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Comparative Efficacies of Imarsil and Activated Charcoal in Reducing Aflatoxin M_1 in Cows' Milk

By Flora Oluwafemi, Aminat. Badmos, Adelodun Kolapo, Sarafadeen Kareem & Oladipo Ademuyiwa

The Polytechnic, Nigeria

Abstract- Many health risks associated with Aflatoxin M_1 (AFM_1) drive the demand for its control. Adsorption studies of AFM_1 were performed using activated charcoal (AC) and imarsil (0.5, 1 or 2%) at aflatoxin contamination rates of 9, 231 or 456 ng/L for 5 h at 4, 16, 28 and 32°C. The aflatoxin-adsorbing capabilities of the two adsorbents depend on the adsorbent, adsorbent concentration, contact time and treatment temperature. At 4, 16 and 28°C, Imarsil demonstrated significant reductions ($p<0.05$) at the highest contamination rate and adsorbent concentration; while at 32°C, significant reductions ($p<0.05$) were observed at all contamination rates and adsorbent concentrations. However, at all treatment temperatures AC exhibited a very poor adsorbent capacity, except at 32°C where a mild activity was only exhibited at the highest contamination rates and adsorbent concentration. Results from the present study indicate that imarsil demonstrates a potential for aflatoxin reduction in the developing tropical world.

Keywords: *cow's milk, aflatoxin M_1, HPLC, adsorbents, activated charcoal, imarsil.*

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Comparative Efficacies of Imarsil and Activated Charcoal in Reducing Aflatoxin M_1 in Cows' Milk

Flora Oluwafemi [α], Aminat. Badmos [σ], Adelodun Kolapo [ρ], Sarafadeen Kareem [ω] & Oladipo Ademuyiwa[¥]

Abstract- **Many health risks associated with Aflatoxin M_1 (AFM_1) drive the demand for its control. Adsorption studies of AFM_1 were performed using activated charcoal (AC) and imarsil (0.5, 1 or 2%) at aflatoxin contamination rates of 9, 231 or 456 ng/L for 5 h at 4, 16, 28 and 32ºC. The aflatoxin-adsorbing capabilities of the two adsorbents depend on the adsorbent, adsorbent concentration, contact time and treatment temperature. At 4, 16 and 28ºC, Imarsil demonstrated significant reductions ($p<0.05$) at the highest contamination rate and adsorbent concentration; while at 32ºC, significant reductions ($p<0.05$) were observed at all contamination rates and adsorbent concentrations. However, at all treatment temperatures AC exhibited a very poor adsorbent capacity, except at 32ºC where a mild activity was only exhibited at the highest contamination rates and adsorbent concentration. Results from the present study indicate that imarsil demonstrates a potential for aflatoxin reduction in the developing tropical world.**

Keywords: cow's milk, aflatoxin M_1, HPLC, adsorbents, activated charcoal, imarsil.

I. Introduction

Milk is an important component of human diets. Milk plays an important role in nutrition, growth, development and immunity (Keira and Mao, 2004). The composition of milk varies from species to species (Kataoka, 2002). Although cow's milk has continued to play an important role in human nutrition, growth and development, raw milk obtained from cows may contain a wide range of contaminants. Galvano *et al.* (2001) reported that milk, regarding mycotoxin, is mainly contaminated with aflatoxin M_1 (AFM_1), and consumption of such milk might be a principal route for entrance of AFM_1 into the human body.

Aflatoxins are fungal metabolites that contaminate the food supply in certain areas of the world (Gourama and Bullerman, 1995; Smela *et al.,* 2001). The contamination of food with aflatoxins is more serious in tropical countries, where relative humidity is high, and the temperatures are conducive to the growth and production of aflatoxins by moulds. These toxins are produced by *Aspergillus flavus*, *A. parasiticus* and *A. normius*, which grow on improperly stored foods. Aflatoxin M_1 is a toxic metabolite of aflatoxin B_1 (AFB_1): it is formed by enzymatic hydroxylation of the B_1 carried over from contaminated feed, primarily cereal grains. It is normally excreted in the urine and also in the milk of dairy cattle (Creepy, 2002; Gurbay *et al.,* 2006; Oliveira and Ferraz, 2007). In a related observation, AFM_1 is present in the milk of nursing women who eat food containing AFB_1 (Henry *et al.,* 2001; Oluwafemi, 2012). The occurrence of AFM_1 in milk is transitory in nature, usually reaching a peak within two days after the ingestion of the contaminated commodity and disappears within 4-5 days after the withdrawal from a contaminated food source (Henry *et al.,* 2001).

The major concerns with aflatoxins are their potent carcinogenic, mutagenic and teratogenic effects in humans (Battacone *et al.*, 2003, Kocabas and Sekerel, 2003). Although AFM_1 is less carcinogenic and mutagenic than AFB_1, it exhibits a high level of genotoxic activity and certainly represents a health risk due to its possible accumulation and linkage to DNA (Shundo and Sabino, 2006). Avoidance of contaminated food/feed is rarely possible, and feeds that contain relatively low concentrations of AFB_1 may still have deleterious effects on sensitive species such as poultry (Doer et al., 1983; Giambrone *et al.,* 2005; Rauber *et al.*, 2007). Unfortunately, residues of AFB_1 and AFM_1 in different animal products, such as meat, eggs and milk, intended for human consumption have been reported (Pattersen *et al.,* 2005; Mumksgaard *et al.,* 2007; Oluwafemi, 2012).

Recently, several approaches to preventing aflatoxins from entering the food chain such as decontamination or remediation of feed and feedstuffs have been proposed (Bailey *et al.,* 1998; Ledoux *et al.*, 1999). A variety of adsorbents such as bentonite (Rosa *et al.*, 2001), zeolite (Miazzo Roso *et al.*, 2000), hydrated sodium calcium aluminosilicate (HSCAS) (Kubena *et al.,* 1993; Scheideler, 1993; Ramos and Hernandez, 1997), clinoptilolite (Oguz *et al.*, 1994), dietary clay (Philips, 1999), *Saccharomyces cerevisiae* (Celik *et al.*, 2001) and activated charcoal (AC) (Jindal *et al.,* 1994) have been used successfully to detoxify AFB_1 in contaminated feeds. In a very recent study, Manafi and Khosravinia (2013) reported on the efficacy of an herbal mycotoxin binder (a unique combination of minerals,

Author α ω: Department of Microbiology, Federal University of Agriculture, Abeokuta. e-mail: foluwafemi2000@yahoo.co.uk
Author σ: Department of Microbiology, Federal University of Agriculture, Abeokuta. Mycotoxin Laboratory, National Agency for Food, Drug and Administration, Lagos.
Author ω: Department of Biology, The Polytechnic, Ibadan. Nigeria.
Author ¥: Department of Biochemistry, Federal University of Agriculture, Abeokuta.

antioxidants and enzymes) for the control of aflatoxin in broiler/breeder diets.

Little attention has been paid to studies on adsorption of AFM_1 from milk meant for human consumption. This study is reasonable given the understanding that the control of aflatoxin in feed will automatically translate into alleviation of AFM_1 in dairy cattle that are fed such remediated feed (Smith et al., 1994). However, it is pertinent to note that this wide assumption is hardly applicable to free-range dairy cattle because the diet of such cattle is difficult to monitor or control. Incidentally, a large portion of dairy cattle in many developing countries such as Nigeria are raised under a free-range system. As such, control measures for aflatoxin in products obtained from those animals should be designed, and this is the goal of the present study.

Imarsil™, is an inexpensive synthetic absorbent obtained from oxidized natural polymer of *Brachystegia nigerica* (Akpan and Kareem, 2002) *B. nigerica* is a legume used especially in the eastern states of Nigeria as condiment to thicken soup. Its thickening characteristics have been attributed to the presence of hydrocolloid property or gelling property (Odum, 2000). Imarsil as an oxidized polymer of *B. nigerica* is considered as an efficient absorbent because of its quick and simple recovery approach especially in the clarification of microbial enzymes from fermentation broth (Kareem and Akpan, 2003).

The objective of the present study is to compare the efficacy of easily and locally accessible adsorbents, such as imarsil and activated charcoal, in the reduction of AFM_1 contamination of milk.

II. Materials and Methods

a) Chemicals and standards

Imarsil™ was prepared as previously described by Akpan and Kareem (2002). Solvents such as acetonitrile, methylene chloride, and methanol were of HPLC grade. The standard AFM_1 was purchased from Chromogen (New Delhi, Delhi, India). Immunoaffinity column was Aflastar M1 R, (lot: AF 1011 1012), supplied by Roma Labs Diagnostic Technopark 13430, Tulln, Austria.

b) Adsorption Studies

The adsorption studies of aflatoxin were performed using a 4 x 4 x 2 x 3 x 3 factorial design involving four different contact times (2, 3, 4, or 5 h), four temperature levels (4, 16, 28, or 32°C), two adsorbents (activated charcoal or imarsil) at three different concentration (0.5, 1 or 2%) and three concentrations of aflatoxins (9, 231 or 456 ng/L AFM_1).

Recent report of survey of AFM_1 in cows' milk from free-grazing cows in Nigeria indicated that toxin levels in positive samples ranged from 9.0 to 456.0 ng/L (Oluwafemi *et al.*, and 2014). Therefore, milk samples (50mL) were spiked with AFM_1 at the three concentrations of 9, 231 and 456 ng/L AFM_1. These were passed through a separating funnel containing activated charcoal and imarsil at three different concentrations (0.5, 1 or 2 %). The experimental setups were in place for 5 hrs with samples taken at 2, 3, 4 and 5 hrs. The experiment was repeated at four different temperatures: 4, 16, 28 and 32°C. Quantification of AFM_1 in the remediated milk samples was performed by a modification of the method of Smith *et al* (1994) as recently described by Oluwafemi *et al.* (2014).

c) Nutrient analysis

The nutrient contents such as moisture, protein, fat, carbohydrates and saturated fatty acid were determined using the AOAC method (1993) before and after the administration of the adsorbents.

d) Statistical analysis

The comparisons between means were evaluated using Student's t-test and analysis of variance. A value of $p < 0.05$ was considered significant.

III. Result and Discussion

The efficacy of the different tested adsorbents in reducing the AFM_1 in the contaminated milk samples is shown in Figures1a -4 b. The aflatoxin-adsorbing capabilities of the two investigated adsorbents depend on the adsorbent, adsorbent concentration, contact time and treatment temperature. At the investigated temperatures of 4, 16 and 28°C, Imarsil demonstrated a significant reductions ($p<0.05$) of AFM_1 contents of contaminated milk at the highest contamination rate (0.456 µg/l) and adsorbant concentration(2.0%) (Figures 1a, 2a and 3a). However, at 32°C significant reductions ($p<0.05$) were observed at all contamination rates and adsorbant concentrations (Figure 4a). On the contrary, at all treatment temperatures AC exhibited a very poor adsorbant capacity, except at 32°C where a mild activity was exhibited only at the highest contamination rates and adsorbant concentration (Figures 1b, 2b, 3b and 4b).

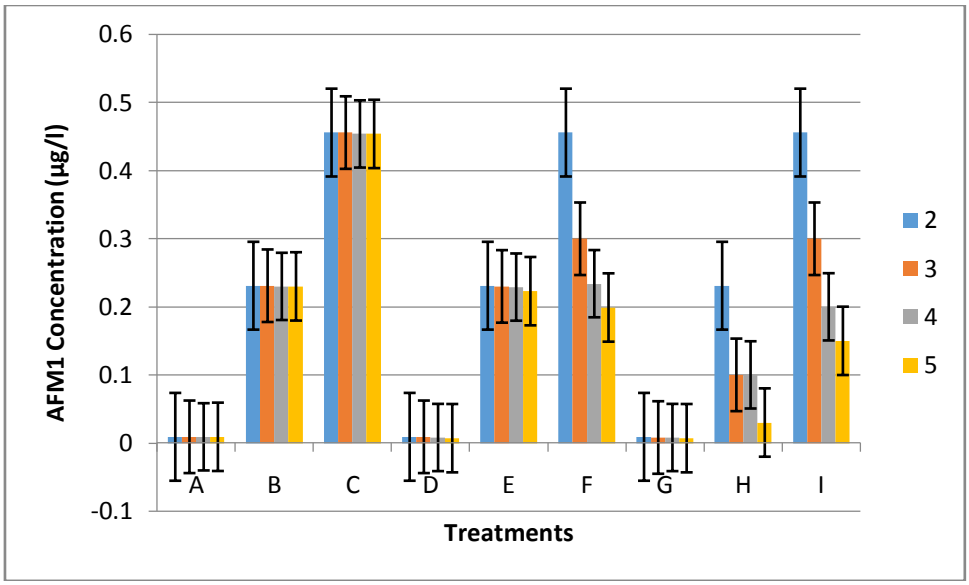

Figure 1a : Effect of Imarsil on AFM1 content of Contaminated milk treated for 5 hrs at 4C

KEY

A=0.009 µg/lAFM_1 +0.5 % Imarsil; B=0.231 µg/l AFM_1 +0.5 %Imarsil; C= 0.456 µg/l AFM_1 +0.5 %Imarsil
D=0.009 µg/l AFM_1 +1.0 % Imarsil; E=0.231 µg/l AFM_1 +1.0 % Imarsil; F=0.456 µg/l AFM_1 +1.0 % Imarsil;
G=0.009 µg/l AFM_1 +2.0 % Imarsil ; H=0.231 µg/l AFM_1 +2.0 %Imarsil; I=0.456 µg/l AFM_1 +2.0 % Imarsil

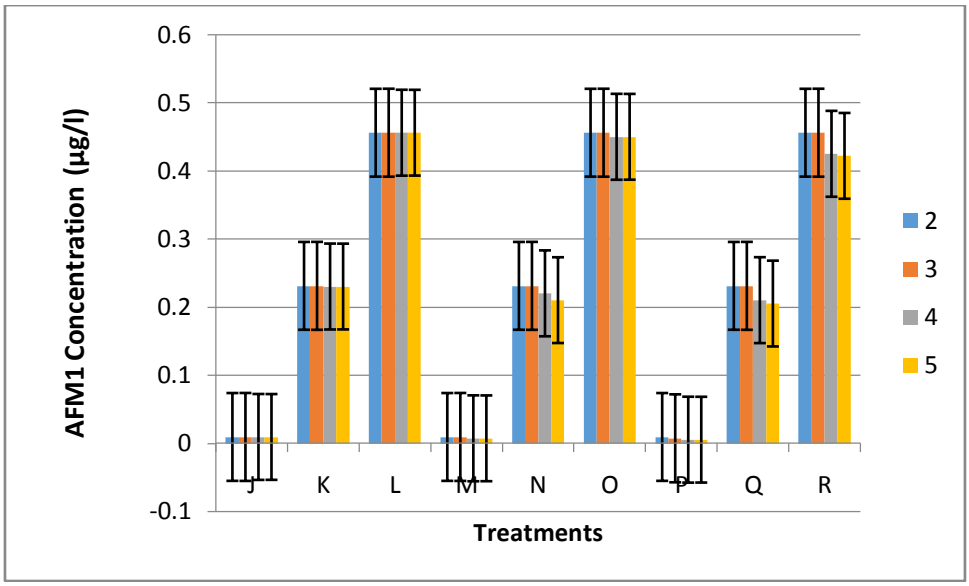

Figure 1b : Effect of Charcoal on AFM1 content of Contaminated milk treated for 5 hrs at 4C

KEY

J=0.009 µg/lAFM_1 +0.5 % Charcoal; K=0.231 µg/l AFM_1 +0.5 % Charcoal; L= 0.456 µg/l AFM_1 +0.5 % Charcoal
M=0.009 µg/l AFM_1 +1.0 % Charcoal; N=0.231 µg/l AFM_1 +1.0 % Charcoal; O=0.456 µg/l AFM_1 +1.0 % Charcoal;
P=0.009 µg/l AFM_1 +2.0 % Charcoal; Q=0.231 µg/l AFM_1 +2.0 % Charcoal; R=0.456 µg/l AFM_1 +2.0 % Charcoal

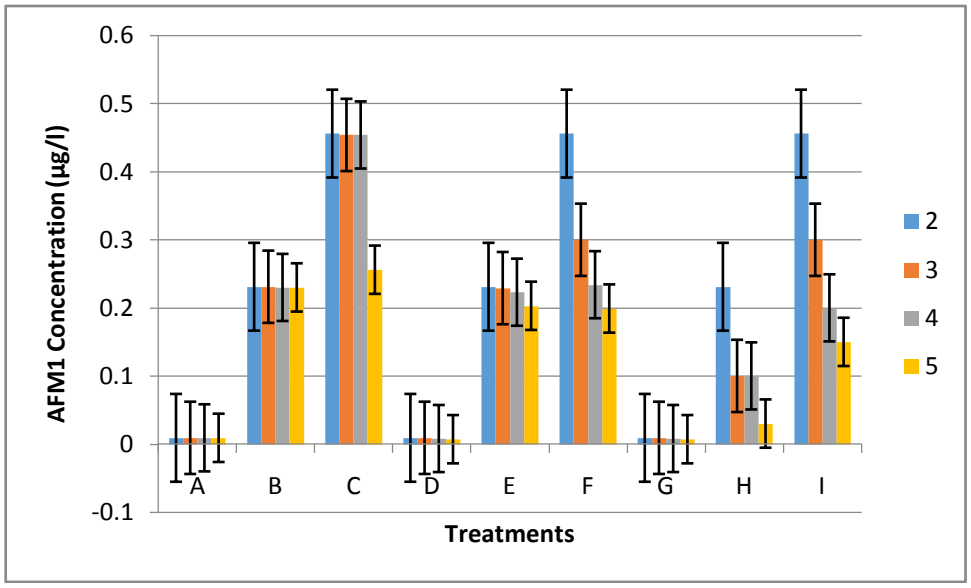

Figure 2a : Effect of Imarsil on AFM1 content of Contaminated milk treated for 5 hrs at 16C

KEY

A=0.009 µg/lAFM$_1$ +0.5 % Imarsil; B=0.231 µg/l AFM$_1$ +0.5 %Imarsil; C= 0.456 µg/l AFM$_1$ +0.5 %Imarsil
D=0.009 µg/l AFM$_1$ +1.0 % Imarsil; E=0.231 µg/l AFM$_1$ +1.0 % Imarsil; F=0.456 µg/l AFM$_1$ +1.0 % Imarsil;
G=0.009 µg/l AFM$_1$ +2.0 % Imarsil; H=0.231 µg/l AFM$_1$ +2.0 %Imarsil; I=0.456 µg/l AFM$_1$ +2.0 % Imarsil

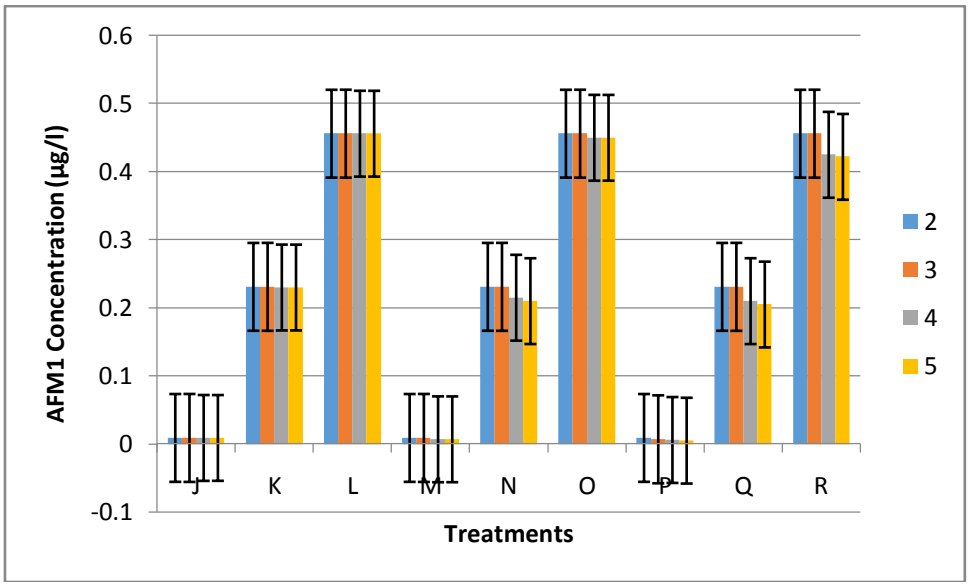

Figure 2b : Effect of Charcoal on AFM1 content of Contaminated milk treated for 5 hrs at 16C

KEY

J=0.009 µg/lAFM$_1$ +0.5 % Charcoal; K=0.231 µg/l AFM$_1$ +0.5 % Charcoal; L= 0.456 µg/l AFM$_1$ +0.5 % Charcoal
M=0.009 µg/l AFM$_1$ +1.0 % Charcoal; N=0.231 µg/l AFM$_1$ +1.0 % Charcoal; O=0.456 µg/l AFM$_1$ +1.0 % Charcoal;
P=0.009 µg/l AFM$_1$ +2.0 % Charcoal; Q=0.231 µg/l AFM$_1$ +2.0 % Charcoal; R=0.456 µg/l AFM$_1$ +2.0 % Charcoal

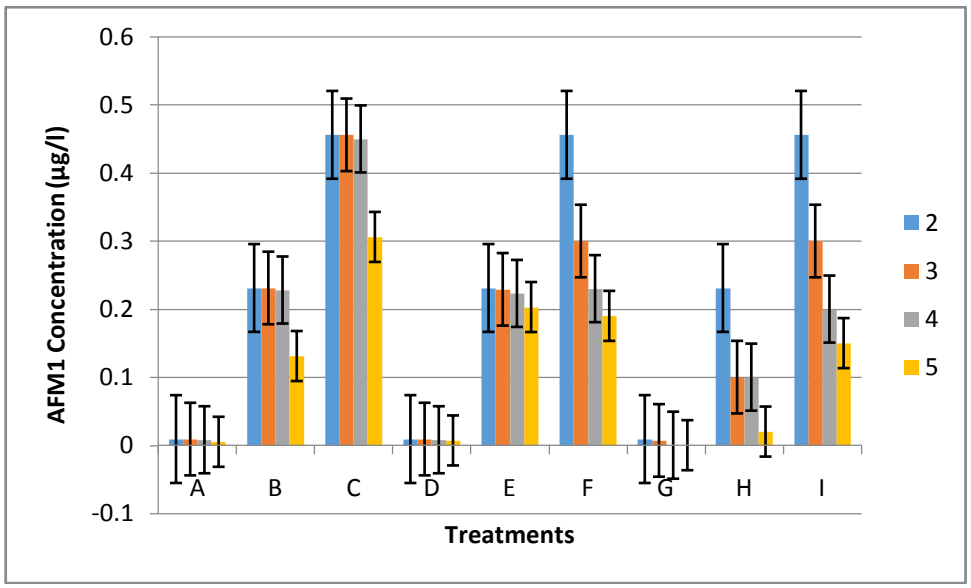

Figure 3a : Effect of Imarsil on AFM1 content of Contaminated milk treated for 5 hrs at 28C

KEY

A=0.009 µg/lAFM_1 +0.5 % Imarsil; B=0.231 µg/l AFM_1 +0.5 %Imarsil; C= 0.456 µg/l AFM_1 +0.5 %Imarsil
D=0.009 µg/l AFM_1 +1.0 % Imarsil; E=0.231 µg/l AFM_1 +1.0 % Imarsil; F=0.456 µg/l AFM_1 +1.0 % Imarsil;
G=0.009 µg/l AFM_1 +2.0 % Imarsil; H=0.231 µg/l AFM_1 +2.0 %Imarsil; I=0.456 µg/l AFM_1 +2.0 % Imarsil

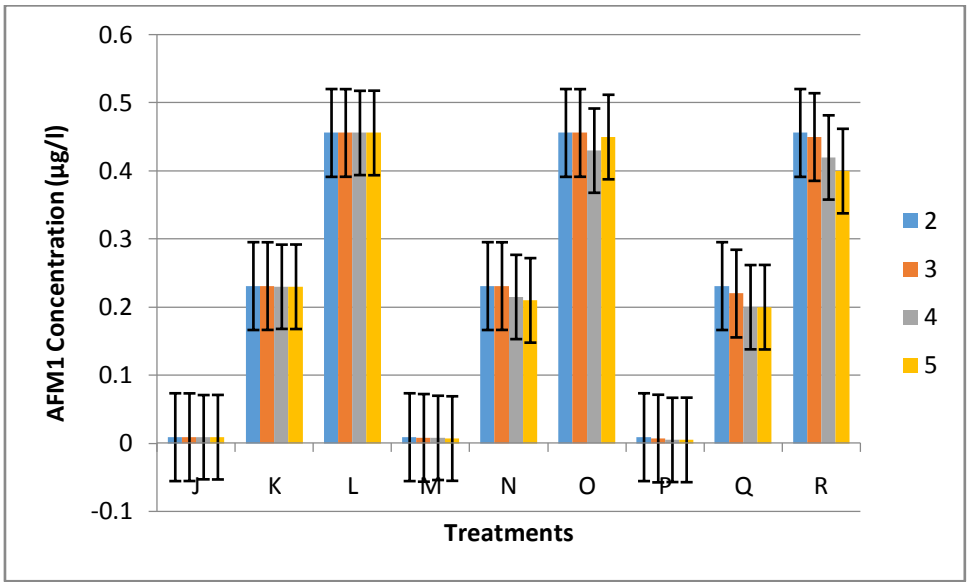

Figure 3b : Effect of Charcoal on AFM1 content of Contaminated milk treated for 5 hrs at 28C

KEY

J=0.009 µg/lAFM_1 +0.5 % Charcoal; K=0.231 µg/l AFM_1 +0.5 % Charcoal; L= 0.456 µg/l AFM_1 +0.5 % Charcoal
M=0.009 µg/l AFM_1 +1.0 % Charcoal; N=0.231 µg/l AFM_1 +1.0 % Charcoal; O=0.456 µg/l AFM_1 +1.0 % Charcoal;
P=0.009 µg/l AFM_1 +2.0 % Charcoal; Q=0.231 µg/l AFM_1 +2.0 % Charcoal; R=0.456 µg/l AFM_1 +2.0 % Charcoal

Imarsil exhibited 0.4- 87% reduction at 4 and 16°C, while 12-100 and 22-100% reduction in AFM_1 were observed at 28 and 32°C, respectively. The efficacy of AC was significantly ($p<0.05$) lower than the observed values for imarsil: this adsorbent only achieved reductions of 0.4-22% at 4 and 28°C and 0.4-44 and 0.4-77% at 16 and 32°C, respectively. AFM_1 removal is thus concentration-, time- and temperature-dependent.

