in various treatments.

Treatments	Weeding efficiency, %	Plant damage, %	Actual field capacity, ha/h	Field efficiency, %
T_{1S}	88.01	1.11	0.063	96.93
T_{1D}	93.20	1.83	0.085	94.10
T_2	83.22	3.67	0.940	80.92
T_3	87.97	2.63	0.690	87.08
T_4	98.02	0.56	0.0018	-

Table 4. Analysis of variance for performance indicators and other parameters.

Source	Weeding efficiency	Plant damage	Bulk density	Clod mean weight diameter	Actual field capacity, ha/h	Fuel consumption
			F-values			
Replication	0.7044182	2.468080	14.54738	0.7598153	1.560357	0.3691275
Treatments	262.6447**	32.28242**	3.768921*	48.69866**	650.8756**	14463.56**

*Significant and ** Highly significant, respectively at $P \leq 0.05$.

reversible shovel does not provide better soil cutting leading to lower weeding efficiency. Weeding efficiency of manual weeding method (T_4) was observed highest among all the treatments which may be due to the fact that more precisely intra row area could be covered in manual method of weeding. Statistical analysis (Table 4) indicated that the weeding efficiency for different weeding methods varied significantly at 5% level of significance except treatments T_{1S} and T_3.

Plant damage

The plant damage for single pass and double pass of rotary tiller was found 1.11 and 1.83% (Table 3). The plant damage for treatment T_{1D} (double pass of rotary tiller) was found to increase by about 0.72% compared to treatment T_{1S} (single pass of rotary tiller). This may be due to the increase in depth of operation causing more uprooting of the plants. The plant damage, on an average, for other weeding methods viz manual weeding, rotavator and cultivator was found 0.56, 2.63 and 3.67% respectively. The lowest plant damage was observed in case of manual weeding that may be because of shallow depth of operation and care taken during the weeding operation. Among the mechanical methods of weeding, single pass of rotary tiller showed minimum plant damage. The plant damage was found statistically significant for all the weeding methods (Table 4).

Field capacity and field efficiency

Actual field capacity for different weeding methods was determined which showed higher field capacity for treatment T_2 followed by treatments T_3 and T_1 (Table 3). The higher field capacity for treatment T2 was due to more width of operation of cultivator. The field capacity of rotary tiller in double pass (T_{1D}) was found 35% higher when compared with its single pass which may be due to higher speed of operation. The field capacity for different weeding methods was found statistically significant (Table 4). The field efficiency (Table 3) for single pass of rotary tiller was found to vary in between 96.69 to 97.18% with an average of 96.93% which was found slightly less (94.1%) for double pass of the tiller. The average field efficiency of weeding by rotavator and cultivator was 87.08 and 80.92% respectively.

Fuel consumption

The fuel consumption for single pass of rotary tiller (T_{1S}) was found 0.58 l/h and little less, 0.53 l/h, for its double pass operation (T_{1D}). The fuel consumption for other treatment T_2 and T_3 (weeding by cultivator and rotavator) was found as 3.19 and 2.87 l/h respectively (Table 5). The statistical result indicated that the fuel consumption for different weeding methods varied significantly at 5% level of significance (Table 4).

Clod size and bulk density

The clod mean weight diameter for single and double pass of rotary tiller was found as 7.67 mm and 4.01 mm respectively (Table 5). The reduction in clod size, in case of double pass, was about 47.7% which may be due to

Table 5. Fuel consumption and changes in soil parameter values in different treatments.

Treatments	Fuel consumption, l/h	Fuel consumption, l/ha	Clod size, mm	Bulk density, g/cc	Moisture content, %
Initial			-	1.34	16.68
T_{1S}	0.58	9.21	7.67	1.27	15.16
T_{1D}	0.53	6.24	4.01	1.26	13.63
T_2	3.19	3.39	8.08	1.29	13.92
T_3	2.87	4.16	4.98	1.23	14.99
T_4	-	-	8.09	1.24	13.78

Table 6. Basic parameters for cost estimation of different equipment.

Power source/ Equipment	Initial cost, INR	Salvage value, INR	Useful life, year	Annual use, h	Effective field capacity, ha/h	Work capacity, h/ha
Tractor	575000	57500	10	1000	-	
Rotavator	73000	7300	8	720	0.69	1.45
Cultivator	27000	2700	10	720	0.94	1.06
Rotary tiller	46000	4600	10	720	0.074	13.51
Manual method	ND	ND	ND	ND	0.0018	555.56

ND- Not defined.