Previous studies that evaluated the ability of AC to reduce AFB1 toxicity have produced conflicting results. Studies by Dalvi and Ademoyero (1984), Dalvi and McGowan (1984) and Hesham *et al.* (2004) indicated that AC was able to decrease aflatoxin toxicity, while Kubena *et al.* (1990), Edrington *et al.,* (1996) and Denli and Okan (2006) reported no significant differences in performance of birds following the addition of charcoal to rations that included aflatoxins. Denli and Okan (2006) had suggested that the conflicting results could have been due to the differences in chemical content, specifically the cationic compounds of the charcoal used. In the present study, it is evident that AC demonstrated a comparatively weak efficacy for AFM_1 removal. Hence, it is also probable that the previously observed conflicting results regarding the efficacy of AC to adsorb aflatoxin could be as a result of failure to standardize the experimental conditions such as concentrations of aflatoxin, adsorbent and detection methods.

The moisture, protein, fat, carbohydrates and saturated fatty acid contents of the investigated milk before the adsorption studies were 87.8, 3.2, 3.9, 4.8 and 1.4% respectively. After remediation with both Imarsil and AC, the nutrient contents of remediated milk were the same, suggesting that these adsorbents had no effect on the essential nutrients of milk.

Earlier reports have demonstrated that imarsil possesses a flocculating ability, and hence it has been used for enzyme purification (Kareem and Akpan, 2003; Kareem and Adebowale, 2007). Economic and logistical considerations sometimes restrict the use of conventional techniques to detoxify aflatoxin (Smith *et al.* 1994). The use of high affinity adsorbents such as imarsil to significantly diminish the AFM_1 content of contaminated milk as shown in the present study therefore represents a notable approach to the management of aflatoxicosis in the developing tropical world.

IV. Conclusions

The results from the present study indicate that imarsil demonstrates a potential to reduce aflatoxin M_1 and by extension ameliorate the risk of aflatoxicosis in the developing tropical world. However, further studies to evaluate imarsil's in vivo activity, its effect on biochemical indicators in both humans and animals and the organoleptic qualities of the remediated milk will be needed.

V. Acknowledgments

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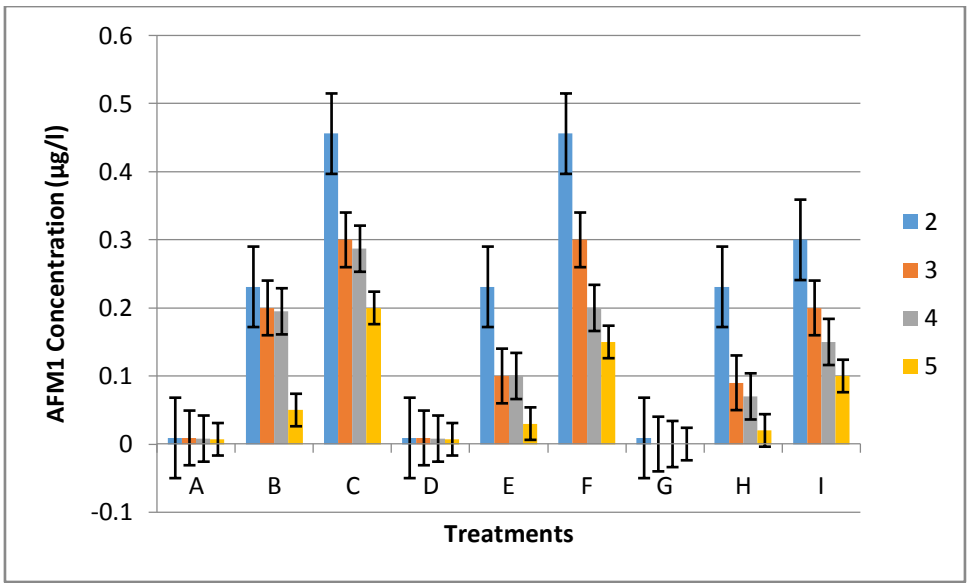

Figure 4a : Effect of Imarsil on AFM_1 content of Contaminated milk treated for 5 hrs at 32C

KEY

A=0.009 µg/lAFM_1 +0.5 % Imarsil; B=0.231 µg/l AFM_1 +0.5 %Imarsil; C= 0.456 µg/l AFM_1 +0.5 %Imarsil

D=0.009 µg/l AFM_1 +1.0 % Imarsil; E=0.231 µg/l AFM_1 +1.0 % Imarsil; F=0.456 µg/l AFM_1 +1.0 % Imarsil;

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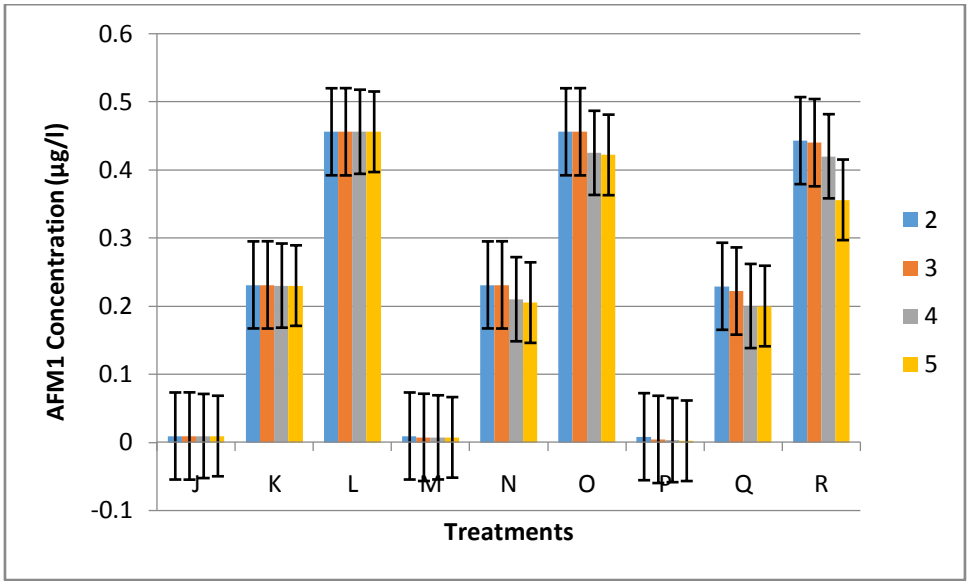

Figure 4b : Effect of Charcoal on AFM1 content of Contaminated milk treated for 5 hrs at 32C

KEY: As in Fig 3b

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Changes in Carbon Stocks and Sequestration Potential under Native Forest and Adjacent Land use Systems at Gera, South-Western Ethiopia

By Mohammed A. & Bekele L.
Mizan-Tepi University,Ethiopa

Abstract- The current study evaluated the differences in soil and biomass carbon (BC) stocks of native forest, annual crop field and coffee based agroforestry at Gera, South-west Ethiopia. A total of 24 sample plots were collected by Stratified random sampling method. After measuring the required parameters; BC (above and below ground), and SOC, texture, bulk density and pH were analyzed. The results showed that, BC significantly varied with land use types. On the other hand, the SOC under native forest and coffee based agroforestry has no significant difference, while it shows significant difference under the annual crop field. The present study indicated that, the total carbon stock in the native forest is greater than coffee based agroforestry which shows much greater difference than annual crop field. This may indicate that, conversion of annual crop field to coffee based agroforestry can increases carbon stock and sequestration potential in the study area.

Keywords: annual crop field; biomass carbon; coffee based agroforestry; land use change; native forest; soil organic carbon.

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I. Introduction

Forest conversion and land-use change in the tropics are major factors leading to losses in carbon stocks and increasing concentration of greenhouse gases in the atmosphere. The effect of land use changes on soil properties may vary for different soils, vegetation types and ecological zones (Lal 1999; Palm *et al.*, 2000; Bekele 2006; Fantaw *et al.,* 2008). Agricultural practices lead to a reduction in carbon stocks mainly due to removal of above ground biomass as harvest with subsequent burning and/or decomposition and losses of soil carbon by erosion (Lal 1999; Balesdent and Balbane 1996; Fahnestock *et al.,* 1996). Thus, there is a need for developing sustainable agricultural systems to maintain and improve biomass and soil organic compound (SOC) content while mitigating the land degradation and greenhouse gas emissions (Patrick et al., 2005; Takahashi et al., 2010). In tropics especially south and south-western highlands of Ethiopia, the deforestation of native forest has been significantly increased during the past 100 or more years (Pohjonen and Pukkala 1990; sited in Bekele 2006), which might be due to human habitation (Bekele 2006). Carbon in the soil is an important factor when studying global carbon budgets (Wilding et al., 2001; Berg and McClaugherty 2003; Lehtonen et al., 2004). Estimating the carbon stock in reliable values is necessary for understanding the global Carbon cycle, as well as for developing national inventories of greenhouse gases (Lehtonen et al., 2004); while estimating its spatial variability is important when developing carbon budgets, explaining climate change and characterizing ecosystems (Davis et al., 2004). Soil carbon can act as a source or as a sink for CO_2 in the atmosphere (Fisher and Binkley 2000; Högberg et al., 2002; Fröberg 2004) and can be considered as the biogeochemical linkage between the other major Carbon reservoirs: biosphere, atmosphere and hydrosphere (Wilding et al., 2001).

Forests sequester and store more carbon than any other terrestrial ecosystem and are an important natural brake on climate change (Lal 2005; IPCC 1997; Milne and Brown 1997). Tropical forests account for 40% of carbon stored globally in terrestrial biomass (Alves et al., 1997; Brown 1997) and contribute as much as 36% of the net exchange between atmosphere and terrestrial vegetation (Melillo et al., 1993). Thus, small changes in net carbon stock of tropical forests could result in significant storage or release of carbon to the atmosphere. The high productivity of these forests may make them particularly responsive to the growth enhancement from rising atmospheric CO_2 concentrations (Nabuurs et al., 1997; Prentice and Lloyd 1998; Tian et al., 1998). In order to reduce carbon in the atmosphere, it is important to investigate which type of land use is suitable for long-term carbon sequestration. When native forest is converted to agroforestry and/or, agricultural land, carbon stock may decline to some extent (Price and Willis 1993). Several researchers also revealed that the promising management practices to sequester biomass, and SOC and to reduce soil degradation are adopting agroforestry system (Cannell et al., 1995; Brown et al., 1996; Batjes and Sombroek 1997; Takahashi et al., 2010).

However, little is known of how coffee based agro-forestry practices in the vicinity of Gera Native forest, south western Ethiopia affect the storage of carbon in the biomass and soil matrix. Hence, the

Author α: Collage of Agriculture and Natural Resources, Mizan-Tepi University, Mizan-Aman, Ethiopia.
e-mail: mohammedabaoli@gmail.com
Author σ: Wondo Genet School of Natural Resources and Environmental Studies, Hawassa University; Hawassa, Ethiopia.

present investigation was undertaken estimate the difference in carbon stock (biomass and soil) between coffee based Agroforestry land use and other land uses namely annual crop field and native forestland use systems. Research hypothesis raised here is does coffee based agroforestry land use system has higher C Stocks and sequestration potential than annual crop field and native forestlands.

II. Materials and Methods

a) General description of the study area

Gera is found in Jimma Zone of Oromiya Region, South-west Ethiopia. It is located within the longitudinal range 35° 57′ and 37° 37′ East and latitudinal range of 7° 13′ and 8° 56′ North.

The altitude of the area falls in the range between 1500–2900masl. The mean annual maximum and minimum temperature is 24.2°C and 14.2°C, respectively and mean annual rainfall is between 1800 and 2000mm. The major soil types are: *Arcisol, Nitisol* and *Leptosol*. The remnant forest vegetation at Gera area can be categorized as tropical Afromontane moist forests which have been further classified into: natural forest (virgin and disturbed) and plantation forests. The vegetation cover of the area was estimated to be 56% of the total area.

b) Research Methods

i. *Site Selection*

For this study, coffee based agroforestry, annual crop field and native forest types of land uses were considered. For selection of study site, informal survey was conducted to collect important information about the ages under particular land uses. Farmers were asked the time when they started converting the forest into coffee based agroforestry and annual crop fields. The site was selected along two altitudes: 1890 and 2100 m.a.s.l., where the three treatments were assigned. The selected annual crop fields and coffee based agroforestry are about 20 years old since converted from native forests. The native forest was also sampled adjacent to the selected land uses as control.

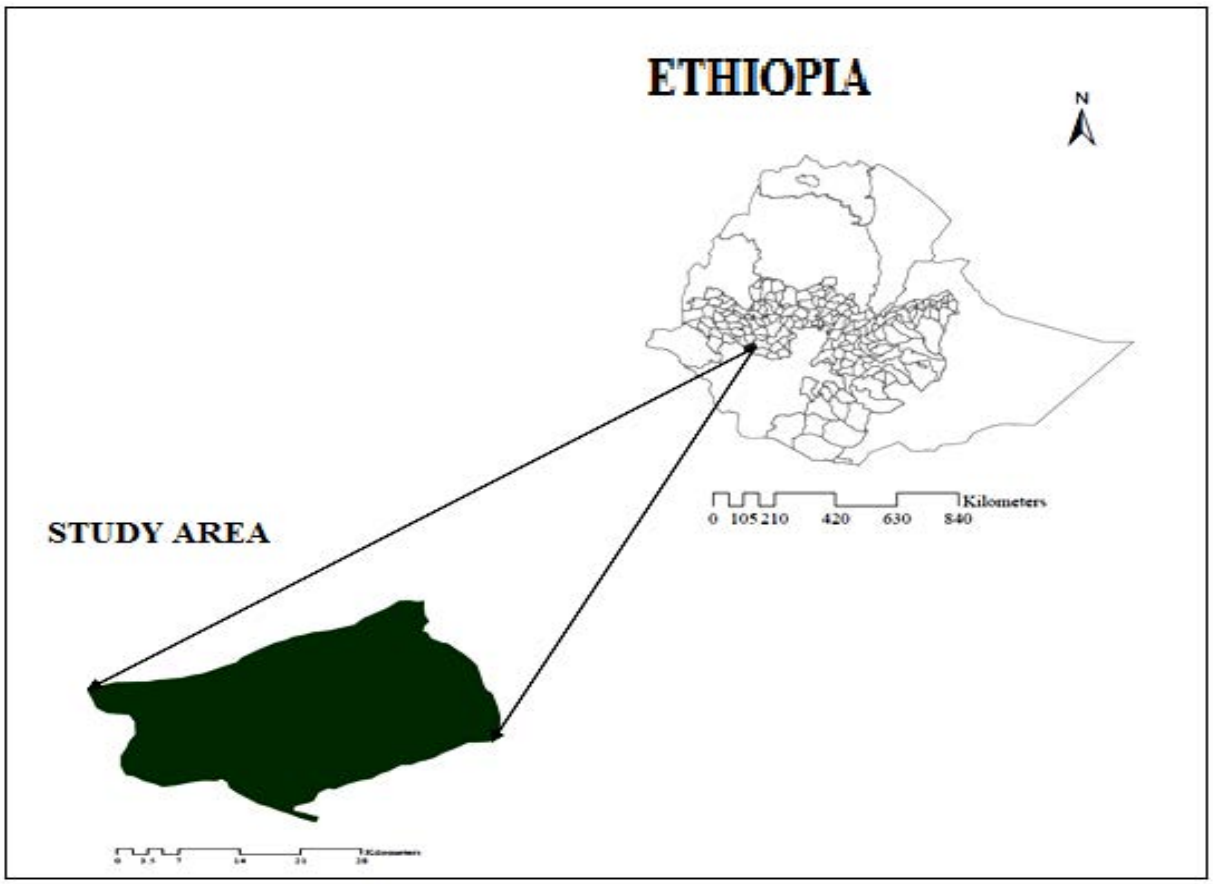

Figure 1 : Map of the study area

ii. *Plot Allocation and Measurement*

Stratified random sampling was used to collect data for the study. At each land uses, parameters were measured and their GPS coordinates were taken. Most coffee based agroforestry were rectangular in shape and large in size. A 100 m x 100 m sized plots were divided into 25 m x 25 m subplots. To choose the sample plot, each plot was numbered and lottery

method was used for randomization. The centre points of each division were located and four subplots with 15 m x 15 m were laid out perpendicular to the borders. There were four sample plots for each land uses at each elevation and a total of twenty four sample plots were collected from the site at both elevation.

iii. *Estimating above-ground biomass*

The diameter of all trees in each plot greater than or equal to 5cm at breast height were measured by using calliper and/or tape meter. The species type was recorded and their heights were measured using hypsometers. The diameter for coffee shrub was measured at 15 cm above ground (Sugara et al., 2006), while it was at the ground level for Enset (*Ensete ventricosum*) and Banana (*Musa paradisiaca*) (Blomme et al., 2008). Based on average diameter, total height, above ground biomass and carbon stock were calculated by following appropriate allometric equations. The above ground biomass of individual tree was estimated by following Brown et al., (1989). This equation was used to estimate above ground biomass in several studies (Roshetko et al., 2002; Lascol et al., 2006).

$$Y = e^{x}\{-2.134 + 2.530 * ln\,(D)\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where D = diameter (cm) and Y = total above ground biomass in (Mgha-1).

The equation used for estimating aboveground biomass of banana, based on pseudo-stem diameter was developed in (Hairiah et al., 2001). Thus, the biomass of banana and Enset in this study were estimated following this general biomass allometric equation and then converted to C content.

$$Y = (0.0303\ D)^{2.1345} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Where D is diameter (meters)

Above ground biomass of coffee plants was estimated by using the following regression formula as mentioned by Sugara et al., (2006) in shade tree coffee systems.

$$\log 10\,(B_T) = -1.113 + 1.578 * \log 10\,(d_{15}) + 0.581 * \log 10(h) \ldots\ldots\ldots 3$$

Where d15 = diameter at 15cm, h= height and BT= is total aboveground biomass.

The above-ground biomasses of all individual trees, Banana, Enset and coffee in a plot were summed to calculate total biomass for each plot, and the plot-level values of estimated above-ground biomass were then converted to biomass per hectare (Mg ha^{-1}) for each land use. Aboveground biomass was converted into C by multiplying by 0.5 (Mac Dicken 1997):

$$AGBC = Y \times 0.5 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

Where Y is total of above ground biomass in (Mg ha^{-1}), and AGBC is above ground biomass Carbon in (Mgha^{-1}).

According to Cairns et al., (1997), root biomass of tropical trees in moist area is about 22% of above ground biomass. Depending on this, root biomass of individual tree was estimated by taking 22% of the above ground biomass (root biomass = 0.22 x Y). Study by Blomme et al., (2008) indicates that, the below ground biomass for Enset and Banana (root + corm) is 35% and 31%, respectively, of their above ground biomass. In this study, below ground biomass was estimated by using these results and, then converted to biomass carbon according to equation 5. The shoot: root ratio (biomass) of coffee often assumed for tropical trees ranged between 4:1 and 2:1 (van Noordwijk et al., 2002). In this study, we have used the least ratio (4:1) for coffee below ground biomass in order to decrease overestimation and then converted it to biomass carbon following equation 5.

$$BGBC = RB \times 0.5 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 5$$

Where BGBC is below ground biomass carbon, RB is root biomass which is equal to 0.22Y.

$$TBC = AGBC + BGBC \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 6$$

Where TBC is total biomass carbon.

iv. *Soil Analysis*

Soil samples were analyzed for bulk density, soil organic carbon, pH and textural fractions by removing undisturbed soil using core sampler from each land use categories. From each plot, five points were established in each direction (north, east, south and west) one meter inside the plot boundary, and one at the centre. At these five points, soil samples were collected from 0 to 30 cm depth by using soil auger. Soil samples were air dried at room temperature and were then sieved by 2 mm size mesh. The samples were

mixed and homogenised and sub samples were taken for estimation of Carbon, pH and textural analysis. SOC was analysed according to Walkley and Black (1934), Bulk density was determined by drying the sample in an oven drier at 105°C for 24 hours. Total SOC stock per hectare ($Mgha^{-1}$) was calculated according to the following equation (Bekele, 2006):

$$SOC(Mgha^{-1}) = SOC(gKg^{-1}) \times d \times BD(g^{-3}) \times 10 \ldots\ldots\ldots\ldots(7)$$

Where d is sampled soil depth in meter (m), and BD is bulk density (gm^{-3}).

Soil pH was measured potentiometerically using a pH meter in 1:2.5 (v/v) soil water suspensions and textural fraction was determined by hydrometer method.

c) Data analysis

The results were subjected to analysis of variance (ANOVA). All statistical computations were made by using SAS (2004) version 9.0 computer software. The least significant difference (LSD) at $P \leq 0.05$ was used to determine statistically significant differences within each variable at each altitude. We conducted paired t-tests to test for significant differences in biomass and SOC stocks for each category of land uses at both elevations.

III. Results and Discussion

a) Biomass carbon

Biomass carbon was found significantly higher in the native forest (134.34 ± 26.94 $Mgha^{-1}$) than in the coffee based agroforestry (58.27 ± 12.30 $Mgha^{-1}$) and in the annual crop field land (0.04 ± 0.03 $Mgha^{-1}$). The biomass carbon of coffee based agroforestry was significantly higher than that of annual crop field, but there was no significant difference in biomass carbon between altitudes across land uses.

Table 1 : Mean values of biomass carbon (BC) across the land use types at each elevation

Organic Carbon	Elevation (m.a.s.l)	Land uses types		
		Annual crop fields	Coffee based agroforestry	Native Forest
BC ($Mgha^{-1}$)	1890	0.05±0.03a	54.46±7.45b	135.00±36.63c
	2100	0.02±0.02a	62.23±17.14b	133.79±16.61c

Note: Parameters with similar letter are not significant in each row at P <0.05

Biomass carbon in tree-based systems (native forest and coffee based agroforestry) showed higher biomass carbon than that of annual crop field with few trees. Tree-based land-use systems sequester CO_2 through the C stored in their biomass (Vitousek and Denslow 1986; Clark and Clark 2000; Roshetko et al., 2008). This may subject to increase or decrease in C flux to the atmosphere as a result of harvest, re-growth and conversion to other land uses. In agreement with the present study, the amount of biomass C in the agroforestry systems was several times higher than the C contents in the annual agricultural system (Bangroo et al., 2011). Dossa et al., (2008) also has shown the biomass C stock in the shaded coffee agroforestry system was higher than that in the open agricultural system. Our result in coffee based agroforestry is within the range of Carbon values (50 –75 $Mgha^{-1}$) reported for tropical agroforestry systems (Lefebvre et al., 1993). The lower biomass carbon in annual crop field was consistent with the small number of trees that are included in hedges on the borders of farmland, and other trees left on the farm landscape. After 20 years of land conversion, the amount of BC (above ground and belowground) lost due to conversion to coffee based agroforestry was about 56.65% of the original biomass C of native forest, and the loss due to conversion to annual crop field was about 99.97%. High BC has been lost when native forest was converted to annual crop field land because of huge biomass removal during the process of land use conversion.

The result of this study suggest that losses of biomass C can be minimized when native forest was converted to coffee based agroforestry system than annual crop field, and increased C storage (C sequestration) can be achieved by converting annual crop field land into coffee based agroforestry land use systems or even to forest lands. Coffee based agroforestry systems have the comparative advantage over annual crop field systems in biomass carbon sequestration.

b) Soil organic carbon

SOC at 0-30 cm soil depth within the three land use types is shown in Table 2. SOC ($Mgha^{-1}$) in native forest, coffee based agroforestry and annual crop field land were 95.52 ± 3.65, 92.48 ± 7.02 and 65.17 ± 2.58, respectively. Native forest and coffee based agroforestry contained significantly higher SOC as compared to the annual crop field land but there were no significant difference between coffee based agroforestry and native forest. Moreover, SOC was not significantly different between each land uses at the two elevations.

Table 2 : Mean values of soil organic carbon (SOC) across the land use types at each elevation

Organic Carbon	Elevation (m.a.s.l)	Land uses types		
		Annual crop fields	Coffee based agroforestry	Native Forest
SOC ($Mgha^{-1}$)	1890	63.34±2.95a	90.65±8.89b	92.57±2.41bc
	2100	66.99±2.21a	94.30±5.14b	98.95±4.84bc

Note: Parameters with similar letter are not significant in each row at P <0.05

The stock of SOC results from the balance between litter input and decomposition over time (Liski et al., 2002), while stored in the soil as humus and related stable organic compounds, the C is not circulating through the atmosphere (Berg and McClaugherty 2003). As a part of the dynamic carbon cycle of forests, soil C is linked to the development of vegetation and also affected by the past events (Liski et al., 2002; Nabuurs et al., 1997). In the present study, about 31.95% of SOC was lost following conversion of native forest to annual crop field land, which was cultivated for 20 years. Consistently, conversion of native forests to annual crop field land resulted in 20-50% loss of SOC (Sampson and Scholes 2000). According to Bekele (2006), deforestation of native forest followed by 75 years of continuous cultivation depleted the SOC by 43% at Belete native forest. The loss of SOC in his study is higher than the present study, but the age of cultivation and larger soil depth might have contributed for the higher amount of loss.

The SOC was not in a linear relationship with the number of years of cultivation as indicated in a chrono-sequence study (Lemenih et al., 2004). In his study, Lemenih et al., (2004) indicated that; much of the SOC was lost in the first few decades. The lower SOC contents in crop field land sites was due to various factors such as the breakdown of aggregates because of cultivation, increase in aeration of the soil and increase in the rate of mineralization by soil micro-organisms (Balesdent et al., 1990; Lal 1999; Lemenih et al., 2004). The SOC depends on the balance between the annual input of dead plant material and the annual loss of SOC by decomposition (Nabuurs et al., 1997, McDonagh et al., 2001; Lemenih et al., 2004; Bangroo et al., 2011).

The SOC loss from the conversion of native forest to coffee based agroforestry remained very low after 20 years of cultivation following deforestation. In most terrestrial ecosystems, the majority of net primary production is shed in the form of plant litter, which originates from above and below ground plant organs. Tree species differ in their allocation of C to above and below ground components and in their fine root mortality (Cairns et al., 1997). There is also a considerable site-specific variation in the quality and quantity of litter produced by different tree species (Aerts 1997). These factors may explain the similar amounts of SOC in coffee based agroforestry as in native forest while having lower biomass C than the native forest. In addition, it may suggest that the coffee based agroforestry system protects the loss of SOC and if the annual crop field reverts to coffee based agroforestry in the study area; it could lead to SOC sequestration.

c) Total carbon stock

Total C (BC + SOC) in native forest, coffee based agroforestry and annual crop field land were 230.09 ± 27.88, 150.73 ± 12.21 and 65.40 ± 2.64 Mgha-1respectively. There were significant differences in total C between the native forest, coffee based agroforestry and annual crop field land. Further, there was no significant difference in total C between the elevations for each land uses (Fig.2). Coffee based agroforestry land uses had the second largest total C stock and has significantly higher total C than the annual crop field. The difference between native forest and coffee based agroforestry was mainly from the difference in biomass C.

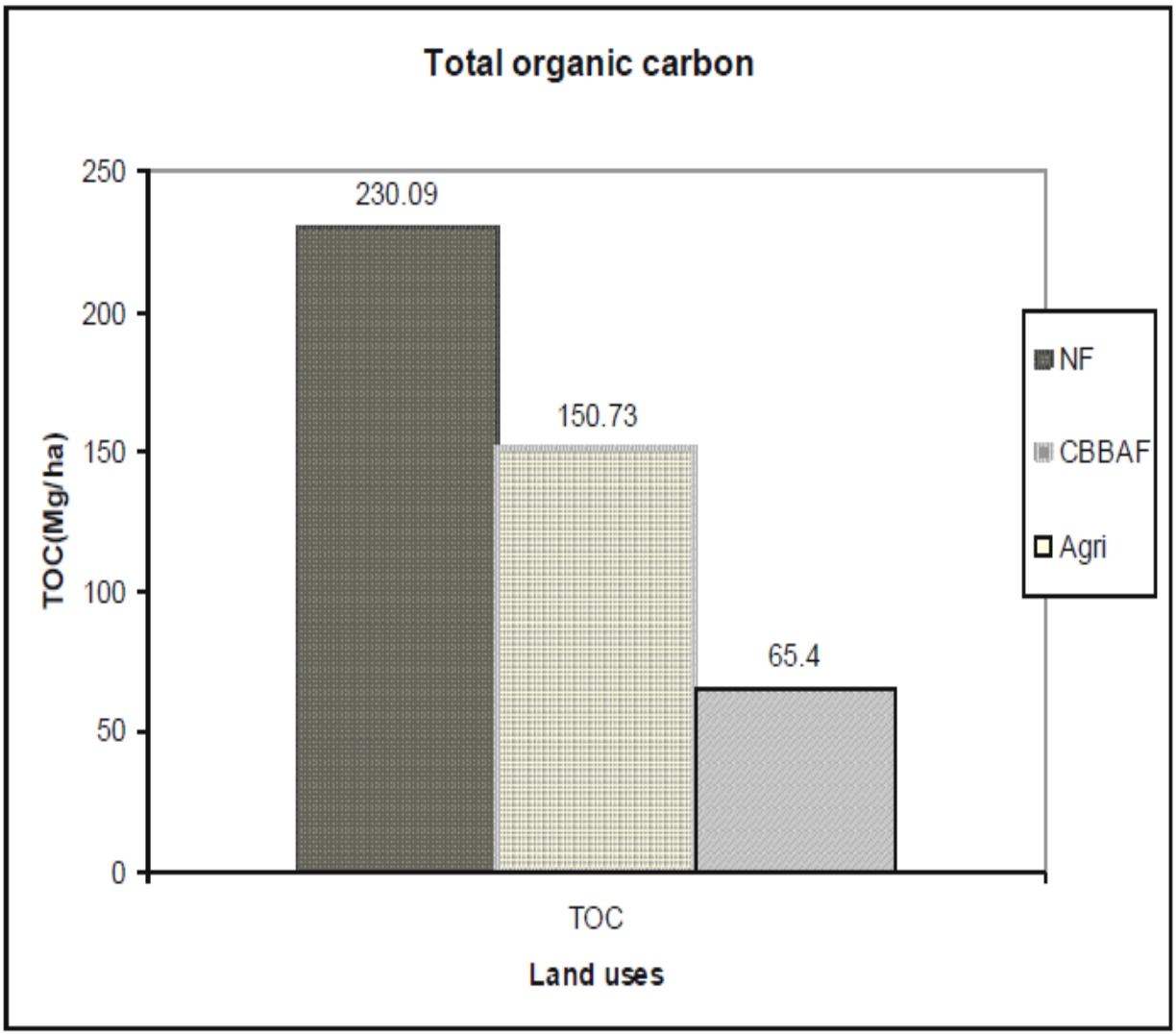

Figure 2 : TOC in each land uses

NF = native forest, CBAF= coffee-based agroforestry and, Agri= annual crop field

In agreement with this finding, Milne and Brown (1997) have shown that, forest land conversion to agroforestry would actually loose C, but to a much less extent than the conversion to annual crop field. The higher total C in coffee based agroforestry than annual crop field is because of the higher SOC as well as the higher biomass C in coffee based agroforestry as compared to that in annual crop field. The coffee based agroforestry has diverse plant communities and higher in number than that of annual crop field land. Any disturbance of vegetation or of the soil itself is likely to alter the balance between litter input to the soil and decomposition loss, and so cause a change in the reservoir of carbon (Milne and Brown 1997). Factors and processes that determine the rate of change in biomass and soil C stock influence the total C stocks.

This study did not consider C from coarse woody debris and associated necromass and this could lead to an underestimation of the total C stocks. According to Keller et al., (2000), coarse woody debris mass varied from 49.7 to 59.9 Mgha-1 in mature forest sites in Eastern Amazonia and it was about 16% of above ground biomass. Delaney and Powell (1998) also found that dead wood mass contributed 33.3 – 42.3 $Mgha^{-1}$ necromass in tropical moist and wet forest zones in Venezuela, which were 9.6 –12.4% of the total above ground biomass. However, the results of present findings indicated that, land use change mainly affects the organic carbon stock either in their biomass and soil matrices. It shows that native forest cleared for crop production and coffee based agroforestry in the study area lose high organic carbon in both biomass and soil within 20 years of subsequent cultivation after deforestation.

IV. Conclusion

The results of this finding indicated that, land use change mainly affects the organic carbon stock

either in their biomass and soil matrices. It shows that native forest cleared for crop production and coffee based agroforestry in the study area lose high organic carbon in both biomass and soil within 20 years of subsequent cultivation after deforestation. Native forest and coffee based agroforestry have much higher biomass carbon as compared to annual crop field, and native forest has higher biomass carbon than coffee based agroforestry. On the other hand, Native forest has similar amount of SOC as that of coffee based agroforestry, and it has higher SOC than annual crop field. Major declines were observed for annual crop field, which mainly because of biomass removal which is the principal source of plant organic carbon. Despite the clear decline in SOC within 20 years, is resulted from reduced above and belowground litter inputs and increased microbial decomposition, and it may from aeration while land cultivation is undertaken. The higher total C in native forest as compared to annual crop field and coffee based agroforestry shows that; the conversion of native forest to coffee based agroforestry reduces emission of C as compared to annual crop field. In addition, the conversion of annual crop field to coffee based agroforestry can sequester large amount of C in the soil as well as in the biomass.

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Gene Action and Combining Ability Analysis for Yield and Yield-Related Traits in Ridge Gourd [*Luffa Acutangula* (L.) Roxb.]

By Anand Narasannavar, V. D. Gasti, Sridhar, Sheela Malghan, & Kumara B. R
University of Horticultural Sciences, Bagalkot, India

Abstract- Combining ability estimates for growth, earliness, yield and quality parameters were studied following Line × Tester approach in ridge gourd. Fifty-one cross combinations were evaluated for 15 traits. The variance due to SCA was higher than the GCA for all the characters, indicating the importance of non-additive gene action. Comprehensive assessment of parents by considering gca effects of 15 characters studied has resulted into identification of lines, viz., KRG-2, KRG-3, KRG-4, KRG-11, KRG-16 and tester ASM as good combiners and PN as average combiners over all characters. Maximum and positively significant sca effects was observed in the cross KRG-9 x ASJ (0.24) followed by KRG-10 x PN (0.22), KRG-6 x ASM (0.16), KRG-5 x ASM (0.15) and KRG-3 x ASJ (0.14) for fruit yield per vine as well as fruit yield per plot and hectare. KRG-9 × ASJ showed significant sca effects for earliness characters like days to first female flower appearance (-6.19), node to first female flower appearance (-5.31) and days to first harvest (-8.61).

Keywords: *combining ability, luffa acutangula, ridge gourd.*

GJSFR-D Classification : *FOR Code: 309999p*

Strictly as per the compliance and regulations of :

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Abstract- Combining ability estimates for growth, earliness, yield and quality parameters were studied following Line × Tester approach in ridge gourd. Fifty-one cross combinations were evaluated for 15 traits. The variance due to SCA was higher than the GCA for all the characters, indicating the importance of non-additive gene action. Comprehensive assessment of parents by considering gca effects of 15 characters studied has resulted into identification of lines, viz., KRG-2, KRG-3, KRG-4, KRG-11, KRG-16 and tester ASM as good combiners and PN as average combiners over all characters. Maximum and positively significant sca effects was observed in the cross KRG-9 x ASJ (0.24) followed by KRG-10 x PN (0.22), KRG-6 x ASM (0.16), KRG-5 x ASM (0.15) and KRG-3 x ASJ (0.14) for fruit yield per vine as well as fruit yield per plot and hectare. KRG-9 × ASJ showed significant sca effects for earliness characters like days to first female flower appearance (-6.19), node to first female flower appearance (-5.31) and days to first harvest (-8.61).

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I. Introduction

Ridge gourd (*Luffa acutangula* (L.) Roxb.) is an important cucurbitaceous vegetable crop widely grown in tropical and subtropical parts of the world. It belongs to genus *Luffa* of Cucurbitaceae and has a chromosome number 2n=26. The genus derives its name from product 'loofah' which is used in bathing sponge, doormats, pillows and also cleaning utensils. In addition to culinary properties, it has therapeutic properties and is used for extraction of fibres [1]. Ridge gourd, being predominantly monoecious, is a cross pollinated crop and provides ample scope for utilization of the hybrid vigour. During recent years, the exploitation of hybrid vigour and selection of parents on the basis of combining ability have expanded a new alley in crop improvement. These studies are generally used to assess the performance of lines in hybridization programme and to understand the gene action involved in different characters.

Author α σ ρ: Department of Vegetable Science, KRCCH, Arabhavi. e-mail: anand0486@gmail.com
Author ω: Department of Vegetable Science, College of Horticulture Bagalkot.
Author ¥: Department of Plantation, Medicinal, Spices and Aromatic Crops, KRCCH, Arabhavi.

II. Materials and Methods

The experimental material consists of 20 parents *viz.* KRG-1, KRG-2, KRG-3, KRG-4, KRG-5, KRG-6, KRG-7, KRG-8, KRG-9, KRG-10, KRG-11, KRG-12, KRG-13, KRG-14, KRG-15, KRG-16, KRG-17 used as lines and three testers namely ASJ, ASM and PN and one standard check Naga. An experiment was carried out at Vegetable Science Department, K. R. C. College of Horticulture, Arabhavi, University of Horticultural Sciences, Bagalkot during summer and *kharif,* 2012. The experiment consists of 20 parents and 51 hybrids and were evaluated in randomized block design with two replications. A spacing of 1.2 m × 0.9 m was followed and other cultural practices were followed as per the package of practices of UAS, Dharwad [2]. Observations on five randomly selected plants were recorded for various growth, earliness, yield and quality parameters. The Line × Tester analysis is one of the most appropriate methods in preliminary screening of the breeding material for combining ability and data was analyzed as per the Kempthorne [3] to determine general and specific combining ability.

III. Results and Discussion

The analysis of variance (Table 1) for genotypes showed significant differences for all the characters. The estimates of mean sum of squares due to parents showed significant differences for all the characters except node to first female flower, per cent fruit set, number of fruits per vine and fruit yield per vine indicating the presence of sufficient variability among the parents studied. The magnitude if variance due to sca was greater than gca for all the characters and GCA: SCA less than unity also confirmed the preponderance of non-additive gene action for all the traits. These results are close conformity with Purohit[4] and Neeraja [5].

The estimates of *gca* effects of each parents are presented in Table 2. Among the 20 parents, seven parents showed significant and positive gca effects for fruit yield per vine, the highest was observed in the line KRG-3 (0.29) followed by KRG-11 (0.12), KRG-10 and KRG-2 (0.08). The parent KRG-3 was found to be good general combiner for all the character except number of

leaves 90 days after sowing (DAS), days to first female flower appearance, node to first female flower appearance, sex ratio, per cent fruit set, average fruit weight and flesh thickness.

The line KRG-5 (-2.99) and tester PN (-1.84) exhibited negative and significant *gca* effects for days to first female flower appearance. For days to first harvest significant and highest *gca* effects was observed in the parent KRG-5 (-5.62) followed by KRG-3 (-4.28) and PN (-1.69). These results are in agreement with Ahmed *et al.* [6]. The parents *viz.* KRG-5 and PN exhibited the significant and negative *gca* effects for both days to first female flower appearance and days to first harvest so, these parents may be used in breeding programme for earliness.

`The female parent KRG-11 exhibited the maximum and significant *gca* effects for number of leaves at 90 DAS (6.77) and number of branches at 90 DAS (2.09) whereas the male parent ASJ for number of leaves at 90 DAS (6.43) and number of branches at 90 DAS (0.37) exhibited positive and significant *gca* effects. None of the parents exhibited positive and significant *gca* effects for per cent fruit set. For average fruit weight the line KRG-12 (75.28) exhibited maximum and significant *gca* effects whereas, KRG-1 (5.40) exhibited significant and maximum *gca* effects for fruit length. The line KRG-3 was the good general combiner for number of fruits per vine (1.20), fruit diameter (0.59), fruit yield per vine (0.29), fruit yield per plot (4.34) and fruit yield per hectare (13.52) whereas, KRG-2 exhibited the maximum and significant *gca* effects for flesh thickness (0.50).

However parents KRG-2, KRG-3, KRG-4, KRG-11, KRG-16, ASM and PN exhibited significant *gca* effects for the most of the traits. Due to predominant role of non-additive gene action for yield and its components, it is difficult to bring together desirable genes by pedigree method. In this situation formation of central gene pool by bringing together the multiple parents having the good *gca* effects suggested by Jensen [7] might prove to be useful.

The crosses having desired significant specific combining effects are presented in Table 3. Out of 51 crosses, 16 crosses exhibited positively significant and 15 crosses exhibited negatively significant sca effects for fruit yield per vine. Maximum and positively significant sca effects was observed in the cross KRG-9 x ASJ (0.24) followed by KRG-10 x PN (0.22), KRG-6 x ASM (0.16) and KRG-3 x ASJ (0.14).

The highest positive *sca* effects was exhibited (Table 3) by the cross KRG-11 x PN (90.46) followed by KRG-6 x PN (70.63) for number of leaves per vine. For number of branches significant *sca* effects and maximum *sca* effects (1.86) were exhibited by KRG-3 x ASM followed by KRG-11 x PN (1.68) and KRG-15 x PN (1.45). For days to first female flower appearance, the cross KRG-15 x ASJ (-7.35) followed by KRG-15 x PN (-6.82) and KRG-11 x ASM (-6.32) exhibited maximum negative and significant *sca* effects. Among the crosses only cross KRG-9 x ASJ (-5.31) was exhibited negative and significant *sca* effects for node to first female flower appearance which is desirable.

The cross KRG-12 x PN (-8.67) followed by KRG-17 x PN (-7.83) exhibited significant in desirable direction (negative) for sex ratio. For per cent fruit set the cross KRG-16 x PN (12.38) exhibited positive and significant *sca* effects. None of the testers and crosses exhibited positive and significant *sca* effects for number of fruits per vine. For average fruit weight maximum and significant sca effects was observed in the cross KRG-4 x ASM (85.99) followed by KRG-13 x PN (81.08) and KRG-6 x ASJ (75.70) whereas, the highest positive and significant *sca* effects was exhibited by the cross KRG-1 x ASJ (8.20) followed by KRG-12 x PN (5.48) and KRG-14 x ASM (4.45) for fruit length. Maximum and significant sca effects was observed in the cross KRG-12 x PN (1.10) for fruit diameter. Two crosses KRG-6 x ASJ (0.85) followed by KRG-1 x ASM (0.69) exhibited the positive and significant *sca* effects for flesh thickness.

It was interested to record that out of 51 crosses, showing high specific combining ability effects, two crosses were the product of one parent having a high general combining ability, one cross was the product of one parent having a low general combining ability and remaining one cross involved the both parents having high general combining ability. Similar results were also reported by Neeraja [5] in ridge gourd. The crosses involving parents with good general combining ability effects can be exploited effectively by conventional breeding procedure like pedigree method. However the crosses one good combiner and other average or poor combiner could produce desirable transgressive segregators if additive genetic system was operative in good combining parents and epistatic effects also act in the same direction.