Similarly clod size in treatment T_2 and T_4 was also comparable. However, statistical analysis showed that clod size varied significantly, at 5%, for all the weeding methods (Table 4).

The average bulk density (Table 5) for treatment T_{1S} and T_{1D} was found as 1.27 and 1.26 g/cc. The reduction in bulk density values, in rotary tiller, was observed nearly same. The average bulk density for treatments T_2, T_3 and T_4 was found as 1.29, 1.23 and 1.24 g/cc respectively. The decrease in bulk density was observed higher (8.05%) in case of treatment T_3 and the same was observed less (3.88%) in case of weeding by cultivator (T_2) when compared with other treatments. The bulk density value for treatment T_2 was found significantly higher than other treatments. The change in bulk density values for all other treatments except T_2 was found insignificant (Table 4).

Moisture content

Soil moisture content was determined for each test plot and the results have been presented in Table 5. The average initial soil moisture content of the experimental plots was observed as 16.68%. The final soil moisture content was observed to reduce for all the treatments as compared to initial value, however, the moisture loss was observed more in treatments T_{1D} and T_4 followed by T_2, T_3 and T_{1S}. In treatments T_2 and T_4 the moisture loss was observed to be almost similar that may be due to bigger size of clods providing more surface area for moisture evaporation.

Cost analysis

Cost of weeding operation for different treatments was determined using the data presented in Table 6. The detailed analysis is presented in Table 7 which showed least expenditure (INR 374.37 per ha) for treatment T_2 followed by T_3 (INR 507.27 per ha), T_1 (INR 1186.18 per ha). Highest expenditure of INR 13194.55 per ha was found incase of T_4 that is, manual method of weeding. The minimum cost of weeding in T_2 is due to the higher field capacity of cultivator as compared to weeding by other methods. Manual weeding was found to be expensive which is due to very less field coverage per unit of time. Similarly the cost reduction over the conventional method was found highest (97.16%) in T_2 followed by T_3 (96.16%) and T_1 (91.01%).

Conclusion

Among the mechanical methods, treatment T_{1D} and T_{1S} (weeding by rotary tiller - one and two pass) was found more effective compared to treatments T_2 (weeding by cultivator) and T_3 (weeding by rotavator) based on higher weeding efficiency and minimum plant damage. Treatment T_{1S} and T_3 was found equally effective as far as weeding efficiency is concern. The cost of weeding, when compared with conventional method, reduced in

Table 7: Different components of cost estimation for various treatments

Power source/ Equipment	Depreciation, INR/h	Interest on capital @ 10% per anum, INR/h	Insurance, taxes & shelter @ 3% per anum, INR/h	Total fixed cost with tractor, INR/h	Fuel cost, INR/h	Lubrication cost @30% of fuel cost, INR/h	Total repair and maintenance cost with tractor @ 6%,, INR/h	Labour charge, INR/h	Total variable cost, INR/h	Total cost of operation		Cost reduction over manual method, %
										INR/h	INR/ha	
Tractor	51.75	31.63	17.25	-	-	-	-	-	-		-	-
Rotary tiller (T_1)	5.75	3.51	-	9.26	39.20	11.76	3.83	23.75	78.54	87.8	1186.18	91.01
Cultivator (T_2)	3.38	2.06	-	106.06	143.55	43.07	36.75	23.75	247.12	353.18	374.37	97.16
Rotavator (T_3)	11.41	5.58	-	117.61	129.15	38.75	40.58	23.75	232.23	349.84	507.27	96. 16
Manual weeding/ interculture (T_4)	-	-	-	-	-	-	-	23.75	-	-	13194.55	Base

Assumptions: The insurance, taxes and shelter cost have been considered negligible for equipment, Fuel rate: Diesel @INR 45/lit and Petrol @INR 70 /lit, labour wage - INR 190 per day of 8 h.

T2, T3 and T1 by 97.16, 96.16 and 91.01% respectively. The conventional method of weeding was found expensive compared to mechanical methods. The use of rotary tiller, among the mechanical methods, can be recommended to the farmers for efficient weed management even though the cost of operation is high. The advantage is that as it covers single row of the crop it can be used even at a later stage when plant grows tall enough. The use of cultivator and rotavator is not feasible at later stage (beyond 120 days of crop) as it covers more than one row and the plant will get damage when the height of the plant is more than the toolbar height.

Conflict of Interest

The authors have not declared any conflict of interest.

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