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Table 1 : Analysis of variance (mean sum of squares) of Line × Tester analysis for various characters in ridge gourd

Sl. No.	Character	Replications	Genotypes	Parents	Parents vs Crosses	Crosses	Lines	Testers	Line × Tester	Error
	Degree of freedom	1	70	19	1	50	16	2	32	70
1	Number of leaves on 90 DAS	2992.11	2713.58**	2253.55**	2652.41**	2889.63**	4336.66NS	1707.65NS	2239.98**	159.91
2	Number of branches at 90 DAS	18.316	3.23**	3.25**	2.97**	3.23**	4.46NS	4.4.7NS	2.53**	0.163
3	Days to first female flowering	43.94	47.98**	54.95**	6.92NS	46.15**	55.74NS	89.01NS	38.68**	11.57
4	Node to first female flower	3.71	15.02*	12.73NS	2.08NS	16.15*	11.69NS	37.93NS	17.02*	9.40
5	Days to first harvest	156.34	39.32**	46.36**	0.88NS	35.99**	38.41NS	129.45*	28.93**	14.29
6	Sex ratio (%)	21.93	60.05**	68.32**	17.33NS	57.77**	42.18NS	259.45*	52.95*	30.66
7	Per cent fruit set	474.76	99.19*	93.23NS	62.95NS	102.19*	73.07NS	45.91NS	120.26*	62.94
8	Number of fruits per vine	12.30	1.23**	0.76NS	22.22**	0.98*	1.35*	3.54**	0.65NS	0.64
9	Average fruit weight (g)	108.86	4412.09**	3415.40**	35021.75**	29533.38**	4480.72NS	1076.19NS	4462.62**	285.14
10	Fruit length (cm)	5.70	40.10**	41.02**	358.34**	33.39**	46.25*	104.96*	22.49**	7.85
11	Fruit diameter (cm)	0.008	0.81**	0.98**	0.84NS	0.74**	0.76NS	1.87NS	0.67*	0.39
12	Fruit yield per vine (g)	0.003	0.054**	0.069NS	0.108**	0.108**	0.073*	0.037NS	0.035**	0.002
13	Fruit yield per plot (kg)	3.48	1.78**	1.44**	16.58**	1.61**	1.95**	0.43NS	1.51**	0.22
14	Fruit yield per hectare (q)	297.56	152.38**	123.37**	1417.86**	138.10**	167.06NS	37.59NS	129.90**	18.74
15	Flesh thickness (cm)	0.07	0.48**	0.53**	0.42NS	0.46**	0.56NS	1.13NS	0.37*	0.22

Table 2 : General combining ability effects of parents for growth, earliness, yield and quality parameters in ridge

Sl. No.	Parent	Number of leaves at 90 DAS	Number of branches at 90 DAS	Days to first female flowering	Node to first female flower	Days to first harvest	Sex ratio	Per cent fruit set	Number of fruit per vine	Average fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit yield per vine (kg)	Fruit yield per plot (kg)	Fruit yield per hectare (q)	Flesh thickness (cm)
Lines																
1	KRG-1	-28.73**	-0.78**	-2.32	-1.41	-0.78	-0.87	2.92	-0.03	-10.18	5.40**	0.04	0.07**	-0.01	-5.21**	-0.19
2	KRG-2	-7.60	0.55**	-1.82	-2.11	-0.28	-0.91	-1.31	0.14	-35.10**	2.76*	0.56*	0.08**	-0.34	4.71**	0.50*
3	KRG-3	2.37	1.29**	-2.49	-1.37	-4.28**	-3.33	4.37	1.20**	-12.76	2.56*	0.59*	0.29**	4.34**	13.52**	0.3
4	KRG-4	-5.90	-0.15	-2.46	-0.97	-0.78	0.33	-1.39	0.17	22.50**	1.80	0.33	0.01	-0.84**	-0.64	0.01
5	KRG-5	-17.70**	-0.71**	-2.99*	-0.67	-5.62**	-3.38	-0.31	0.34	-14.67*	-3.50**	-0.12	0.04	-5.68**	-2.95	-0.13
6	KRG-6	0.77	-0.85**	2.68	-0.01	0.55	2.29	1.33	-0.46	28.61**	-4.62**	-0.57*	-0.07**	0.49*	-3.88*	0.21
7	KRG-7	11.10*	-0.48*	0.34	1.13	0.05	0.60	3.49	-0.36	-39.86**	-4.20**	0.31	-0.02	-0.01	-4.21*	0.31
8	KRG-8	5.24	-0.28	-2.16	0.43	-1.28	0.48	-3.47	0.1	-11.31	-1.47	0.05	0.07**	-1.18**	-0.38	0.21
9	KRG-9	-34.06**	-1.11**	-0.99	2.79*	-0.55	2.25	1.48	-0.33	5.48	-1.70	-0.15	-0.08**	0.49*	-5.51**	0.23
10	KRG-10	-11.03*	0.09	-2.82	-1.94	-0.95	4.18	2.48	0.14	4.88	-1.00	0.00	0.08**	-1.01**	7.04**	-0.06
11	KRG-11	66.64**	2.09**	6.18**	2.13	2.55	1.33	4.57	0.70*	-12.62	0.26	0.26	0.12**	2.49**	6.11**	-0.04
12	KRG-12	24.64**	0.99**	0.18	1.03	-1.12	0.96	-8.15*	-0.3	75.28**	0.46	0.27	-0.08**	-1.14**	-4.35*	0.34
13	KRG-13	-31.90**	-0.15	-2.49	-0.07	4.72**	-6.57**	-5.32	-0.66	17.18*	-1.70	-0.64*	-0.14**	4.16**	1.79	-0.61
14	KRG-14	-23.06**	-0.35*	4.51**	0.73	3.88*	-1.59	1.94	-0.43	-22.24**	0.20	-0.33	-0.10**	3.82**	-5.45**	-0.49*
15	KRG-15	4.64	1.02**	5.68**	-0.87	0.55	3.2	-1.42	-0.03	3.15	-0.60	-0.16	-0.07**	0.49*	-1.28	-0.15
16	KRG-16	-2.96	-0.11	0.84	-0.07	1.38	1.11	1.27	-0.46	16.84*	3.50**	-0.26	-0.12**	1.32**	-0.06	-0.24
17	KRG-17	47.67**	0.02	0.18	1.26	0.88	-0.09	-2.49	0.27	-15.20*	1.96	-0.18	-0.09**	0.82**	0.74	-0.20
	S.Em±	5.16	0.16	1.39	1.25	1.54	2.26	3.24	0.33	6.84	1.14	0.26	0.02	0.19	1.77	0.19
	CD at 5%	10.29	0.32	2.77	2.49	3.07	4.51	6.46	0.66	13.64	2.27	0.52	0.04	0.38	3.53	0.38
	CD at 1%	13.66	0.42	3.68	NS	4.08	5.98	NS	0.87	18.11	3.02	NS	0.05	0.5	4.69	0.5
Testers																
1	ASJ	6.43**	0.37**	1.19*	1.07*	2.14**	2.31*	0.94	-0.37*	4.6	1.93**	-0.08	-0.04**	-0.05	-0.43	0.02
2	ASM	1.17	-0.03	0.66	-0.03	-0.45	0.75	-1.3	0.15	1.68	-0.42	-0.19	0.01	-0.08	-0.77	-0.19*
3	PN	-7.60**	-0.35**	-1.84**	-1.04	-1.69*	-3.06**	0.36	0.22	-6.27*	-1.51**	0.26*	0.03*	0.13	1.2	0.17*
	S.Em±	2.17	0.07	0.58	0.53	0.65	0.95	1.36	0.14	2.9	0.48	0.11	0.01	0.08	0.74	0.08
	CD at 5%	4.33	0.14	1.16	1.06	1.30	1.89	NS	0.28	5.78	0.96	0.22	0.02	NS	NS	0.16
	CD at 1%	5.75	0.19	1.54	NS	1.72	2.52	NS	NS	NS	1.27	NS	0.03	NS	NS	NS

Table 3 : Specific combining ability effects of hybrids for growth, earliness yield and quality parameters

Sl. No.	Cross	Number of leaves 90 DAS	Number of branches 90 DAS	Days to first female flowering	Node to first female flower	Days to first harvest	Sex ratio	Per cent fruit set	Number of fruits per vine	Average fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit yield per vine (kg)	Fruit yield per plot (kg)	Fruit yield per hectare (q)	Flesh thickness (cm)
1	KRG-1 × ASJ	5.30	0.53	1.65	0.19	-1.30	-0.07	2.95	0.07	19.57	8.20**	0.24	0.03	0.71*	6.55*	-0.18
2	KRG-1 × ASM	2.87	-0.37	-1.82	-1.30	-3.72	1.81	3.45	0.05	-8.96	-5.75**	0.73	0.09**	0.05	0.49	0.69*
3	KRG-1 × PN	-8.17	-0.15	0.18	1.11	5.02	-1.74	-6.40	-0.12	-10.62	-2.46	-0.97*	-0.13**	-0.76*	-7.04*	-0.51
4	KRG-2 × ASJ	21.27*	0.39	-0.85	1.89	3.20	-2.44	-8.87	-0.4	-0.51	3.14	0.07	0.01	-0.80*	-7.40*	0.13
5	KRG-2 × ASM	-17.87*	-0.51	1.18	-1.90	0.78	-1.4	4.04	0.78	-0.66	1.59	0.01	0.07*	1.20**	11.12**	-0.19
6	KRG-2 × PN	-3.40	0.12	-0.32	0.01	-3.98	3.84	4.82	-0.38	1.17	-4.72*	-0.07	-0.09**	-0.40	-3.72	0.06
7	KRG-3 × ASJ	-10.6	-1.74**	2.81	1.36	4.70	0.75	-0.22	-0.46	-43.26**	-3.96*	0.28	0.14**	-1.04**	-9.61*	-0.08
8	KRG-3 × ASM	5.67	1.86**	-0.66	0.17	-1.22	3.83	-5.18	-0.29	11.95*	-0.61	-0.17	0.07*	0.95**	9.25**	0.00
9	KRG-3 × PN	4.93	-0.12	-2.16	-1.53	-3.48	-4.58	5.39	0.75	31.94**	4.58*	-0.11	0.03	0.92**	8.56**	0.08
10	KRG-4 × ASJ	-1.73	1.39**	-1.69	-3.04	-3.80	-2.47	8.13	0.47	-51.56**	1.6	-0.16	0.12**	0.63	5.84	0.07
11	KRG-4 × ASM	-1.67	-0.21	-2.66	0.47	1.28	-5.44	-12.70*	0.15	85.99**	0.85	0.4	-0.07*	0.30	2.81	0.09
12	KRG-4 × PN	3.40	-1.18**	4.34	2.57	2.52	7.91*	4.57	-0.62	-34.43**	-2.46	-0.24	-0.05	-0.93**	-8.65**	-0.15
13	KRG-5 × ASJ	-4.33	-1.24**	2.81	1.56	-2.47	-1.05	-1.79	-0.10	11.69	-1.6	-0.27	-0.15**	-0.55	-5.04	-0.31
14	KRG-5 × ASM	5.63	-0.14	-1.16	-3.23	1.12	-5.46	2.75	0.18	-15.72	-1.15	0.15	0.15**	0.12	1.07	0.24
15	KRG-5 × PN	-1.30	1.38**	-1.16	1.67	1.35	6.51	-0.96	-0.08	4.04	2.74	0.13	0.00	0.43	3.96	0.07
16	KRG-6 × ASJ	-33.10**	-0.01	0.65	-1.81	3.86	3.00	2.97	-0.70	75.70**	-0.08	-0.79	-0.22**	-0.88*	-8.16**	0.85*
17	KRG-6 × ASM	-37.53**	-1.21**	-3.32	0.50	-2.55	-4.99	-1.11	-0.12	1.21	-1.63	-0.02	0.16**	0.63	5.82	-0.81
18	KRG-6 × PN	70.63**	1.22**	2.68	1.31	-1.31	1.99	-1.87	0.82	-76.90**	1.71	0.82	0.07*	0.25	2.35	-0.04
19	KRG-7 × ASJ	-23.63*	0.03	-3.02	-1.84	-2.14	1.12	8.54	-0.10	-1.14	0.6	0.36	-0.02	-0.51	-4.73	0.08
20	KRG-7 × ASM	35.33**	0.63*	2.01	1.97	0.45	-3.71	-10.89	0.28	4.28	-1.35	-0.07	0.03	0.46	4.25	0.03
21	KRG-7 × PN	-11.70	-0.65*	1.01	-0.13	1.69	2.59	2.34	-0.18	-3.14	0.74	-0.29	-0.01	0.05	0.48	-0.11
22	KRG-8 × ASJ	-10.86	0.83**	1.48	4.46*	-0.80	4.06	-0.85	0.34	45.08**	1.37	0.51	0.10**	0.80*	7.42*	0.3
23	KRG-8 × ASM	10.80	0.43	-1.99	-2.43	1.78	-2.89	-2.12	0.21	-17.45	-0.48	0.03	0.01	0.12	1.14	-0.01
24	KRG-8 × PN	0.06	-1.25**	0.51	-2.03	-0.98	-1.17	2.97	-0.55	-27.63*	-0.89	-0.54	-0.11**	-0.92**	-8.56**	-0.29
25	KRG-9 × ASJ	31.94**	0.36	-6.19*	-5.31*	-8.64**	1.37	-5.58	0.47	5.61	0.6	0.79	0.24**	0.77*	7.10*	0.43
26	KRG-9 × ASM	-21.50*	-0.24	3.34	9.20**	2.45	3.26	9.37	-0.15	-17.50	-1.05	-0.92*	-0.12**	-0.74*	-6.88*	-0.08
27	KRG-9 × PN	-10.44	-0.12	2.84	-3.89	6.19*	-4.63	-3.79	-0.32	11.89	0.44	0.13	-0.12*	-0.03	-0.22	-0.36
28	KRG-10 × ASJ	37.30**	0.76*	0.65	0.63	5.36*	-1.39	-3.52	0.00	11.67	-0.8	-0.63	-0.05	0.52	4.88	-0.57
29	KRG-10 × ASM	-19.13*	-0.94	1.68	-1.57	1.45	6.61	6.01	-0.72	18.44	1.05	0.51	-0.17**	-1.64**	-15.20**	0.38
30	KRG-10 × PN	-18.17*	0.18	-2.32	0.94	-6.81*	-5.22	-2.48	0.72	-30.11*	-0.26	0.12	0.22**	1.11**	10.32**	0.19

Table 3. Continued…

Sl. No.	Cross	Number of leaves	Number of branches	Days to first female flowering	Node to first female flower	Days to first harvest	Sex ratio	Per cent fruit set	Number of fruits per vine	Average fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit yield per vine (kg)	Fruit yield per plot (kg)	Fruit yield per hectare (q)	Flesh thickness (cm)
		90 DAS	90 DAS													
31	KRG-11 × ASJ	-57.46**	-1.54**	4.15	-3.44	2.86	-0.80	3.16	0.54	-48.98**	1.04	-0.28	-0.04	-0.89**	-8.22**	0.31
32	KRG-11 × ASM	-33.00**	-0.14	-6.32*	0.67	-2.05	-4.48	3.79	-0.39	27.06*	-0.71	-0.41	-0.11**	-0.34	-3.13	-0.11
33	KRG-11 × PN	90.46**	1.68**	2.18	2.77	-0.81	5.28	-6.95	-0.15	21.88	0.32	0.69	0.15**	1.22**	11.36**	0.42
34	KRG-12 × ASJ	15.84	0.86**	3.65	2.06	4.03	4.00	2.77	-0.06	-45.17**	-7.06**	-1.17*	0.16**	0.67*	6.18*	-0.96
35	KRG-12 × ASM	18.80*	0.06	-0.82	-1.43	-0.88	4.68	7.89	-0.49	-3.01	1.59	0.07	-0.15**	-0.71*	-6.56*	0.03
36	KRG-12 × PN	-34.64**	-0.92**	-2.82	-0.63	-3.15	-8.67*	-10.66	0.55	48.18**	5.48**	1.10*	-0.01	0.04	0.04	0.93
37	KRG-13 × ASJ	-15.03	1.29**	4.82*	0.96	-0.30	-5.88	-5.14	0.10	18.24	0.2	0.33	-0.01	0.76*	7.02*	-0.04
38	KRG-13 × ASM	11.73	-0.61*	-4.66	-0.33	0.78	2.32	-3.28	0.58	-99.33**	-0.05	-0.23	0.09**	0.41	3.83	0.07
39	KRG-13 × PN	3.30	-0.68*	-0.16	-0.63	-0.48	3.57	8.42	-0.68	81.08**	-0.16	-0.1	-0.08**	-1.17**	-10.85**	-0.03
40	KRG-14 × ASJ	-11.46	-1.31**	-1.19	-0.34	-1.97	3.62	-1.19	-0.63	18.64	-1.40	0.23	-0.08**	-0.90**	-8.35**	0.17
41	KRG-14 × ASM	8.20	0.59*	1.84	2.27	-0.88	-0.26	-6.75	0.85	-54.55**	4.45*	-0.06	0.04	0.01	0.10	-0.18
42	KRG-14 × PN	3.26	0.72*	-0.66	-1.93	2.85	-3.36	7.99	-0.22	35.92**	-3.06	-0.17	0.04	0.89**	8.24**	0.01
43	KRG-15 × ASJ	35.24**	-0.37	-7.35**	1.76	-2.64	-0.05	5.34	0.77	-43.26**	1.8	0.26	0.04	0.83*	7.73*	0.16
44	KRG-15 × ASM	-0.90	-1.07**	14.18**	0.17	-0.05	-0.60	6.35	-0.75	60.04**	1.35	0.24	-0.09**	-0.61	-5.65	0.14
45	KRG-15 × PN	-34.34**	1.45**	-6.82**	-1.93	2.69	0.65	-11.69*	-0.02	-16.78	-3.16	-0.50	0.05	-0.23	-2.08	-0.30
46	KRG-16 × ASJ	-10.76	-0.24	-0.52	0.56	3.03	-7.47	-3.18	0.20	25.86*	-0.70	0.47	0.04	-0.06	-0.57	0.40
47	KRG-16 × ASM	36.90**	1.06**	0.51	-1.73	-0.88	2.60	-9.21	-0.42	25.26*	1.05	-0.24	0.04	0.38	3.5	-0.30
48	KRG-16 × PN	-26.14**	-0.82**	0.01	1.17	-2.15	4.87	12.38*	0.22	-51.12**	-0.36	-0.23	-0.08**	-0.32	-2.93	-0.10
49	KRG-17 × ASJ	32.10**	0.03	-1.85	0.33	-2.97	3.70	-3.54	-0.53	1.79	-3.00	-0.23	-0.03	-0.07	-0.67	-0.14
50	KRG-17 × ASM	-4.33	0.83**	-1.32	-1.47	2.12	4.13	7.61	0.25	-16.42	0.85	-0.02	-0.09**	0.24	2.24	0.01
51	KRG-17 × PN	-27.77**	-0.85**	3.18	1.14	0.85	-7.83*	-4.07	0.28	14.63	2.14	-0.25	0.12**	-0.17	-1.57	0.13

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An Analysis of Credit Utilization and Farm Income of Arable Crop Farmers in Kwara State, Nigeria

By S. U. Isitor, D. A. Babalola & K. S. Obaniyi
Babcock University, Nigeria

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Keywords: *credit utilization, farm income, collateral, kwara, poultry, nigeria.*

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S. U. Isitor [α], D. A. Babalola [σ] & K. S. Obaniyi [ρ]

Abstract- This article assessed credit utilization among arable farmers in Kwara state, Nigeria and its influence on farm income. The data analyzed were collected from 100 farmers purposively sampled. Despite an average of 11years experience, 47% of the farmers have not benefited from agricultural credit. Average income per hectare for farmers who were able to access funds for their farm business was higher (₦52,000/$325) than for those who did not (₦35,430/$221) however, average loan granted (₦55,550/$347)was lower than applied for (₦77,900/$486). Lack of collateral was a major limitation for sourcing for credit. Factors determining farmers' decision to use credit included household size, use of hired labour, cooperatives participation, awareness of credit sources, past loan size, possession of collateral and proximity to the credit lending institution. Policies and programmes directed at enhancing these factors will increase farmers' decision to use agricultural credit.

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I. Introduction

In most parts of Sub-Saharan Africa, expanded crop production has been due to expanded planting farm areas for staple crops than from yield increases (Phillip *et al.,* 2008). The implication of this had been large outlays of financial requirements of the farming folks for the needed assets which are predominantly land and labour. Poor farmers tend to resign to subsistence farming because of their inability to acquire required credit support to keep in business (Ammani, 2012). Financing agriculture involves lending money to farmers to stimulate the productivity of the limited farm resources (Muniraj, 1987; Adegeye and Dittoh, 1985; Osuntokun, 1992). Eswaram and Kotwal (1990) suggested that the provision of agricultural credit makes available additional capital that can be used to enhance the level of household's productive and physical capital. Access to credit is expected to enhance farming households' ability to acquire capital intensive technology and assets to facilitate and improve farming activities resulting in greater capacity to invest in cultivation of high yielding crops and larger farm holdings (Nwankwo, 1983; Palmer and Ojo, 1983; Feder *et al.,* 1985; Emereole, 1995; Nwaru, 2004; Nwaru and Onuoha, 2010; Ammani, 2012). This may in turn lead to efficient resource allocation, increase farmers' technical efficiency and, by implication, increase farmers' profitability. Similarly, Qureshi et al. (1996) observed that an increase in credit to agriculture will lead to increase food production and farmers' income because as the demand for credit increases, farmers output also increases, resulting in improvement in their well being. Nwaru and Onuoha (2010) further observed that when agricultural credit is properly extended and utilized, it encourages diversification which stabilizes and often increases resource productivity, agricultural production, value added and net incomes of farmers. Credit is therefore a necessary input in the various aspects of farm operations. Agricultural production needs to rise at least by some six percent per annum for Africa to be able to meet its food needs and for African agriculture to become a real motor for economic development ((Okuneye, 2001; Enweze, 2006).

Nigerian agriculture is abysmally under-financed. Currently agriculture accounts for about 40 percent of the GDP, yet it receives only one percent of total commercial bank loans (Global Agricultural Information Network [GAIN] 2011). This is significantly below the level of other developing countries, e.g. Kenya and Brazil which reportedly registers 6 percent and 18. In Nigeria, 85 percent of the total food production is left in hands of small – scale farmers (Okuneye, 1997) and production employs crude technologies and is labour intensive with little or no forms of savings or storage facilities. With poor socio-economic and production characteristics of the farmers, inconsistent and unfocussed government policies, poor infrastructural base, low level of agricultural investment, poorly developed agricultural research system, under-developed land property rights, low level of technology, inefficient use of resources, natural disasters and lack or insufficient access to credit and other production resources interacting in a synergism to restrict the agricultural sector, the result is low production, low farm income, high prices of food items, inflation,

Author α ρ: Department of Agricultural Economics and Extension, Landmark University, Omu-Aran, Kwara State, Nigeria.
e-mail: akindan15ster@gmail.com
Author σ: Department of Agricultural Economics and Extension, School of Agriculture & Industrial Technology, Babcock University, Ilishan-Remo, Ogun State, Nigeria.

underdevelopment and concomitant poverty (Okuneye, 2001). The Federal Government has continued to broaden the economic base of the country through revamping of the agriculture sector. It is anticipated that this will alleviate poverty and generate employment within the nation. The provision of adequate finance, therefore, becomes a necessity to facilitate the extent to which planned projects and programs could be executed in public finance (Adegbite *et al.,* 2008). Farmers were to source credit from commercial and agricultural banks, cooperative societies and government initiated public agricultural credit institutions and schemes. However, only about 11 percent of rural farmers source credit from these formal sources (World Bank 2000; Ammani, 2012). Poor awareness and access to credit coupled with poor fund utilization and repayments have been posited as the major factors militating against the success of existing credit schemes (Binswanger *et al.,* 1993; Agbor, 2004; Phillip *et al.,* 2008). In modern farming business in Nigeria, beyond poor access, efficient utilization of credit is fast becoming a major factor limiting farm productivity and income (Ololade and Olagunju, 2013). It is against this background that this study assessed the determinants of credit utilization and its influence on farm income.

II. Research Methodology

The study was carried out in Irepodun Local Government Area of Kwara State, South-West Nigeria. Kwara state has an area of 35,705 square kilometers and 3,570,500 hectares of cultivable land, making it the largest in South-West Nigeria (Nigeria Bureau of Statistics [NBS] 2009). The study location is within the humid tropical climatic zone of Nigeria, with rainfall as high as 199.1mm which encourages significant agrarian activities. Of the 16 local governments in the state, Irepodun is among the top 6 largest with a population of over 150,000 persons, majority of which practice farming either as primary or secondary occupation (NBS, 2009). Significant cultivation of arable crops such as cassava, maize and leafy vegetables take place in the study area.

Primary data were collected from 100 arable crop farmers growing both maize and cassava (representing arable crops). The farmers were purposively selected. Data gathered were analyzed using descriptive statistics and the Logit regression model.

a) Model specification

The choice of the logit model is because the dependent variable is a dummy. Following Gujarati (1998), the model is specified as follows:

$$\text{Ln}\ (P_i/(1-P_i) = \beta_0 + \beta_1 X_1 + \ldots + \beta_{17} X_{17} + e_i\ .$$

Where:

P_i= probability of farmer's decision to access and utilize credit for production

$1-P_i$ = probability of not utilizing credit for production

β_0 = Intercept

β_i (1,2,3...,17) = Regression coefficients,

X_i (1,2,3...,17) = Independent variables, and

e_i = error term.

The independent variables specified as factors influencing farmer's decision to access and utilize credit for production and are defined below:

X_1 = Gender (Dummy: 1=male, 0=female)

X_2 = Age (years)

X_3 = Household size

X_4 = Education (Dummy: 1=sec.more than sec. edu., 0=less than)

X_5 = Farming experience (years)

X_6 = Cultivation of other crops besides maize & cassava (Dummy: 1=yes, 0=no)

X_7 = Farm size (Ha)

X_8 = Labor type (Dummy: 1=Hired, 0=family)

X_9 = Labor Cost (₦)

X_{10} = Farm Income (₦)

X_{11} = Other Income (₦)

X_{12} = Cooperative membership (Yes= 1, No=0)

X_{13} = Awareness of credit source (Dummy: 1=yes, 0=no)

X_{14} = Past Loan size (₦)

X_{15} = Collateral Need (Dummy: 1=yes, 0=no)

X_{16} = Loan Interest (%)

X_{17} = Distance to credit source (km)

III. Result and Discussion

a) Results of descriptive statistics

Results in Table 1 shows that the majority of the farmers in the study area are above 40 years old (63%) and they are mostly male (73%). The predominance of male farmers is an indication that agribusiness is generally labour intensive and still a strenuous enterprise in Nigeria (Babalola, 2014). Furthermore, the tedious and time-consuming nature of the cultural practices involved in arable cropping discourages most prospective female entrances into the business. The majority of the respondents (63%) had up to secondary education which shows considerable literacy level among the farmers in the study area. This is expected to positively influence their adoption of innovations and utilization of credit (Siyanbola, 2012). Average household size was greater than 6 members. This is above the national average of approximately 5 (Babalola, 2014; NBS, 2009). Household size is expected to vary directly with expenditure (Babalola and Babalola, 2013; Gebremedehin and Scott 2003), thus, with increasing household size, the more likely that

farmers will divert funds originally meant for farm production to cater for domestic household needs. In corroboration with good literacy level, farmers' experience in farming is expected to increase quality and quantity of output by reducing postharvest losses and increase the use of technology. The results showed that, averagely, farmers have up to 11 years farming experience which is relatively long enough for them to have gained mastery of the enterprise having passed through more than ten production cycles. Although, about 64 percent of the farmers were aware of where to source for agricultural credit and 53 percent have actually sourced for credit, some 36 percent still lack awareness and up to 47 percent have not benefited from agricultural credit.

Table 1 : Farmers' personal characteristics

Characteristics	Mean (±SD)	Freq n=100	(%)
Gender: Male		73	73
Household size	6.68 (±2.51)		
Age (years)	45 (±9.99)		
Educ. level:			
Below secondary		37	37
Secondary & above		63	63
Farming Experience	10.5 (±6.10)		
farm size	2.68 (±1.44)		
Belong to Cooperative		52	52
Awareness of credit source		64	64
Sourced/ used credit		53	53
Major income: farm		63	63
*GFI/ season	97,815 (±45,700)		
Major occupation:			
Farming		59	59
Non- farming		41	41

** GFI (Gross Farm Income) in naira, N1~ $ 0.00625*

Source: Computed from Field survey (2014).

Furthermore, 52 percent of the farmers participated and have benefited from cooperative membership, 48 percent still do not participate. The importance of cooperatives in providing credit to farmers has been detailed in past studies (Ololade and Olagunju 2013; Nto *et al.* 2011; Ayinde *et al.* 2008). The major occupation of most (59%) of the respondents was farming. Average farm size was 2.68 hectares and average farm income per season was ₦ 97,815 (approx. $611). If farming households (average 6 members) without other source of income were to live solely on the farm income for a minimum cropping season of 4 months, individual member of the household will be living below poverty line of $1 per day. Efforts to increase farm income therefore are germane in the study area.

Results in Table 2 show the distribution of farmers by awareness of sources of credit. Most of the farmers are aware of the micro-finance bank (60%) and cooperatives (60%) as sources of credit. It is interesting to note that many of the farmers (63%) are not aware of the possibility of sourcing for funds from the Bank of Agriculture (BOA) whose primary mandate is to finance agricultural activities. The most popular informal source of credit among the farmers (46%) was the money lender scheme. Most of the farmers (60%) reported that they got to know about the credit sources through radio programme (Table 3).

Table 2 : Distribution of farmers by awareness of sources of credit

Credit sources	†Freq for	%
Formal sources:		
State govt agric fund	39	39
Micro-finance Banks	60	60
Cooperatives	60	60
Bank of Agriculture (BOA)	37	37
Commercial Banks	14	14
Non-government Organizations NGOs	18	18
Informal sources:		

Produce buyers	40	40
Thrift Collections	39	39
Money lenders	46	46
Friends & family	24	24

†existence of multipleresponse

Table 3 : Distribution of farmers by media of information of credit sources

Sources of information	†Freq	%
Radio	60	60
Newspaper	42	42
Extension agent	22	22
Research centre	5	5
Cooperatives	52	52
Friends/Relatives	35	35

†existence of multipleresponse

The expected effort of the extension agents in providing farmers with useful information relating to agricultural financing and fund management to facilitate commercial production appears to be poor in the study area with only 22 percent of the farmers claiming to have sourced information through extension service.

Results in Table 4 shows that 83 percent of the farmers utilized the loan given to expand their existing farm business. The results also showed that all the beneficiaries utilized the loan given for agricultural purposes therefore, with more funding commercial-lization will be encouraged among the farmers. Previous experience of the farmers as recorded in Table 5 showed that 61 percent had applied for loan some times in the past but only 25 percent got the loan as at when needed and only 24 percent paid back as expected despite the fact that they could pay back by installment.

Table 4 : Distribution of farmers by mode of utilization of credit if and when accessed

Mode of utilization (n=53)	†Freq	%
To start a new farming business	12	22.6
To expand existing farming business	44	83.0
To fund the regular cultural practices	20	37.7

†existence of multipleresponse

Table 5 : Distribution of farmers by their experience with credit

	†Freq	%
Past application for loan	61	61
Got credit as at when needed	25	25
Paid back as expected	24	24
Repayment mode:		
Installment	43	43
Full payment	12	12
Present application for loan	60	60
Qualify for loan	57	57
Present loan beneficiary:	53	53
*Amount applied for (mean)	77,900(±10,050)	
*Amount granted (mean)	55,550(±7,250)	
Need for collateral	57	57
Type of collateral:		
Land	21	21
Building	5	5
Farm asset	18	18

*†existence of multiple response; * in naira, ₦1~ $ 0.00625*

Out of the 60 farmers that have currently applied for loan, 57 qualified and 53 were granted. However, average loan applied for was ₦77,900 (approx. $486) but average loan granted was ₦55,550 (approx. $347). The fact that farmers were not granted the amount of loan applied for and as at when needed, given that agriculture is a time sensitive enterprise, may be responsible for poor repayment response. The need

for collaterals for loan acquisition (especially land asset) was expressed by most of the farmers (57%). Thus, poor farmers who do not have the required asset for collaterals are not able to access credit.

Results in Table 6 shows that average income per hectare for farmers who were able to access and use funds for their farm business was higher (N 52,000) than income per hectare for those who did not utilize borrowed credit (₦35,430). Lack of collateral was reported by the majority of the farmers (74%) as the limitation for sourcing for credit (Table 7). This result is consistent with the findings of Philip *et al.* (2008).

Table 6 : Income analysis by credit utilization

	Average income ₦	Average income per Ha ₦
Farmers with credit utilization	101,907	52,000
Farmers without credit utilization	86,750	35,430

Table 7 : Distribution of farmers' by limitation to sourcing credit

Limitations	†Freq	%
Fear of inability to pay back	11	11
Lack of collateral	74	74
Lack of awareness of credit source	36	36
Inability to access credit source	46	46
None	16	16

†existence of multiple response

Source: Field Survey, 2014

b) Factors influencing agricultural credit utilization

The data on the determinants of farmers' utilization of agricultural credit were analyzed, using the logit regression model. A number of variables were hypothesized to determine the farmers' decision to utilize agricultural credit in the study area such as socio-economic, farm-level, institutional, awareness variables. The result of the logit model analysis is presented in Table 8. The significance of the diagnostic statistics (chi-squared and log-likelihood values) shows a good fit for the model.

The result showed that the significant and positive determinants of farmers' decision to utilize credit include use of hired labour ($p< 0.1$), participation in cooperatives ($p< 0.05$), awareness of credit source ($p< 0.1$), past loan size ($p< 0.05$) and possession of collateral ($p< 0.05$). In other words enhancing these factors enhances farmers' decision to use credit. Labour costs constitute a significant portion of the cost of production (Ammani 2012) therefore, as farmers increase scale of production, more funds will be required to hire labour.

Apart from lending out loans to members from members' contributions, the activities of the cooperative societies in helping members secure loan from lending institutions is well known (Babalola 2014; Ololade and Olagunju 2013; Siyanbola 2012). However, many of the farmers still do not participate in cooperative activities (Table 1). Furthermore, significant and negative determinants of farmers' decision to utilize credit include size of their household ($p< 0.05$) and distance away from the credit source ($p< 0.05$). Conversely, reducing these factors will enhance farmers' decision to use credit. The negative influence of large households may be as a result of the action of the credit lending institutions setting a benchmark for the household size of beneficiaries so as to curtail loan diversions. Furthermore, farmers with large households often source farm labour from the households thus saving the huge amount that would have been spent on hired labour.

Table 8 : Determinants of credit utilization

Variables	Beta Coeff.	S.E.
Gender	0.626	1.665
Age	-0.059	0.128
Household Size	-0.878**	0.456
Education	0.158	1.738
Farming experience	-0.132	0.141
Cultivation of other crops	3.077	2.579
Farm size	0.797	0.517

Labor type	5.062*	2.822
Labor Cost	-0.006	0.017
Farm Income	-0.004	0.024
Other Income	0.273	1.797
Cooperative participation	0.44**	2.778
Awareness	4.230*	2.912
Past Loan size	0.065**	0.027
Possession of Collateral	5.530**	2.846
Loan Interest	0.100	0.192
Distance	-1.738**	0.726
Constant	-4.394	7.458

**Sig at 10%, **Sig and 5%; Nagelkerke R^2 = 0.847;*
*-2 Log likelihood = 29.163**; Chi-square= 87.489***

IV. Conclusion and Recommendations

This study assessed credit utilization among arable crop farmers in Kwara state, Nigeria and its influence on farm income. Major occupation among respondents was farming however, farm income was generally low. The study showed that utilization of credit increased farmers' income. The most popular source of credit among the farming folks was the micro-finance bank and most of the farmers who sourced for credit did so to expand existing farm enterprise however, Loan repayment was poor among the credit beneficiaries. The need for land asset as collateral was reported as major limitation to accessing credit among the farmers. factors determining farmers decision to use credit included size of household, use of hired labour, membership of cooperatives, awareness of credit sources, past loan size, possession of collateral and proximity to the credit lending institution.

Based on the research findings, it is recommended that government and other stakeholders' efforts should be directed towards policies and programmes that will further enhance those factors that increase farmers' decision to use agricultural credit. The extension agency, cooperative societies and research institutes are well appropriate organs for educating and disseminating agro-allied information and raising awareness. Thus, in collaboration with the financial institution especially the Bank of Agriculture and commercial banks, awareness and education on credit sourcing and management should be incorporated in their package for outreach to the farming folks. Policy arrangement to enable poor farmers, without appropriate landed properties for collateral, to access funds for farming activities should be put in place.

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Factors Affecting the Agrarian Distress Proneness in Vidarbha

By N. M. Kale, D. M. Mankar & Dr. P. P. Wankhade
Dr.Panjabrao Deshmukh Krishi Vidyapeeth, Akola (MS), India

Abstract- The present study was carried out in Akola, Buldana, Amravati, Washim, Yavatmal and Wardha districts of Vidarbha in Maharashtra during 2012-2013. An exploratory design of social research was used. In total 240 farmers (120 farmers having land bellow 2 ha (Marginal to Small) + 120 farmers having land above 2 ha. (Semi-medium to Large farmers) were selected by random sampling method; it covers 24 villages and 9 Tahsils of six districts of Vidarbha. The main objective of this study was to study the agrarian distress proneness level amongst the selected farmers in Vidarbha. The composite index of agrarian distress of selected respondents was obtained with the help of Composite Index of selected 16 factors. The composite index were analysed by using the method of Prem Narain, et.al (2011). The salient findings revealed that near about cent percent (98.58%) selected farmers were having high composite index of agrarian distress. The non-remunerative prices (having Mean Severity Score 4 out of 3), weather related uncertainties (MSS=3.99), fluctuation in market rates (MSS=3.95), rise in cost of inputs (MSS=3.92), lack of irrigation facilities (MSS=3.87), lack of accurate weather information (MSS=3.66), crops damages by wild animals (MSS=3.46), etc.

Keywords: *agrarian distress, composite index, mean severity score, non-remunerative prices.*

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Factors Affecting the Agrarian Distress Proneness in Vidarbha

N. M. Kale [α], D. M. Mankar [σ] & Dr. P. P. Wankhade [ρ]

Abstract- The present study was carried out in Akola, Buldana, Amravati, Washim, Yavatmal and Wardha districts of Vidarbha in Maharashtra during 2012-2013. An exploratory design of social research was used. In total 240 farmers (120 farmers having land bellow 2 ha (Marginal to Small) + 120 farmers having land above 2 ha. (Semi-medium to Large farmers) were selected by random sampling method; it covers 24 villages and 9 Tahsils of six districts of Vidarbha. The main objective of this study was to study the agrarian distress proneness level amongst the selected farmers in Vidarbha. The composite index of agrarian distress of selected respondents was obtained with the help of Composite Index of selected 16 factors. The composite index were analysed by using the method of Prem Narain, et.al (2011). The salient findings revealed that near about cent percent (98.58%) selected farmers were having high composite index of agrarian distress. The non-remunerative prices (having Mean Severity Score 4 out of 3), weather related uncertainties (MSS=3.99), fluctuation in market rates (MSS=3.95), rise in cost of inputs (MSS=3.92), lack of irrigation facilities (MSS=3.87), lack of accurate weather information (MSS=3.66), crops damages by wild animals (MSS=3.46), etc. were the severely affecting factors for agrarian distress in selected six districts of Vidarbha. Hence Central and State government should take care of all mentioned factors for reducing the agrarian distress.

Keywords: agrarian distress, composite index, mean severity score, non-remunerative prices.

I. Introduction

Over two and half lakh farmers have committed suicide between 1995 and 2011 across India, including in states like Andhra Pradesh, Maharashtra, Karnataka, U.P., Punjab, Haryana and Kerala. Most of the victims belong to small and marginal farmers, and many belonging to backward class and scheduled castes (Murthy, 2013). According to the data available from National Bureau of Crime Record the number of farmers suicides have been on increase year after year [Sainath, P (2012) in The Hindu]. Several scholars who have analysed the farmers suicides contend that these suicides are the legacy of the economic reforms [Mishra (2006), Deshpande and Prabhu, 2005.]. As per the Mishra, 2007 and Kale, 2008 poor returns to cultivation and absence of non-farm opportunities are indicative of the larger socio-economic malaise in rural India.

Author α σ ρ: Associate Professor, Professor and Head and, Assistant Professor, Department of Extension Education, Dr.Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S).
e-mail: nmkale1964@gmail.com

Thus the various factors behind distress are more or less similar across the country. Major among them are market imperfections and economic, social, psychological, technological and institutional (Rao, 2008). However, for the purpose of the extent exercise, the focus of the study would be restricted to mostly the economic aspect that leads to "distress".

As per the Radhakrishna Committee Report (Anonymous, 2007) the Government of India declared 31 districts in four States (Andhra Pradesh-16, Karnataka-6, Maharashtra-6 and Kerala-3) as distress districts. These districts are mostly rainfed, agriculturally less developed and low productivity districts, where the Prime Minister's Relief and Rehabilitation package is being implemented. This package is designed with regional specificity to address issues of moisture conservation, infrastructural development, augmentation of non-farm sources of income and employment to farmers. Among distress districts, six districts are from Vidarbha region of Maharashtra State. These districts are Yavatmal, Buldana, Amravati, Akola, Washim and Wardha.

The current research study was conducted with the objectives to study the socio-economic profile of the selected respondents, to assess the factors affecting the agrarian distress in distress districts, to find the agrarian distress proneness level of the respondents according to the Composite index of agrarian distress of selected 16 factors and to document the suggestions from the respondents for betterment of farming business.

II. Methodology

Present research investigation was carried out in six distress districts of Western Vidarbha region of Maharashtra with exploratory design of social research. These districts were namely Akola, Buldana, Amravati, Washim, Yavatmal and Wardha districts of Vidarbha in Maharashtra. From each district four villages where selected randomely and from each selected village 5 marginal to small and 5 semi-medium to large land holding farmers were interviewed with the help of structured interview schedule. Thus this investigation was confined to a sample of 240 farmers (120 marginal to small + 120 semi-medium to large land holding farmers) from 24 Villages of six districts of Vidarbha region of Maharashtra.

a) Composite index of Agrarian distress

Operationally agrarian distress proneness refers to the inability of the respondent to cope up with existing farming business. A teacher made scale consisting of 16 factors (Table 2) that adversely affect the farming business of the farmers were used to measure the Agrarian Distress Proneness. The responses were taken on four point continuum according to adverse effect of each factor as severe, somewhat, can't say, not at all by assigning the scores of 4, 3, 2, and 1 respectively. The distribution of the respondents were done according to the Composite index of agrarian distress of selected 16 factors. The composite index were analysed by using the method of Prem Narain, et.al (2011). The distribution of the selected farmers according to obtained (0 to 1) composite index of agrarian distress have been done by equal interval method as follows.

Sr.No.	Level of agrarian distress proneness according to the Composite index of agrarian distress (0 to 1)	Frequency (%)
1	Low (Up to 0.33)	
2	Medium (0.34-0.66)	
3	High (Above 0.66)	

b) Mean Severity Score (MSS)

The responses were taken on four point continuum according to adverse effect of each selected factor as severe, somewhat, can't say, not at all by assigning the scores of 4, 3, 2, and 1 respectively. Sum of the raw score of each selected factor was the distress proneness score of an individual farmer which was converted into Mean Severity Score with the help of following formula. On the basis of MSS each identified Factor has been ranked.

$$\text{Mean Severity Score (MSS)} = \frac{\text{Sum of the raw score of each selected factor}}{\text{Total number of Respondents}}$$

III. Results and Discussion

a) Profile of farmers

The data with respect to various characteristics of the selected group of the farmers have been furnished in Table 1. It was observed from Table 1. that 45.42 per cent of the selected farmers were under old age category i.e. above 50 years, followed by more than one third respondents (37.50%) were from middle age group having age between 36 to 50 years. The remaining 17.08 per cent respondents were from young age group. From the above data it was inferred that from all age group respondents were selected for this study.

Out of the total respondents, maximum 40.00 per cent of the selected respondents were having high school level education, 21.66 per cent had higher secondary school level education followed by middle school (15%), college level (12.92 %), primary (7.92 %) and 2.50 per cent were illiterates have not attended formal schooling. Majority (70.00%) of the selected respondents were having medium family size having 4 to 6 family members. Among the selected farmers 51.25 per cent have only farming as the occupation, followed by agriculture + labour (34.58%), agriculture+ service/ pension (7.50%), agriculture + non professional business (5%) and Agriculture + allied occupation was observed with only 4 (1.67%) farmers. Thus it was inferred from the above data that lack of allied occupation was noted with majority (98.33%) of the selected farmers.

It is observed from Table 1 that over half (52.50%) of the selected farmers have well/tube well as irrigation source but most of the wells were dry in Buldana and Washim districts due to low rainfall during 2012-13 year and secondly electric load shading was the acute problem with the farmers for using the available water for crops in all selected district.Whereas, sizable 43.33 per cent farmers have no source of irrigation, they have to depend on monsoon rains only, negligible 2.50 and 1.67 per cent farmers have river and canal as a source of irrigation respectively. Majority (97.08%) of farmers have crop-crop farming system and very negligible (2.92%) farmers have crop-dairy/sericulture as the farming system.

Nearly one third (32.92%) of the selected farmers have annual income upto Rs. 50,000 only, followed by in the range of Rs. 50,001 to 1, 00,000 (23.75%), Rs. 1,00,001 to 2,00,000 (23.33%), Rs. 2,00,001 to 4,00,000 (11.67%), Rs 4,00,001 to 8,00,000 (6.25 %) and above Rs. 8,00,000 was observed with only 2.08 per cent farmers. The decreasing trend of annual income was observed with the selected farmers. More than half (51.25%) of the respondents have no bullock pair they totally depend on others, followed by 40.00 per cent of the farmers have one bullock pair whereas, 8.33 per cent have two pairs and remaining one farmer (0.42%) has three bullock pairs. Amongst the selected farmers only 10 per cent have their own tractor and these are the big farmers. Whereas, remaining majority (90%) of the farmers have no own tractor.

The data about the sources of information availed by the all selected farmers revealed that neighbors and VLW/AEO/AO/KVK SMS were used by each 63.75 per cent farmers . This was followed by television (52.08%), news paper (47.92%) as a important sources of information. Majority of the selected farmers (70.42%) farmer having low level of sources of information and remaining (29.58%) comes under medium level of sources of information.

Soybean (91.25%) and pulses (88.75% mostly Tur in Kharif & Gram in Rabi) were grown by majority of selected farmers, followed by cotton (42.92%), cereals (24.17%), fruits and vegetables (10.83%), flower crops were with 4 (1.67%) farmers and only two (0.83%) farmers have medicinal and aromatic plants. Only 22.08 per cent farmers had enrolled/ availed the facility of crop insurance scheme. Majority of the farmers expressed that they have not get any benefit after availing the facility of crop insurance scheme in past due to the wrong assessment of risk at division level. The risk assessment should be done at village level was the suggestion given by the majority of the farmers.

It was observed from Table 1. that 22.08 per cent of the selected farmers were observed defaulters against the institutional crop loan, hence they were not eligible for getting the fresh loan during 2012-13 season. It was noted from the data that 36.67 per cent of farmers not availed the crop loan during 2012-13. It might be due to the fact that 22.08 per cent farmers were defaulter and hence not eligible for getting the institutional loan. Whereas, remaining farmers were have service/pension as a source and due to difficult procedure few of them not have availed the crop loan.While 23.75 per cent had availed loan in the range of Rs. 25,001-50,000, followed by Rs.50,001-1,00,000 (17.92%), upto Rs. 25,000 (10.83%), in the range of Rs. 1,00,001-2,00,000 (7.08%) and remaining 3.75 per cent have availed above Rs. 2,00,000 crop loan during 2012-13.

b) Selected factors and their effect on agrarian distress

In all total 16 factors were selected by taking opinion of the expert and reviewing the review of literature on agrarian distress. The adverse affect of each selected factor on farming business has been measure by taking the responses of the selected farmers as severe, somewhat, can't say, not at all by assigning the scores of 4, 3, 2, and 1 respectively. Sum of the raw score of each selected factor was the severity score of an individual factor which was converted into Mean Severity Score. On the basis of Mean Severity Score (MSS) each selected factor has been ranked and data has been furnished in Table 2.

The data from Table 2 revealed that non-remunerative prices (MSS-4 out of 4), weather related uncertainties (MSS-3.99), fluctuation in market rates (MSS-3.95), rise in cost of inputs (MSS-3.92), lack of irrigation facilities (MSS-3.87), lack of accurate weather information (MSS-3.66) and crops damages by wild animals (MSS-3.46) were on Rank-I, II, III, IV, V, VI and VII respectively. The unavailability /high wages of labour having MSS-3.38 (Rank-VIII), followed by yield uncertainties MSS-3.37 (Rank-IX), lack of storage facilities MSS-3.16 (Rank-X), inadequate market facilities MSS-2.87 (Rank-XI), problem of electric load shedding MSS-2.66 (Rank-XII), lack of technical knowledge MSS-2.57 (Rank- XIII), non availability of chemical fertilizers in market at proper time MSS-2.23 (Rank-XIV), restricted credit and non-availability at proper time MSS-2.02 (Rank-XV) and spurious quality seeds having MSS-1.97 and ranked on XVI. Anonymous, (1998) and Kale, et.al (2011) was also reveals the same type of finding in their research projects.

c) Composite Index of Agrarian Distress

The composite index of agrarian distress of selected respondents was obtained with the help of Composite Index of selected 16 factors. The composite indices were analysed by using the method of Prem Narain, et.al (2011). The distribution of the selected farmers according to obtained Composite Index (0 to 1) of Agrarian Distress have been done by equal interval method in low (Up to 0.33), medium (0.34-0.66), and high (Above 0.66) and the results have been depicted in Table 3.

The data regarding composite index of agrarian distress of selected respondents from Table 3 revealed that majority (99.58%) of the farmers were having high composite index of agrarian distress and remaining one (0.42%) respondent has medium level of composite index of agrarian distress.

Hence this research study clears that near about cent per cent (99.58%) selected farmers were in high agrarian distress and hence government should have to take care of all selected factors for reducing the agrarian distress in selected six distress districts of Vidarbha.

d) Suggestions to prevent agrarian distress

Taking suggestions for avoiding present agrarian crisis is one of the important aspects of this study. It refers to the opinion of respondents about what action should be taken for reducing distress proneness level among the farming community, which can help to some extent for finding out ground realities for agrarian distress and help to suggest different measures to solve farmers' distress in Vidarbha region. The responses received from the respondents are presented in Table 4.

It is clear from Table 4 that cent per cent (100%) respondents suggested for remunerative prices to their farm produce, recently they did not gets the remunerative prices as per the cost of cultivation. Some time input cost is not get return after selling farm produce. Secondly there is variation/ fluctuations in marker priceses. In this year 2012-13 most of the cotton

growers sold their cotton in the month of December-2012 at the rate Rs. 3900 per quintal but after that in the month of March 2013 cotton rate was 5000 per quintal. At this stage most of the farmers not gets the benefits, but benefits were goes to middle man who purchase the cotton in the month of December-2012. This was followed by majority (96%) per cent farmers suggested for timely input in low cost, it may be due to the facts that since from last ten years input cost raised tremendously but unfortunately farm produce will not get the remunerative price as per the cost of cultivation.

Provide subsidy for fencing the farms was the suggestion given by majority (95%) farmers, recently due to the increasing population of wild animals like dear, Rohi, Wild pigs, etc., these wild animals damages the field crops, hence majority farmers had given suggestion for more subsides on farm fencing. Provision/ creation of irrigation facilities was suggested by 83 per cent farmers, followed by provide more subsidy for purchasing the tractor was suggested by 75 per cent farmers, this may be due to the decreasing trend of farm labors in farming business. Construct the cement plug on every Nala in each village was the suggestion reported from 67 per cent farmers, this is the indication of awareness amongst the farming community about soil and water conservation practices, due to the decreasing trend of monsoon rains.

Abundant electric supply on day time for farming business is also important suggestion given by sizable (56%) group of farmers. In rural areas of Vidarbha electric load shading is the acute problem, during day time there are only three days in a week i.e. Monday, Tuesday and Thursday on this day farmers gets the 5 hours electricity during day time. Hence farmers suggested for day time electricity. Availability of information about Govt. Schemes and agricultural technology was reported by 52 per cent farmers, followed by assessments of crop insurance risk should be done at village levels is the suggestion received from 42 per cent farmers, earlier we have seen that very few respondents have availed/enrolled the crop insurance scheme, as per the opinion of farmers earlier they have enrolled the crop insurance scheme but they are not get any benefits. Hence the farmers suggested for village level assessment of risk in crop insurance. Promote the export of farm produce for getting benefits to farmers were reported by 42 per cent farmers, it may be due to the facts that when government promote the export of farm produce like cotton, onions, etc. farmers gets the good prices.

IV. Conclusion and Policy Options

This research study clears that near about cent percent (99.58%) of the farmers have high Composite Index of Agrarian Distress Proneness. The non-remunerative prices (having Mean Severity Score (MSS)-4 out of 4), weather related uncertainties (MSS-3.99), fluctuation in market rates (3.95), rise in cost of inputs (MSS 3.92), lack of irrigation facilities (MSS-3.87), lack of accurate weather information (MSS-3.66) and crops damages by wild animals (MSS-3.46) all these factors were having maximum Mean Severity Score (MSS) amongst the selected farmers and Rank on -I, II, III, IV, V, VI and VII respectively. Hence government should have to take care of all selected factors for reducing the agrarian distress in selected six distress districts of Vidarbha.

In six distressed districts of Vidarbha namely Buldhana, Akola, Washim, Amravati, Yavatmal and Wardha near about cent percent (99.58%) of the farmers have high (Above 0.66) Composite Index of Agrarian Distress. The non-remunerative prices (having Mean Severity Score (MSS)-4 out of 4), weather related uncertainties (MSS-3.99), fluctuation in market rates (3.95), rise in cost of inputs (MSS 3.92), lack of irrigation facilities (MSS-3.87), lack of accurate weather information (MSS-3.66) and crops damages by wild animals (MSS-3.46) were the severely affecting factors. Therefore, it is, recommended that government should give the remunerative prices to the farm produce and takes due consideration of mentioned factors for reducing the agrarian distress in selected six distressed districts of Vidarbha.

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Table 1 : Distribution of selected respondents according to their Characteristics

Sr.No.	Characteristics	Category	Respondents N=240	
			Frequency	%
1	Age	Young (Up to 35 Years)	41	17.08
		Middle (36-50)	90	37.50
		Old (Above 50)	109	45.42
2	Educational level	Illiterate	6	02.50
		Primary school	19	07.92
		Middle school	36	15.00
		High school	96	40.00
		Higher secondary school	52	21.66
		College	31	12.92
3	Family Size	Small (Upto 3)	32	13.33
		Medium (4 to 6)	168	70.00
		Large (7 to 9)	33	13.75
		Very large (Above 9)	7	2.92
4	Occupation	Agriculture + Labour	83	34.58
		Agriculture (only farming)	123	51.25
		Agriculture + Allied occupation	04	01.67
		Agriculture +Non professional business.	12	05.00
		Agriculture+ Service/ Pension	18	07.50
5	Land holding	Marginal (Up to 1.00 ha.)	20	8.33
		Small (1.01 to 2.00 ha.)	100	41.67
		Semi-medium (2.01 to 4.00 ha)	50	20.83
		Medium (4.01 to 10.00 ha.)	60	25.00
		Large (Above 10.00)	10	4.17
6	Irrigation sources	No source	104	43.33
		River	6	2.50
		Well/Tube well	126	52.50
		Canal	4	1.67
7	Farming system	Crop-crop	233	97.08
		Crop-dairy/sericulture	7	2.92
8	Annual income Rs.	Up to 50,000	79	32.92
		50,001 to 1, 00,000	57	23.75
		1,00,001 to 2,00,000	56	23.33
		2,00,001 to 4,00,000	28	11.67
		4,00,001 to 8,00,000	15	6.25

		Above 8,00,000	5	2.08
9	Bullock pair	Nil	123	51.25
		One	96	40.00
		Two	20	8.33
		Three	1	00.42
10	Own Tractor	No	216	90.00
		Yes	24	10.00
11	Information sources	Neighbors	153	63.75
		Local leaders	29	12.08
		Panchayat/society officials	11	4.58
		News papers	115	47.92
		Radio	14	5.83
		Television	125	52.08
		Cinema/film shows	0	0
		Dealer	55	22.92
		VLW/AEO/AO/KVK-SMS	153	63.75
		Leaflets/ Krushi Swandini/ Magazine	41	17.08
		Internet	0	0
12	Information sources level	Low (Up to 33.33)	169	70.42
		Medium (33.34 to 66.66)	71	29.58
		High (Above 66.67)	0	00.00
13	Type of crop	Cereals/ millets	58	24.17
		Pulses	213	88.75
		Soybean	219	91.25
		Cotton	103	42.92
		Fruits and vegetables	26	10.83
		Flower crops	4	1.67
		Medicinal and aromatic	2	0.83
14	Crop Insurance Facility availed during 2012-13	Yes	53	22.08
		No	187	77.92
15	Defaulter Position during 2012-13	Yes	53	22.08
		No	187	77.92
16	Amount of Crop Loan Availed during 2012-13	Not availed	88	36.67
		Upto 25,000	26	10.83
		25,001-50,000	57	23.75
		50,001-1,00,000	43	17.92
		1,00,001-2,00,000	17	7.08
		Above 2,00,000	9	3.75

Table 2 : Ranking of the selected Factors according to their Mean Severity Score amongst selected respondents

Sr.No.	Factors	Ranking of Factors & Mean Severity Score (MSS) N=240
1	Non-remunerative prices	I (4.00)
2	Weather related uncertainties	II (3.99)

3	Fluctuation in market rates	III (3.95)
4	Rise in cost of inputs	IV (3.92)
5	Lack of irrigation facilities	V (3.87)
6	Lack of accurate weather information	V I(3.66)
7	Crops damages by wild animals	VII (3.46)
8	Unavailability /high wages of labour	VIII (3.38)
9	Yield uncertainties	IX (3.37)
10	Lack of storage facilities	X (3.16)
11	Inadequate market facilities	XI (2.87)
12	Problem of electric Load shedding	XII (2.66)
13	Lack of technical knowledge	XIII (2.57)
14	Non availability of chemical fertilizers in market at proper time	XIV (2.23)
15	Restricted credit and non-availability at proper time	XV (2.02)
16	Spurious quality seeds	XVI (1.97)

Table 3 : Distribution of respondents according to Composite index of Agrarian Distress

Sr.No	Composite Index of Agrarian Distress (0-1)	Respondents N=240	
		Frequency	%
1	Low (Upto-0.33)	0	00.00
2	Medium 0.34-0.66)	1	0.42
3	High (Above 0.66)	239	99.58
	Total	**240**	**100.00**

Table 4 : Suggestions given by farmers to prevent agrarian distress proneness levels

Sr.No	Suggestions	Respondents N=240	
		Frequency	%
1	Remunerative prices to farm produce.	240	100.00
2	Timely input in low costs	230	96.00
3	Provide subsidy for fencing the farms	227	95.00
4	Provision/ creation of irrigation facilities.	200	83.00
5	Provide more subsidy for purchasing tractor	180	75.00
6	Construct the cement plug on every *Nala*	160	67.00
7	Abundant electric supply on day time for farming.	127	56.00
8	Availability of information about Govt. Schemes and agricultural technology.	125	52.00
9	Assessments of crop insurance risk should be done at village levels.	100	42.00
10	Promote the export of farm produce for getting benefits to the farmers	100	42.00

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Consequences of Farmers Suicide and Suggestions Perceived from Victim's Households to Prevent Suicides in Vidarbha Region

By Dr N. M. Kale, Dr. D. M. Mankar & P .P. Wankhade
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra), India

Abstract- The present research study was carried out with an exploratory design of social research in suicide hit six districts of Vidarbha region of Maharashtra. These districts were Yavatmal, Washim, Buldana, Akola, Amravati and Wardha. Researcher had selected 200 victims by proportionate method of random sampling and data was collected from victim's households by conducting detail interview. Interview was conducted at residence of respondent so as to review over all situation of the family by researcher. In addition to personal interview, RRA technique, time line study for historical perspectives, observations, discussions with family members and discussions with key informants (Police Patil, Sarpanch, local leaders, other farmers of that village), reviewing victims' actual records of institutional debts etc. were some important methods used for data collection. Findings of the study revealed that the economic consequences of suicides are fatal for the family of the incumbent– includes loss of income, asset depletion and deterioration of human capital among others.

Keywords: *consequences of farmers' suicide, suggestions to prevent suicides, etc.*

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Consequences of Farmers Suicide and Suggestions Perceived from Victim's Households to Prevent Suicides in Vidarbha Region

Dr N. M. Kale [α], Dr. D. M. Mankar [σ] & P .P. Wankhade [ρ]

Abstract- The present research study was carried out with an exploratory design of social research in suicide hit six districts of Vidarbha region of Maharashtra. These districts were Yavatmal, Washim, Buldana, Akola, Amravati and Wardha. Researcher had selected 200 victims by proportionate method of random sampling and data was collected from victim's households by conducting detail interview. Interview was conducted at residence of respondent so as to review over all situation of the family by researcher. In addition to personal interview, RRA technique, time line study for historical perspectives, observations, discussions with family members and discussions with key informants (Police Patil, Sarpanch, local leaders, other farmers of that village), reviewing victims' actual records of institutional debts etc. were some important methods used for data collection. Findings of the study revealed that the economic consequences of suicides are fatal for the family of the incumbent– includes loss of income, asset depletion and deterioration of human capital among others. The above mentioned consequences faced by the family members need to be taken into consideration by various government and non-government organizations and social workers for planning various measures for survival, rehabilitation and future of the victims' families. Majority of the victims' family members suggested for remunerative prices to their farm produce and provision/ creation of irrigation facilities for their farming as the important measures to be taken to prevent the recurrence of suicide tragedies. All these suggestions should also be considered by the policy makers to prevent the suicidal tendency by farmers in distress prone districts of Vidarbha.

Keywords: consequences of farmers' suicide, suggestions to prevent suicides, etc.

I. Introduction

"Jai Jawan, Jai Kisan" – Lal Bahadur Shastri, this slogan of a visionary Late. Prime Minister has lost its potential over the time. After independence, according to Gandhiji's vision of Gram-Swaraj, villages and specially farmers were to be the main focus of any development plan of India. As years pass by, agriculture as an industry lost its importance for policy makers of India. This over the time caused severe distress among the farmers leading to recent dramatic rise in the number of suicides among farmer community. Every day in newspaper invariably there is news related to farmer's suicide.

Government of India had declared 31 districts as distressed district where the Prime Minister's special rehabilitation package is being implemented. In these 31 districts there are six districts from Vidarbha region of Maharashtra. (Anonymous, 2006).In Vidarbha particularly in six districts namely Yavatmal, Amravati, Buldana, Washim, Akola and Wardha, the incidence of suicide of farmers has increased tremendously. Since January 2001 to August 2014, total 10,451 farmers committed suicide (Anonymous, 2014).

This is what we have been hearing from Vidarbha and other part of the country over the last thirteen years. This is now the researchable issue. This research paper deals with various consequences within family after suicidal death of family head or victim farmer in due course of time and for taking suggestions from victim's households, for avoiding this tragic phenomenon, so that in future, we can overcome important root causes by applying various planning and developmental measures in agriculture and with the families of suicide farmers.

II. Methodology

The present study was based on exploratory design of social research and carried out in suicide hit six districts of Vidarbha region of Maharashtra. These districts were Yavatmal, Washim, Buldana, Akola, Amravati and Wardha. In this study respondents were the households of selected victim who committed suicide during 1st January 2006 to 31st December 2006 and had declared as a legal victims by district level committee headed by Collector of the respective district, for allotting compensation of Rs. 1 lakh and had got Rs. 1 lakh compensation. The time period 1st January to 31st December 2006 was selected purposively as in this period maximum numbers of suicides were occurred in selected districts of Vidarbha. Before sampling researcher had contacted personally to the collector

Author: Associate Professor (Extension Education), Department of Extension Education, Post Graduate Institute, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra).
e-mail: nmkale1964@gmail.com

offices of these selected districts, and obtained the complete list of farmers those who committed suicide during 1st January to 31st December 2006. In all, there were 1448 total suicide cases in selected six districts, out of which 874 cases were declared as illegal and 574 cases were declared as legal victims. From the list of 574 legal suicide cases, researcher had selected 200 victims by proportionate method of random sampling. It covers 178 villages and 34 *tahsils / talukas* of six districts.

As suicide is a sensitive social issue and thus the investigation has to be made with very guarded and careful manner, and without hurting the sentiments of the family. Data were collected by personal interview method with the help of structured and unstructured interview schedule. Interview was conducted at residence of respondent so as to review over all situation of the family by researcher. In addition to personal interview, RRA technique, time line study for historical perspectives, observations, discussions with family members and discussions with key informants (*Police Patil, Sarpanch,* local leaders, other farmers of that village), reviewing victims' actual records of institutional debts etc. were some important methods used for data collection.

III. Results and Discussion

a) Consequences

Conceptually, a consequence is defined as the result or effect of an action. Operationally, in present study of farmers' suicide consequences refers to the changes that occurred within the family after suicidal death of family head or victim farmer in due course of time. The changes occurred within family and that also recognized by the family members have been ascertained. While discussing the issue, with victim's households, the different consequences that are presented by family members and also probed by researcher are collected and noted in interview schedule time to time before forgetting the things or leaving the place.

Suicide is a social phenomenon; it creates severe personal, social and economic consequences within family (Jacob 2006). The Vidarbha farmers, who committed suicide, were mostly the family heads and the main bread earner of the family members. The chronically brood agrarian crisis is wholly responsible for their spate of suicides and these suicides have happened, by and large, due to low income level of the households and their deteriorating socio-economic status in the society. Though family head left the severe agrarian crisis, it is very difficult for his family members to survive/ lives in the worst hit zone of Vidarbha. The present field survey has identified various severe consequences or changes that occurred after death of family head within the family and are recognized and perceived by family members. The data pertaining to the identified consequences are presented in four main heads as mentioned in Table 1.

i. *Family disturbance*

In Vidarbha, majority of the farmers, who committed suicide, were from the economically and socially disabled groups. After death of family head by suicide in younger age, whole family was disturbed and faced so many consequences. In over one fourth (25.50%) victims' households, poor economic condition compelled their children's to leave the school and go for wage earning for sharing the consumption expenditure of family.

In 9.00 per cent cases, after death of husband in younger age, widow spouse of victim had left the victim's home and went to live with support of her father and mother (Parents). Impediments of marriages of family members was reported in 5.50 per cent cases, while very less proportion of families (3.50%) children were sent to live with relatives either for education or for wage earning.

ii. *Psychological impact*

After sudden and confidential act of suicide by family head or young member of family, severe psychological impact was observed on other family members. In majority of victims' households (45.50%), due to death of family head, severe anxiety and stress was developing about future life, which leads to mental instability. In 13.50 per cent households; some family members became sick after death of family head and in 4.50 per cent cases sense of hopelessness was reported.

Table 1 : Distribution of victims' household according to their consequences

Sr. No.	Consequences	Number	Percentage
A	Family disturbance		
1	Children of the victims had left the school and went for wage earning	51	25.50
2	Households dislocation and dissolution (particularly victims' wife)	18	9.00
3	Impediments of marriages of family members	11	5.50
4	Children were sent to live with relatives	07	3.50

B	Psychological impact		
1	Develop an anxiety and stress which leads to mental instability	91	45.50
2	Illness of family members	27	13.50
3	Developed a sense of hopelessness	09	4.50
C	Effect on working		
1	Lowered the income of family	113	56.50
2	Loss of interest in work	24	12.00
D	Due to compensation received		
1	Conflict created / developed in family	5	2.50

iii. *Effect on working*

Over half (56.50%) of the households recognized that their family income was lowered after death of family head and 12.00 per cent families expressed loss of interest in farming work.

iv. *Due to compensation received*

For the present study, only the cases those who got the compensation of Rs. 1 lakh were selected, but in meagre cases (2.50%) conflict were created among the spouse of the victims and other older family members. The probable reason is that deceased was the only major income earner for all family members. But while providing Government help, particularly spouse of victim was considered for receiving compensation and not the older family members. But in few cases, spouse of the victim had left the deceased home and went for living with support of her father and mother or living separately. In such cases, conflict was created among the older family members and spouse of the victims due to demand of half compensation from victim's spouse by older family members and due to increasing survival vulnerability of the old family members. These findings are confirmed by the finding of Anonymous (2008) that conflict was created between the victims' spouse and old father of the victim after receiving compensation from Government in Jamb village of Akola District in Vidarbha.

b) Suggestions

Suggestions are one of the important aspects of any research study in social sciences. It refers to the opinion of family members about what action should be taken for avoiding recurrence of suicides, which can help to some extent for finding out ground realities of suicides and help to suggest different measures to solve farmers' distress in Vidarbha region. The responses received from the family members of the deceased farmers were noted and are presented in Table 2.

Table 2 : Suggestions to prevent suicide as perceived by the family members of the deceased farmers

Sr.No	Suggestions to prevent suicide	Frequency	Percentage
1	Remunerative prices to farm produce.	188	94.00
2	Provision/ creation of irrigation facilities.	142	71.00
3	Complete ban on alcohol and gambling	62	31.00
4	Family counseling for increasing self-confidence through local leaders/ social workers.	62	31.00
5	Abundant electric supply for farming.	60	30.00
6	Complete waiving of old loans.	58	29.00
7	Provision of easy, timely and sufficient credit at low interest rate.	55	27.50
8	Creation of subsidiary occupations and other income sources.	45	22.50
9	Crop insurance	32	16.00
10	Availability of information about agricultural technology.	30	15.00
11	Mass marriage system should be encouraged in society.	28	14.00
12	Timely employment by creating non-farm employment opportunities.	26	13.00
13	Strict vigil on the quality of inputs in the market.	20	10.00
14	Immediate government help in natural calamities and in losses by wild animals.	20	10.00
15	Compensation of Rs. one lakh should be stopped.	04	2.00

It is clear from Table 2 that majority (94.00%) family members of the deceased farmers suggested for remunerative prices to their farm produce and provision/ creation of irrigation facilities (71.00%) as the important measures to be taken to prevent the recurrence of suicide tragedies.

Sizable family members of the deceased farmers suggested for complete ban on alcohol and gambling (31.00%), family counseling for increasing self-confidence through local leaders/ social workers (31.00%), abundant electric supply for farming (30.00%), complete waiving of old loans (29.00%), provision of easy, timely and sufficient credit at low interest rate (27.50%), creation of subsidiary occupations and other income sources (22.50%), crop insurance (16.00%), availability of information about agricultural technology (15.00%), mass marriage system should be encouraged in society (14.00%), timely employment by creating non-farm employment opportunities (13.00%), strict vigil on the quality of inputs in the market (10.00%), immediate government help in natural calamities and in losses by wild animals (10.00%), and compensation of rupees one lakh should be stopped (2.00%) were the measures suggested by family members of the deceased farmers to solve farmers' distress in Vidarbha region.

IV. Conclusion and Implication

For many victims' spouse or many widows and their family members, suicide is not about the dead, it is about the living and for them they soldiers on. Every moment of life has been a struggle for them. The above mentioned consequences faced by the family members need to be taken into consideration by various government and non-government organizations and social workers for planning various measures for survival, rehabilitation and future of the victims' families. Majority of the victims' family members suggested for remunerative prices to their farm produce and provision/ creation of irrigation facilities for their farming as the important measures to be taken to prevent the recurrence of suicide tragedies.

Farmers' suicides are the result of the agrarian crisis, which cannot be solved only with firefighting techniques. A well thought concerted strategy for both the short and long term is needed. While planning short and long term measures, the government should to focus on above suggestions made by the family members of deceased farmers. But immediately in short term measures there is an urgent need to declare the remunerative prices for all crops on the basis of cost of cultivation and secondly, in long term measures, the government should focus more on increasing rural infrastructure particularly irrigation facilities in Vidarbha region, because irrigation and other infrastructure facilities are very poor in Vidarbha region. This will definitely help in increasing crop production, productivity, and change in cropping pattern, cropping intensity, and increase in the allied occupations in study area. These things are necessary not only for uphold the farmers economically but also for sustaining them socio-psychologically.

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The Effect of Agricultural Credit Guarantee Scheme Fund (ACGSF) on Production Efficiency of Rural Farmers in Benue State, Nigeria

By Enenche E. A, Ohen. S. B. & Umeze. G. E.
Benue State Fadama III Development Project, Nigeria

Abstract- This research work examined the effect of ACGSF on income generation and poverty alleviation among rural farmers in Benue state. Results of the Stochastic frontier and the inefficiency model showed that the variance parameters for ∂2 and y were 0.2237 and 0.5209 which was significant at 1 percent level. The sigma squared indicated the goodness of fit and correctness of the distributional form assumed for the composite error term while the gamma Y indicates that the systematic influences that are unexplained by the Production Function and the dominant sources of random errors. This showed that the inefficiency effects makes significant contribution to the technical inefficiencies of ACGSF beneficiaries.

Keywords: agricultural credit guarantee scheme fund, public private partnership, agricultural protection, production efficiency, agricultural credit, poverty reduction, income generation, resource use efficiency, input/output relationship, technical efficiency.

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The Effect of Agricultural Credit Guarantee Scheme Fund (ACGSF) on Production Efficiency of Rural Farmers in Benue State, Nigeria

Enenche E. A [α], Ohen. S. B. [σ] & Umeze. G. E. [ρ]

Abstract- This research work examined the effect of ACGSF on income generation and poverty alleviation among rural farmers in Benue state. Results of the Stochastic frontier and the inefficiency model showed that the variance parameters for ∂2 and y were 0.2237 and 0.5209 which was significant at 1 percent level. The sigma squared indicated the goodness of fit and correctness of the distributional form assumed for the composite error term while the gamma Y indicates that the systematic influences that are unexplained by the Production Function and the dominant sources of random errors. This showed that the inefficiency effects makes significant contribution to the technical inefficiencies of ACGSF beneficiaries. The central recommendation made as a way of ensuring production efficiency and poverty alleviation was that farmers should form cooperative societies so that they easily obtain inputs at a lower cost and without conditions, also getting information on production practices.

Keywords: agricultural credit guarantee scheme fund, public private partnership, agricultural protection, production efficiency, agricultural credit, poverty reduction, income generation, resource use efficiency, input/output relationship, technical efficiency.

I. Introduction

Agricultural Credit Guarantee Scheme Fund is one of the laudable programmes put in place by the Federal Government of Nigeria to boost agricultural production, generate revenue for the farmers, alleviate poverty and earn foreign exchange for the country. It is also aimed at ensuring food security, rural transportation and improved nutritional health profile of the citizens (ACGSF manual, 2005).

In addition to the Agricultural Credit Guarantee Scheme Fund which is a Federal government initiative to boost agriculture and rural development, the Benue State Government has evolved her own initiative towards boosting agricultural development programmes to ensure food production amongst other objectives. Poverty is a global phenomenon which threatens the survival of the human population. This informed the United Nations declaration of 1996 as the International Year for the Eradication of poverty (CBN economic and Financial Review, 1996).

It is also important to note that the major goal of any country is to have a society that efficiently harnesses its scare resources such that nobody suffers from basic human needs. Studies on poverty in Nigeria indicated that more than 70% of Nigerians are poor (NEEDS, 2004). Further studies have also shown that about 25% of Benue population are extremely poor, 39% are moderately poor and only a small fraction of 36% are able to meet basic human needs (SEEDS,2004). Also vast majority of the poor live in rural areas and most of them are subsistent farmers.

Though various poverty alleviation programmes and agricultural development policies have been put in place but the twin problems of poverty and absence of food security is still lingering. Even in the urban centres, imported rice and other can foods tend to dominate the market. That this occurs in a country which possesses varying agro-ecological and other natural resources in abundance which is suitable for increased production cannot but be worrisome, hence the establishment of ACGSF to curb the menace.

It is in realization of this economic and social status of the Nigeria rural population and Benue state rural farmers in particular that has necessitated this study with particular focus of ACGSF, which is one of the longest surviving policy strategies towards reducing poverty and improving agricultural output among rural farmers in Nigeria.

a) Objectives of the study

The broad objective of this study is to examine the effect of ACGSF on income generation and poverty alleviation among rural farmers in Benue state. The specific objectives are to:

- Assess the socio-economic characteristics of beneficiaries of ACGSF in Benue state
- Determine the input/output relationship of beneficiaries
- Analyse the resource use efficiency of beneficiaries
- Determine the effect of the Scheme on poverty alleviation

Author α: Benue State Fadama Iii Development Project, Makurdi, Benue State Nigeria. e-mail: ecoenenche@gmail.com
Author σ: Department of Agricultural Economics and Extension, Faculty of Agriculture, University of Calabar, Calabar, Nigeria.
e-mail: drsbohen@yahoo.com
Author ρ: C/O Department of Agricultural Economics And Extension, Faculty of Agriculture, University of Calabar, Calabar, Nigeria.
e-mail: geumeze@yahoo.com

- Determine the effect of the Scheme on income generation.

II. Theoretical Framework

This study is noted in the new classical theory of production which is hinged on efficiency. The idea of the neo-classical theory of efficiency is also based on production function which gives the maximum possible output of a given quantity of input. Alimi (2002) stated that resources must be available and efficiently used in order to achieve optimum production level. Hence, the mission of increasing agricultural productivity to sustain food requirement could be facilitated through efficient management of productive resources. The crucial role of efficiency in increasing agricultural output has been widely recognized by researchers and policy makers. It has also remained an important research both in developed and developing countries. This is particular in developing countries where resources are measured and opportunities for developing and adapting better technology are dwindling.

III. Research Methodology

a) Study Area

Benue state is the study area and it is situated in the middle –belt (north – central) region of Nigeria. The state was created in 1976 out of the then Benue – Plateau State. The state which has its capital in Makurdi has a total land area of 30,955 square kilometer. This is located between latitudes 60 251 and 80 81 North and longitude 70471 and 10000 East, Benue State Ministry of Finance and Economic planning (1980). The state is surrounded by five other states, namely, Nassarawa to the North, Taraba to the North East, Cross River to the South, Enugu to the South west and Kogi to the West. There is a short international boundary between the State and the Republic of Camaroon to the South East. The state has a total population of 4.2 million people. About 70% of these people live in rural areas and engage in agriculture, NPC (2006).

The state also has 23 Local Government Councils and it is heterogeneous in terms of ethnic composition. There are three major groups in the state, namely, Tiv, Idoma and Igede. Out of the 23 Local Government Areas (LGAs), the Tivs have 14, Idoma 7, and Igedes 2. Population of the state by ethnic grouping is 60.9%, 30.4% and 8.7% respectively.

Benue State has lime stone and coal as its mineral resources. Its agricultural resources include yam, Soya beans, groundnuts, beniseed, melon, cassava, cashew nut, pepper, guinea corn, Barbara nut etc. This is perhaps why the state goes by the appellation "Food Basket of the Nation". The major occupation of the people in the state is farming. Those who are not in the farming occupation are either in the civil service or in some menial business.

b) Sample and Sampling Technique

Multi Stage Random Sampling was used to select 450 farmers who served as respondents of the study. In stage 1, 3 LGAs were randomly selected from each of the three senatorial zones in the State giving a total of 9 LGAs. These nine LGAs according to their zones are: Zone A: Kwande, Vandeikya and Logo, Zone B: Makurdi, Gwer West and Tarka and Zone C: Otukpo, Ogbadibo and Obi. In the second stage, five wards were selected from each of the 9 LGAs. In the final stage, 10 households were systematically selected from each of the 45 wards giving us a total of 450 farmers used as sample size.

A total of 450 farmers were selected from nine LGAs out of the 23 LGAs in the State. Each tenth beneficiary is selected and interviewed. Based on this method, 45 ACGSF beneficiaries were considered from each of 45 selected wards, given a total of 450 respondents for the study.

c) Analytical Technique

The study made use of descriptive statistics and inferential statistics. The descriptive statistics include frequency distribution, tables, simple percentages and budgetary analysis

d) Model Specification: Stochastic Frontier Model

The stochastic frontier production function adopted in this study is specified by the Cobb-Douglas functional form defined thus:

$$\text{Log } Yi = b_0 + b_1 \log X_1 i + b_2 \log X_2 i + b_3 \log X_3 i + b_4 \log X_4 i + b_5 \log X_5 i + Vi - Ui$$

Where:

Yi = Output of the ith farmer (kg)

X_1 = Farm size (ha)

X_2 = Labour (man days)

X_3 = Fertilization (dummy: 1 = use fertilizer, 0 = not use fertilizer)

X_4 = Planting materials (kg)

X_5 = Pesticides (in litres)

β_o = Intercept

β_1 = Vector of Production function Parameters to be estimated;

i = 1, 2, 3 ….nth farmer

j = 1, 2, 3…nth input

Vi = Random error that is assumed to be normally distributed with zero mean and constant variance ($\delta v2$) and μi is technical inefficiency effect independent of vi, and have half normal distribution with mean equal to zero ($x = 0$) and constant variance.

Following Battese and Coelli (1995), the mean of farm – specific technical inefficiency μi is defined as:

$$i = 0 + 1Z_1 + 2Z_2 + 3Z_3 + 4Z_4.$$

Where:

i = Technical Inefficiency Effect of the ith farm
Z_1 = educational level of farmers
Z_2 = household size
Z_3 = experience of farmers
Z_4 = age of farmers in years
= parameters to be estimated

Output is expected to be influenced positively by farm size, labour, fertilizer used, agro chemical and quantity of seed planted. Outputs of farmers are expected to have a negative effect on the technical inefficiency effect. This is so because as farmers switch from planting a particular variety of input to another, effective utilization of inputs would be achieved which in turn, increases the technical efficiency of the farming operation.

Age of farmers is expected to have a negative effect on technical inefficiency effects. This is because older farmers may be less energetic and may have developed inefficient production routines and practices, leading to a negative impact of age on efficiency.

Educational level of farmer is also expected to have a negative effect on technical inefficiency. This is because the ability to read could increase the capacity of farmers to understand the implication of the use of some farm inputs and wrong utilization of loans. The result of this would be effective utilization of inputs, which in turn, increases the technical efficiency of the farming operation.

Household size is expected to have negative effect on technical inefficiency and is proxy for family labour. The larger the household size, the more family labour. And the more labour the more the utilization of input.

Farming experience of farmer is expected to have negative effects on technical inefficiency. This is because farming experience determines the rate of adoption of improved techniques. The more the farming experience, the higher the rate of adoption of improved techniques. This would further lead to effective utilization of inputs which in turn increases the technical efficiency of the farming operation.

Availability of credit is also expected to have a negative effect on technical inefficiency. This is because the more the availability of credit, the more the farming activity that will be engaged. Thus this will lead to diversification of fund to both agricultural and non-agricultural activities which will further lead to increase in technical efficiency of the farming activities.

IV. Results and Discussion

a) *Socio-economic characteristics of respondents*

Table 1 : Age, Marital Status, Education and Gender of Respondents

Socio-Economics	Frequency	Percentage (%)
Age		
20-25	06	1.3
26-35	38	8.4
36-45	217	48.3
46-55	180	40
60	09	2
Total	450	100
Marital Status		
Married	3.7	70.4
Single	38	8.4
Divorced	53	11.8
Widow	37	8.3
Widower	5	1.1
Total	450	100
Education Background		
No formal Education	73	16.3
Primary Education	278	61.8
Secondary Education	86	19.1
Tertiary Education	13	2.9
Total	450	100
Gender		
Male	287	64

Female	163	36
Total	450	100

Source: Field survey, 2013.

Table 1 shows that more than half of the farmers (88.3%) were found to be within the age bracket of 36 to 55 years. This is contrary to the findings of past studies which reported the farming population to be ageing (Idown, 1988).

The study further showed that the marital status of the respondents who are married is 70.4%. This may perhaps be a reason why the beneficiaries of the scheme may be doing well with the credit obtained because there will be combined efforts in carrying out their economic activities. The table further showed that 8.4% of the respondents are single and 11.7% are divorce this could have negative effect on the beneficiaries as they will need to employ extra hands to carry out their farming activities. The table in addition shows that 8.3% and 1.1% of the respondents are widows and widowers respectively. This also reveals that there are more widows than widowers.

On educational background of respondents, 16.3% are without formal education while those with only primary education are 61.7%. This further means that farming at the grassroots is done by people who are not too learned. Those with secondary and tertiary education are 19.1% and 2.9% respectively. This is perhaps another factor militating against the judicious utilization of fund (credit) obtained. Those with tertiary education who could be receptive to changes and innovations are so infinitesimal to effect any meaning change. It is significant to note that education influences productivity by affecting farmer's ability to comprehend the production system and complicated information relating to modern technology, and their ability to adjust quickly to farm management practices (Isah, 1995). This means that education is a socio-economic factor that influences farmers' awareness, perception, reception and adoption of modern production practice (Salamatu, 2005).

From gender perspective, the male were found to make up the bulk of ACGSF farming population in the study area representing 64%. About 36% of the sampled beneficiaries of ACGSF are women. This confirms several studies have indicated that women constitute up to 40% of African agricultural work force.

b) Contact with Extension workers and Farming Experience

Table 2 : Distribution of farmers based on Contact with Extension workers, Farming Experience

	Frequency	Percentage (%)
Contact with Extension workers		
Yes	173	38
No	277	62
Total	450	100
Years of Experience		
0-10	73	16.3
11-20	86	19.1
21-30	278	61.8
31-above	13	2.9
Total	450	100

Source: Field survey, 2013.

Contact with extension farmers is expected to give farmers a good opportunity to get information on better managerial practices, new technology and other auxiliary services. Table 2 showed that only 38% of the beneficiaries of the scheme have contact with extension agents. This indicates that large number of farmers has no opportunity of getting information about new and modern production practices from the extension agents.

Table 2 reveals further that 71.8% of the respondents have more years of farming experience ranging from 20 to 30 years and 35.4% of the respondents have years of farming experience ranging from 0 to less than 20. 2.9% of the farmers have years of experience of 30 years and above. Some authors have suggested that farmers with more years of experience are likely to be more efficient in production.

c) Agricultural Activities undertaken by the beneficiaries

Table 3 : Distribution of respondents based on type of agricultural activities

Type of Agricultural Activity	Frequency	Percentage
Rice production	76	16.9
Guinea corn (sorghum) production	79	17.6

Maize production	19	4.2
Cocoa production	00	00
Fish production	00	00
Yam production	155	34.4
Groundnut production	08	1.8
Pepper production	15	3.3
Poultry production	5	1.1
Cassava production	93	20.7
Total	450	100

Source: Field survey, 2013.

Table 3 shows the nature of agricultural enterprise undertaken by the beneficiaries of ACGSF in the studied area. The table further shows that most of the farmers engaged in yam production with a total of 155 of the beneficiaries representing 34.4% of the respondents. This is followed by cassava production which is 20.7 of the respondents and Guinea corn (sorghum) production which is 17.6% of the total respondents. This explains that yam, cassava and sorghum is produced more in the studied area. However, other Crops like rice, maize, pepper and groundnut are also produced but not as much as yam, sorghum, cassava and rice. The table further reveals that livestock production is not practiced much in the studied area.

d) Cost and Returns

Table 4 : Annual Cost Returns to Beneficiaries of ACGSF

Item	Average cost (naira) (mean value of AC)	Percentage
Land preparation	12,000.00	17.39
Planting	15,000.00	21.74
Fertilizer application	6,800.00	9.86
Weeding	7,200.00	10.43
Harvesting	7,733.00	11.21
Seeds/cuttings	20,270.00	29.38
Total variable cost (TVC)	69,003.30	100.00
Total Revenue (TR)	136,666.67	-
Gross Margin (TR-TVC)	67,663.37	

Source: Field survey, 2013.

Beneficiaries of ACGSF may not be producing for the purpose of meeting subsistence needs alone. The farmers may be interested in selling their outputs to raise income. For this reason, efforts were made to determine the cost associated with rural farming and also revenue that accrues to the farmers efforts. In this regard, only the variable cost of production was considered while the profitability was measured as gross margin.

Summarily, labour related activities (land preparation, planting and fertilizer application) and other input making up the short run cost of production is put at 69,003.30 naira to cultivate a hectare of farmer in the study area. Also an average of 136,666.67 naira accrues to a farmer as revenue and 67,663.37 naira is gotten as the gross margin. This translates to approximately 5000.00 naira/per month as income to the farmer. This amount is less than the 18,000.00 naira minimum wage in Nigeria as at the time of this study. It is thus evident that farming is not profitable enough except with improved input so that farmers can work on hectares of land thereby reducing cost of production and increasing marginal revenue.

e) Stochastic Frontier Function Analysis

Table 5 : Maximum likelihood Estimates of the Stochastic Frontier Function and Technical Efficiency

		Coefficient	Standard-error	t-ratio
Constant	β0	0.6444***	0.1005	0.3219
Labour	β1	0.8999**	0.1079	0.4585
ACGSF Fund	β2	0.7780**	0.1077	0.6006
Farm size	β3	0.5499***	0.1143	0.3517
Farming experience	β4	0.6665***	0.1008	0.4932
Planting materials	β5	0.7780***	0.1	0.4932
Pesticides	β6	0.4510***	0.101	0.3912
Constant	δ0	0.7011	0.1002	0.2011
Education	δ1	-0.8494	-0.1314	-0.2045
Household size	δ2	-0.7009	-0.1055	-0.4211
Age	δ3	-0.5987	-0.1102	-0.2131
Farm experience	δ4	-0.6912	-0.1048	-0.4125
Farmers income	δ5	-0.5487	-0.1165	-0.3121
Variance Parameters				
Sigma squared	(δ2)	0.2237		
Gamma	γ	0.5209		
Log Likelihood Function		-0.5331		
LR TEST		0.4569		

*** = significant at 5% level, *** = significant at 1% level*

Stochastic frontier and the inefficiency model which show that the variance parameters for 2 and y are 0.2237 and 0.5209. They are significant at 1 percent level. The sigma squared 2 indicates the goodness of fit and correctness of the distribution to the technical inefficiencies of ACGSF beneficiaries. Thus, the hypothesis that the coefficient of β =0 is rejected. The result shows that inefficiency effects were present and significant. The variance parameters for and Y are 0.2237 and 0.5209. They are significant at the 1 percent level. The sigma squared indicates the goodness of fit and correctness of the distributional form assumed for the composite error term while the gamma Y indicates that the systematic influences that are unexplained by the Production Function and the dominant sources of random errors. This means that the inefficiency effects make significant contribution to the technical inefficiencies of ACGSF beneficiaries. Thus, the hypothesis that the coefficient of β = 0 is rejected. The result shows that the inefficiency effects were present and significant.

Labour (β1). The coefficient of labour (0.999) was significant and had a positive sign. This shows the importance of labour in rural farming in the study area. Several other studies (Okike, 2000; Awoyemi, 2000) have shown the importance of labour in farming, particularly in developing countries where mechanization is only common in big commercial farms. In the study area, farming is still at the subsistence level generally. This involves the use of traditional farming implements such as hoe and machete. Human power plays crucial role in virtually all farming activities. This situation has variously been attributed to small and scattered land holding, poverty of the farmers and lack of affordable equipment (Umoh & Yusuf, 2000). It appears that labour will continue to play important role in agriculture,

affecting its efficiency, until those factors constraining mechanization are addressed.

ACGSF Credit (β2). The production elasticity of output with respect to the amount of loan granted to farmers is 0.7780. By increasing the amount of loan granted to farmers by 10%, output level will improve by a margin of 7.780%. The estimated coefficient is highly statistically significant at 1% level.

Farm size (β3). The coefficient of farm size (0.5485) was found to be positive and significant at 1% level. This result is in line with the findings from Okike's (2000) study of farmers in the savanna zone of Nigeria reported farm size to be significant and positive for the low-population-high-market domain. The result could mean that it is possible to expand farming activity in the study area. It may be possible that competition between infrastructures development and crops for land is not yet keen enough to jeopardize the expansion of crops production. Statistically, the magnitude of the coefficient of farm size shows that output is inelastic to land or farm size. If the farm size is increased by 10%, output level will improve by less than proportionate (by a margin of 5.485%). This means that there is still some scope for increasing output per plot by expanding farmland.

Fertilization (β4). The production elasticity of output with respect to quantity of fertilizer is 0.1796. By increasing the quantity of fertilizer by 10%, output level will improve by a margin of 1.796%. The estimated coefficient is highly statistically significant at 1% level. The finding is at variant with the report by Winrock (1992), which shows non-significant contribution of livestock manure and crop residues in semi-arid sub-Saharan. Though not ascertained, it may be possible that none separation of fertilizer, in to their different forms (e.g. crop residue, livestock manure, inorganic fertilizer, etc) account for the differences in the findings of this study and that reported by Winrock.

Planting materials (β5). The coefficient of planting materials (0.5209) was positive and significantly different from zero. This implies that planting materials are important in crop production in the study area.

Inefficiency Effects (Z1 – Z4). The contribution of farmers' personal characteristics-level of education, age, household size and framers income to farm inefficiency was also studied. The coefficients of all variables are negative. In addition, none of the variable is significant; they do not deserve further discussion.

f) Technical Efficiency Analysis

Table 6 : Distribution of Technical Efficiency ratings among beneficiaries of ACGSF in the study area

Efficiency indices	Frequency of farms	Percentage
0.10 - 0.19	7	2
0.20 – 0.29	3	1
0.30 – 0.39	14	3
0.40 – 0.49	33	7
0.50 – 0.59	169	38
0.60 – 0.69	149	33
0.70 – 0.79	45	10
0.80 – 0.89	30	7
0.90 – 1.00	-	-
Total	450	100
Mean efficiency	0.59	
Minimum	0.11	
Maximum value	0.89	
Mode	0.7	

Source: computed from MLE

Individual farm technical efficiency scores. In line with the parameters already presented and discussed, the technical efficiency score of each respondent was also estimated. This is presented in Table 6 where more than 65% of the respondents were found to be more than 50% technically efficient. About

13% of the respondents were found to be less than 50%. The most efficient ACGSF beneficiaries operated at 89% efficiency while the least efficient ACGSF beneficiaries were found to operate at 11% efficiency level. ACGSF beneficiaries performed at an average technical efficiency of 59% while the most frequently occurring efficiency score was 70%. From the results obtained, although ACGSF beneficiaries were generally relatively efficient. However, by increasing the efficiency in their farming activities would bridge the gap of the remaining 30% and attainment of the 100% optimum would be achieved.

V. Conclusion

The results of the research indicated that ACGSF loans were not adequate for farmers to increase output in the study area. Farming system and practices are characterized by the use of crude implements. These are pedestals on which low yield and poor financial returns are perpetrated. Also agricultural inputs are not within reach, infrastructural facilities are grossly inadequate, illiteracy of household head, lack of farming experience and increased dependency ratio are on the increase and this could boost the tempo of poverty and low production of agricultural commodities.

VI. Recommendation

- As a way of ensuring production efficiency and poverty alleviation among rural farmers, farmers should form cooperative societies so that they easily obtain inputs at a lower cost and without conditions, also getting information on production practices and even providing distribution channels for farmers produce.
- A sustainable macro-economic framework need to be put in place in order to attract Foreign Direct Investment (FDI), which can be an important source of needed credit as well as bringing access to markets, modern management and technology. Macroeconomic stability strengthens confidence and predictability for producers and facilitates risk assessment for lenders.
- The agriculture banking sector must seek ways to diversify instead of reliance on the State to provide credit. A public-private partnership is the hub upon which sustainable agriculture capable of maintaining production efficiency and alleviating poverty can be achieved.
- A good synergy of public-private partnership policy in the provision of education should be evolved so that basic challenges with respect to innovations and changes would be tackled. This would enable farmers make better technical decision and also help in allocating their production input effectively.
- Enabling environment should be created for improved loan recovery like a legal unit under an autonomous condition to prosecute loan defaulters so as to enhance the viability of the institution and prevent it from collapse under pressure of defaulters.

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Mopane Worm (*Gonimbrasia belina*) Utilisation, a Potential Source of Protein in Fortified Blended Foods in Zimbabwe: A Review

By Raphael Kwiri, Clive Winini, Perkins Muredzi, Jeritah Tongonya, Wishmore Gwala, Felix Mujuru & Shannon T. Gwala

Harare institute of Technology/University, Zimbabwe

Abstract- Primarily, Mopane worm (*G. belina*) forms a major part of the most consumed and highly nutritious (protein averages 55.41%) insect in Zimbabwe. The insect offers a great potential source of protein that could be utilised to alleviate diet deficiencies diseases among most vulnerable groups in society. The insect could form a foundation for new food products that are based on its substantial nutritive value. The paper reviews nutritional potential of G. belina to the human diet through its use in fortified blended foods (FBFs) formulations, making it an alternative substitute for conventional sources of protein, such as soybean, common bean and nuts. In view of that, *G. belina* through FBFs could be used as food aid in humanitarian relief programs in Zimbabwe in fighting against rampant malnutrition especially among rural population and urban dwellers.

Keywords: *mopane worm, insects, nutrition, fortified blended foods, proteins.*

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Abstract- **Primarily, Mopane worm (*G. belina*) forms a major part of the most consumed and highly nutritious (protein averages 55.41%) insect in Zimbabwe. The insect offers a great potential source of protein that could be utilised to alleviate diet deficiencies diseases among most vulnerable groups in society. The insect could form a foundation for new food products that are based on its substantial nutritive value. The paper reviews nutritional potential of G. belina to the human diet through its use in fortified blended foods (FBFs) formulations, making it an alternative substitute for conventional sources of protein, such as soybean, common bean and nuts. In view of that, *G. belina* through FBFs could be used as food aid in humanitarian relief programs in Zimbabwe in fighting against rampant malnutrition especially among rural population and urban dwellers. However, several aspects related to food safety and sustainability in insects harvesting are of great concern that needs to be underscored. Further research would be necessary to ascertain the real process development and formulation of FBFs where *G. belina* has been exploited as a source of protein.**

Keywords: mopane worm, insects, nutrition, fortified blended foods, proteins.

I. Introduction

Entomophagy is regarded as a practice of eating insects as food (Srivasatva and Naresh Badu, 2009; Gahukar, 2011). FAO/WHO (2013) estimated that, nearly 1,900 insect species has shown to be edible worldwide, mainly in developing countries such as Zimbabwe (Glew *et al.*, 1999; Ghazoul, 2006; Dube and Dube, 2010). Guhukar (2011) considered, edible insects as natural renewable resource of food that provides nutritional, economic and ecological benefits to the communities. According to Dube and Dube (2010), *G. belina* is the most consumed insect in most communities of Zimbabwe in both rural and urban settlements constituting parts of the traditional diets.

As a global obligation, the Food and Agriculture Organization (FAO, 2010a; FAO., 2010c) of the United Nations initiated a policy and recommended programs that will use insects as a source of protein to feed people. Several authors confirmed that, insects are nutritious food that provide proteins (amino acids including methionine, cysteine, lysine, and threonine), carbohydrates, fats, some minerals and vitamins, and have high energy value (Capinera, 2004; Johnson, 2010; Xiaoming *et al.*, 2010). For instance caterpillars to which *G. belina* belongs, contain proteins to the extent of 50–60 g/100g dry weight. In addition insects proteins are highly digestible (between 77% and 98%) (Ramos-Elorduy, 1997a), although presence of chitin lowers their digestibility, but its removal greatly increases the quality of insect protein (DeFoliart, 1997). Equally, humans digestive flora is able to digest chitin due to the presence of two catalytically active chitinases namely AM Case and chitotriosidase (Van, 2003; Synstad *et al.*, 2004; Paoletti, 2005; Muzzarelli *et al.*, 2012) which alternatively works in different pH ranges (Boot *et al.*, 1995; Renkema *et al.*, 1995; Boot *et al.*, 2001; Chou *et al.*, 2006).

Apart from the above reason, nutritious foods derived from insects present a new available source of protein and requisite step to alleviate food security problems in many developing countries (Kent, 2002; Rowe *et al.*, 2008; Gahukar, 2009; Kumar, 2010). According to Gahukar (2009), food security in developing nations has become problematic due to increased population growth, consumption and demand patterns (Beddington, 2010) and possible decline in food availability. This is against a backdrop in agricultural productivity exacerbated by recent rampant natural factors such as climate change, energy crisis, decreasing soil fertility, incidence of pests and plant diseases, and man-made situations such as lack of purchasing power of consumers and disparity in food distribution (Kumar, 2005; Kumar, 2010; Gahukar, 2011). Currently, adequate human nutrients in form of FBFs are complemented by plant seeds such as soybean (as corn/wheat soya blend), cowpeas, nuts and common bean which are productively on a downward trend (Moreki *et al.*, 2012). Consequently, chronic malnutrition is rampant in many developing nations (Gahukar, 2011; Kinyuru *et al.*, 2011; FAO/WUR., 2013) especially to vulnerable group of the society such as children and lactating mothers (Oniang

Author α σ ρ ω ¥ § χ: Department of Food Processing Technology, School of Industrial Science & Technology, Harare Institute of Technology, Ganges Rd, Belvedere, Harare, Zimbabwe.
e-mails: rkwiri@hit.ac.zw, kwirir@gmail.com;

and Mutuku, 2001; ENCU, 2004). Hoppe et al. (2008) stated that, malnutrition promotes various childhood diseases leading to their death. Furthermore, it accelerates rate of unemployment, illiteracy and impedes overall socio-economic development in many developing nations.

In view of the above, Kinyuru *et al*. (2010) and FAO/WUR, (2013), supported use of insect as a food ingredient that enhances both food`s nutritional quantity and quality. Bukkens (2005) confirmed that, insects are commonly mixed with, or often consumed as supplement to predominant diets centred on maize, cassava, sorghum, millet, beans and rice, and form an ingredient to produce other food items. In line with that, Ekpo and Onigbinde (2005) produced bread containing grubs of the African palm weevil (*Rhynchophorus phoenicis)* that provides major and minor nutrients essential for body growth (Ekpo and Onigbinde, 2005). In addition to that, in Kenya wheat buns were enriched (5% mix) with the termite (*Macrotermes subhyalinus)* (Gahukar, 2011), whereas in Mexico, a thin flat bread made from finely ground maize was enriched with ground mealworm *Tenebrio molitor* larvae (Aguilar-Miranda *et al*., 2002) and in Nigeria termite *Microtermes bellicosus* Smeathman are used to enrich maize protein (Bukkens, 1997).

Likewise, global food security problem particularly in developing countries including Zimbabwe (Moreki *et al*., 2012) is a serious challenge that needs to be addressed in the near future. Increased population growth as opposed to rapid decrease in crop and animal productivity, food and nutritional adequacy pose grave challenge to adequate food security. In view of this development, the production of adequate human nutrients such as protein from crop and animal husbandry represents a serious challenge for the future (van Huis, 2012; FAO/WUR., 2013). Therefore, this paper seeks to review *G. belina* utilisation, as a potential source of protein in FBFs in Zimbabwe. The main purpose of this review is to evaluate whether the nutritional potential of *G. belina* could be harnessed into human diet through FBFs as a potential alternative substitute for conventional protein sources such as soybean. Consequently, this review also briefly summarizes the nutritional composition of both *G. belina* as comparable to other conventional protein sources such soybean, cowpea, common bean just to mention a few. If FBFs containing *G. belina* is commercialised and introduced as a FBF to selected vulnerable groups, it may seal a gap between plant and animal based FBFs, wherein the later contain much needed essential animal protein and fats. The review also emphases on probable food safety and sustainability challenges encountered when utilizing *G. belina* in FBFs. In line with this review further work needs to be undertaken to ascertain actual process development and formulation of FBFs where *G. belina* has been utilised as a source of protein.

a) Fortified Blended Foods used in Zimbabwe

According to the World Food Programme (WFP), FBFs are regarded as Specialised Nutritional Foods (SNF) used to improve the nutritional intake of people in need of assistance world-over. Likewise, Hoppe *et al*. (2008) confirmed that FBFs consist of a mixture of cereals, pulses, fats, vitamins, and minerals intended to provide a balanced intake of essential nutrients for vulnerable groups. However, Rowe *at al*. (2008) stressed the need of FBFs to contain adequate calories (400kcal/100g) and protein (15g/100g), fortified with essential micronutrients. SNFs might also include micronutrient powders, Ready-to-Use Foods and High-Energy Biscuits (HEBs). According to Hoppe *et al*. (2008), FBFs are used on a very large scale to feed populations in most developing countries, especially malnourished individuals and vulnerable groups (Hertz, 1997; Rowe *et al*., 2008). Rowe *et al*. (2008) estimated that, around 50%, 20% and 15% of FBFs are distributed globally in Africa, Asia and Latin America and the Caribbean continent respectively. In Zimbabwe alone USAID (2012) reported that, for the period between 2007 and 2011 WFP distributed 43223mt of corn soy blend (CSB) and 602844mt of cereal (maize, sorghum, wheat, rice included) (USAID., 2012).

Hoppe *et al*. (2008) reiterated that, CSB and wheat soy blend (WSB) are the most commonly used FBFs. In Zimbabwe CSB and WSB are the most predominantly distributed FBFs. They are made from the most common or staple grains mainly cornmeal or wheat meal. According to Anonymous (2011), the cereal component provide the largest proportion of energy, a large part of the protein and significant amounts of micronutrients for those dependent on food aid. In addition to that, the soy flour component acts as an important source of protein and provide a range of micronutrients. The blend is mixed and fortified with mineral-vitamins premix sourced from a reputable supplier such as Roche (Anonymous, 2011). Other types of FBFs exist based on sorghum and soy, bulgur, wheat and soy, or combinations of cereals with heat-treated soy in its full fat form or as defatted flour. There are also FBFs that contain milk, corn soy milk (CSM) and wheat soy milk (WSM) (Hoppe *et al*., 2008). WFP has given specifications for the energy, protein, and fat content of the FBFs (Table 1) According to Hoppe *et al*. (2008) CSB consists of; 80% maize and 20% soy, and WSB consists of; 75% wheat and 25% soy. However, FBFs containing *G. belina* is not available and have not been formulated mainly because of lack of adequate studies that have been done to evaluate its suitability based on its extensive nutritional information.

Table 1 : Nutritional value of commonly used food aid commodities (FBFs)

Food commodity (100-200g)	Key ingredients	Energy (kcal)	Protein (g)	Fat (g)
Super cereal plus	Corn/wheat/rice soya, milk powder, sugar, oil, Vitamins &Minerals	394-787 kcal	16-33g (17%)	20g (23%) contains EFA
Super Cereal	Corn/wheat/rice soya, Vitamins & Minerals	376-752 kcal	15-31g (16%)	8-16g (19%)

Source: (WFP., 2013) Specialized Nutritious Foods Sheet

b) Conventional Protein Sources used in Fbfs in Zimbabwe

In Zimbabwe emergency cases which include severe droughts, floods just to mention a few are on an increase thereby placing demands on government and donor community to provide food aid on affected communities. The Government and the donor community are normally involved in providing food (FBFs included) to the affected people. The most common emergency food packages are in the form of maize, which is the staple crop, bulgar, rice, iodised salt, vegetable cooking oil, wheat flour – all which are energy foods; specially formulated food mixes like CSB, WSB, dried kapenta fish, dried legumes (sugar beans, soy, cowpeas, lentils chickpeas, peas, etc) all forming a protein rich component in the food aid.

i. *Soybean (Glycine max)*

Several authors confirmed that, families from Nigeria, Zimbabwe and Kenya that grow and utilise soya been in their diets are healthier than those families that do not use soybean as part of their diets (Mendel and Fine, 1912; Adelodun, 2011). This is owed to great invaluable nutritive and health benefits furnished by soy based products, hence a huge need for a renewed, concerted effort and sustainable incorporation of soybean into African diet. The International Institute of Tropical Agriculture (IITA) soybean success story recorded in Nigeria, Zimbabwe, Uganda and South Africa must be replicated in other African counties (Adelodun, 2011). Mature raw soybeans has a proximate; protein composition of 40.1 - 44.5%, (Table 2) (Da Silva, 2009), though it adequately provide sufficient amount of carbohydrate, digestible fibres and minerals etc. In addition to its high food value, it is one of the least expensive sources of protein when compared to eggs, milk, beef, and cowpea (IART&T., 1998; Adelodun, 2011). Soybean seeds are the most common protein source of fortified blended foods in Zimbabwe. According to the (WHO/FAO, 2007) soybean seeds processing into floor should secure optimum flavour and palatability, as well as to control such factors as trypsin inhibitor, hemaglutinins and other anti-nutritional factors.

ii. *Common bean (Phaseolus vulgaris)*

According to (Gajzaho, 1998) Phaseolus vulgaris is also known as French, garden, haricot, kidney, pinto, navy black, pink, black eye, cranberry, great northern or dry bean and is consumed by humans as green in pods (canning and freezing) or dry seeds. In Zimbabwe common bean is grown for domestic use in rural areas countrywide, consumed as relish and surplus is disposed of to commercial markets. In times of drought, donor agencies supply protein rich common bean as a food supplement. In general, *Phaseolus vulgaris* contains about 15.1-15.4% protein, 48.5-49.5% carbohydrates, and 15.7-15.9% fat and small amounts of other nutrients (Table 2) (Audu & Aremu, 2011).

iii. *Cowpea (Vigna unguiculata)*

Vigna unguiculata is known to be a low input legume crop grown throughout Zimbabwe and Africa. The chemical composition of cowpea is similar to that of most edible legumes. In general, the cowpea contains about 15.5-15.7% protein, 60.2-60.9% soluble carbohydrates and small amounts of other nutrients (Table 2) (Alayande et al., 2012). The cowpea is mainly grown in the rural areas for domestic use and if higher yields are obtained the surplus crop is preserved and used in times of poor harvest. Several authors confirmed that, cowpea seeds resemble other legumes in their potential contribution to protein nutrition based on amino acid profile (Omueti and Singh, 1987; Nielsen et al., 1993; Alayande et al., 2012). In addition cowpeas are lower in anti-nutritional factors than many other legumes as reflected by moderately high protein efficiency ratio values even in unheated seed (Phillips, 1982). Likewise, research has been applied to develop new food ingredients and products made from cowpea and other starchy legumes (Zamora and Fields, 1979; Sosulski *et al.,* 1982). Although cowpea is mainly consumed in cooked form, (Aykroyd *et al.,* 1982) stated that not all anti-nutritional substances are completely destroyed by this thermal treatment. Cowpeas are known to have a content of anti-nutritional factors and some of these are acquired through fertilizers and pesticides together with naturally-occurring chemicals (Igile, 1996). Moreover, the consumption of cowpea seeds can come with an added risk of exposure to mycotoxins and their health risks.

iv. *Groundnut (Arachis hypogaea L.)*

Hildebrand (1982) stated that, in Zimbabwe more than 90% of the groundnuts production comes from the rural areas, and this sector retains about 90% of its production for local use. Most of the agricultural industry is in the central plateau region on elevations between 300 and 1600m, although cropping below 800m is largely dependent on irrigation. The highest reported field scale yield in the world was in Zimbabwe, 9.6tonnes /ha of unshelled nuts (Hildebrand, 1982). Groundnut (peanut) is among the major oilseeds in the world. The peanut cultivar plays an important role in the economy of several countries (China, India, U.S.A. Netherlands, Germany, Russia, and Spain) (Campos-Mondragon et al., 2008). Raw groundnut seeds contain 23.5-26.6% protein, 49.8-53.4% fat and 18.9-23.4% carbohydrates (Table 2) (Ayoola, *et al,* 2012). Traditional processing methods like for example roasting and de-hulling combined increased, crude protein, ash, content while fat, carbohydrate fibre and decrease anti-nutritional factors such as phytates, condensed tannins, trypsin and alpha-amylase inhibitors (Ejigui *et al.,* 2005). In Zimbabwe ground nut seeds are consumed at various stages of maturity levels in their raw state, boiled or heat treated. The ground nut is also roasted and crushed to form a paste used as bread spread and as a chief ingredient of a number of traditional relish stews. The high oil and protein content of the seeds make it suitable for use as a common ingredient in the cooking of porridge for all ages.

Table 2 : Conventional protein sources nutritional composition (g/100g)

Source	Proximate analysis contents (g/100g)				References
	minerals	proteins	carbohydrates	fats	
Glycine max	-	40.1 - 44.5	30.6 - 34.4	18.2 – 20	Da Silva, 2009
Phaseolus vulgaris	3.9-4.9	15.1-15.4	48.5-49.5	15.7-15.9	Audu & Aremu, 2011
Vigna unguiculata	3.8-4.4	15.5-15.7	60.2-60.9	2.2-2.6	Alayande et al., 2012)
Arachis hypogaea L.	2.0- 2.5	23.5-26.6	18.9-23.4	49.8-53.4	Ayoola, et al, 2012

c) Mopane Worms (G. belina) distribution in Zimbabwe

Several authors confirmed that, *G. belina* is the most popular and lucrative caterpillar on the African continent (Timberlake, 1995; Timberlake, 1996; Dube and Dube, 2010; FAO/WUR., 2013). Dube and Dube (2010) and Moreki *et al.* (2012) agreed that Mopani worm feed almost absolutely on the leaves of the Mopane tree, *Colophospermum mopane.* The mopane woodlands in Zimbabwe are mainly found in the southern districts for instance in Chivi, Mberengwa, Mwenezi, Beitbridge and Chiredzi etc. According to Timberlake (1995), Mopane tree is foremost over large tracks of moderately clay soils (without extreme water logging) in southern Africa (Zimbabwe included) within an altitudinal range of 300-1000m (even up to 1200m in Zimbabwe, (Figure 1)) and annual rainfall zone of 400-700mm with a long dry season. The geographical distribution of Mopani worm lies within the Mopane woodland belt or districts as shown in Figure 1 and other host plants (Gardiner, 2005). Viljoen (1989) reported that, the same tree could be found in area with as little rainfall as 100mm. Similarly, in Zimbabwe as shown in indicated districts in Figure 1, the Mopani worm is located in the semi-arid regions (natural region IV and V, where there are little or no commercial agricultural activities and communities rely mostly on drought resistant crops such as sorghum and millet (Viljoen, 1989). Unreliable climate causes regular failure of staple grains and a high level of vulnerability to food insecurity especially in those districts indicated in Figure 1. Traditionally, Mopani worms have been harvested for subsistence use by rural households (Ashipala *et al.,* 1996) and they are thought to make a significant contribution to rural diets, although there has never been a proper assessment.

The Mopani worm is bivoltine in most areas that is, two generations are produced each year. The first major outbreak being between November and January followed by a minor second outbreak between March and May (van Voorthuizen, 1996; Stack *et al.,* 2003; Gardiner,2005). However, van Voorthuizen (1976) pointed out that Mopani worm population numbers vary from year to year at a single locality though (Roberts, 1998) was quick to point out that the population numbers are on the decrease as a result of increase in their exploitation, declining selective harvesting (Hobane, 1995) and general decrease on the Mopani woodlands due to deforestation.

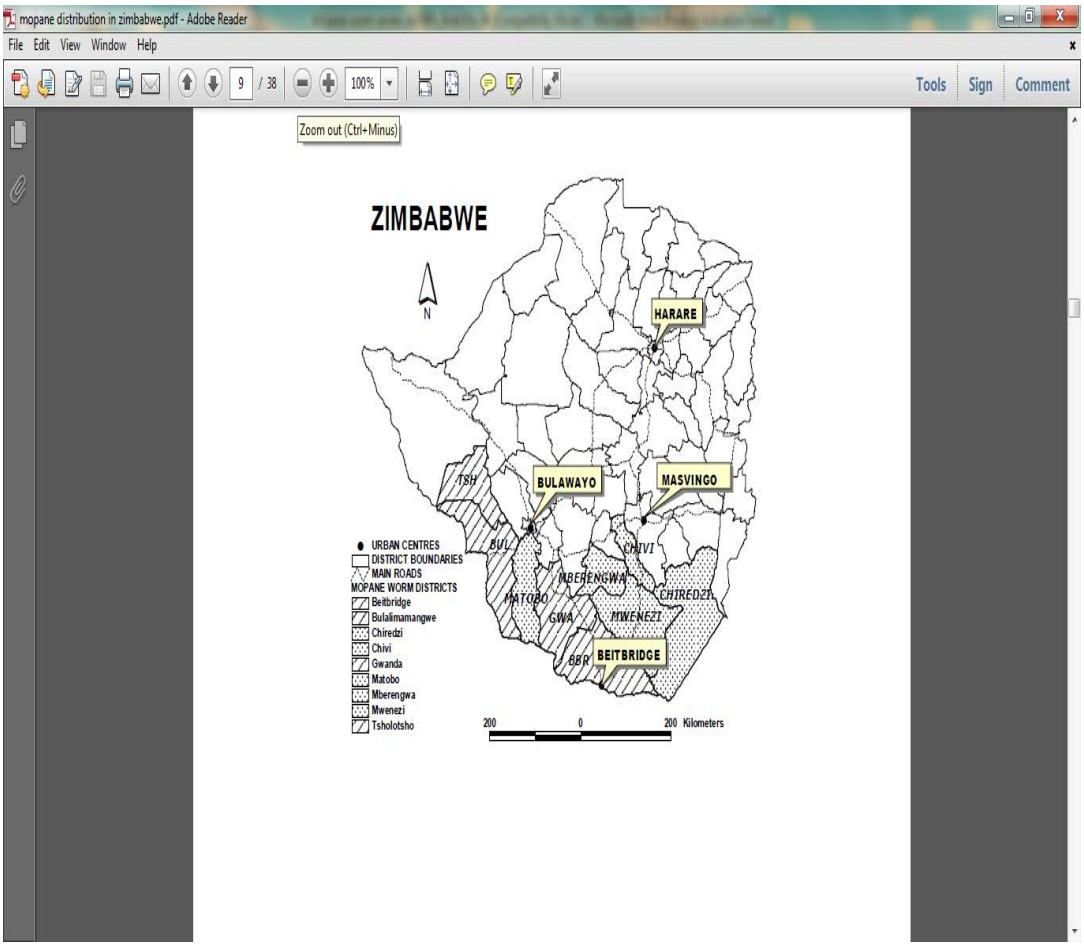

Figure 1 : G. *belina* distribution in Zimbabwe by district

d) Mopani Worm (G. belina) harvesting and processing

Essentially, *G. belina* requires ecological harvesting so as to ensure a good crop for the following season. According to Dube and Dube (2010), a woodlot of 4000 hectares would support 19 million worms, which would translate to193 tonnes of Mopane worms. Normally, *G. belina* life cycle start in October when the eggs hatch marking the first generation. Wiggins (1997), Timberlake (1996) and Toms (2001) confirmed that, young Mopane worms or larvae feed on the leaves of the Mopane trees where they hatch and as they grow, molt 4 times (there are five larval stages) before they reach their maximum size. FAO (2010a) indicated that, principally Mopane worms are gathered by hand from the ground and from the trunks, branches and leaves of the trees. In some cases trees or branches are cut and the larvae harvested. The Mopane worm has a tough skin and is protected by black or dark reddish brown spines which can be painful and cause lacerations and the spines and associated hairs seem to have a slight rusticating effect. In addition, when the larvae are handled, they often exude a slimy green fluid from the mouth (Gardiner, 2005). According to Kozanayi & Frost (2002) the fluid irritates any scratches on the hand, so hand protection (by use of gloves) helps their harvesting and degutting. Taylor (2003) noted that, traditional method of degutting by hand is common and faster, hence the most preferred method (Kozanayi and Frost, 2002).

Soon after harvesting, Mopane worm can be kept in live storage for a maximum of 3 days (FAO, 2010a). After being degutted, washed and usually cooked using water and salt (Taylor, 2003) (for 30 minutes and sun dried for 2 hours (Allotey and Mpuchane, 2003), the larvae can be preserved by either sun-drying or smoking. Drying degutted Mopane worms prolongs their shelf life to almost a year therefore maintaining a steady supply of protein in the diet of the people in the area. Thereafter, the Mopane worm will be ready for storage in polythene bags. FAO/WUR, (2013) pointed out that considerable amount of care should be taken to avoid contamination throughout the various processing stages to ensure safe product.

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e) Proximate composition of Mopane Worms (G. belina)

G. belina is the most common specie of the Mopane worm. According to Moreki *et al*. (2008) although the Mopane worm is seasonal, it provides a readily available and cheaper source of animal protein. The Mopane worm contain comparatively higher quantities of protein, fat, carbohydrate valuable minerals than beef and chicken (Moreki *et al*., 2012) However, the Mopane worm contain 27% chitin of dry weight (Sekhwela, 1989; Ohiokpehai *et al*., 1996; Majeti and Kumar, 2000) which blocks digestive enzyme accessing protein and lipid substrates thereby reducing the utilisation of the these nutrients (Mahata *et al*., 2008). Above all, increase in roughage intake for instance chitin through Mopane worm) reduce some gastro-intestinal diseases, hence this makes the insect an all-rounder in providing nutritious balanced meal (Illgner and Nel, 2000; Mpuchane *et al*., 2000; Mohapatra *et al*., 2002).

Besides being used as a protein source by people in semi-arid environments of Botswana, Namibia, South Africa and Zimbabwe (Marais, 1996; Styles, 1996), Mopane worms could also be used in animal feed formulations (Mpuchane *et al*., 2000). Several authors confirmed huge growing interest in Mopane worm as a food resource for both human and animals in the near future (due to its excellent nutritional information, Table 3) (Illgner and Nel, 2000; Mpuchane *et al*., 2000; Ghazoul, 2006). According to Siame *et al*. (1989) and Madibela *et al*. (2007), *G. belina* contains about 50% crude protein and is abundant in the wilderness during its season of availability. Madibela *et al*. (2009) reported that, degutting improves the crude protein concentration of the worms by 10%. Although *G. belina* has been used as part in day to day meals in Southern Africa because of its nutritional value, but to date it has not been used as a protein source in fortified blended foods. Based on it nutrients composition it can be a good alternative source of protein instead of some convectional sources of proteins such as soybean.

Table 3 : Mopane worm *(G. belina)* nutritional composition

Contents	*Mean value
Crude protein (%)	55.41
Digestible protein (%)	53.3
Carbohydrate (%)	8.16
Ash %	8.26
Neutral detergent Fibre %	27.8
Acid Detergent fibre %	16
Acid detergent Lignin	5.2
Acid Detergent Insoluble Nitrogen (%)	0.9
Fat (%)	16.37

Potassium (mg/g)	35.2
Calcium (mg/g)	16.0
Phosphorus (mg/g)	14.7
Magnesium (mg/g)	4.1
Iron (mg/g)	12.7
Zinc (mg/g)	1.9
Sodium (mg/g)	33.3

**Mean value calculated from various sources*

Source: (Dreyer and Wehmeyer, 1982; Illgner and Nel, 2000; Gardiner, 2003; Gardiner, 2005; Madibela et al., 2009; Moreki et al., 2012; Simone et al., 2013)

f) Mopone worm sustainability and rural community livelihoods enhancement

Importantly, harvesting caterpillars for human consumption has positive and negative impacts on forests. FAO (2010a) noted that, reducing caterpillar populations is beneficial to host trees, although harvesting practices that include cutting of branches or felling trees contribute to forest degradation and deforestation. In line with that, Roberts (1998) indicated that a decline in the abundance of Mopane worms was mainly due to increasing exploitation of Mopane trees (Hobane 1995), a general increase in pressure on Mopane woodlands, and increased frequency of drought. In support of that, Bartlett (1996) indicated evidence from parts of Botswana where Mopane moths had disappeared after heavy harvesting. In addition to that, frequent veld fires may reduce populations of edible caterpillars at the expense of non-edible beetles which pose a threat to food security and nutrition (Flower *et al.*, 1999; FAO, 2010a).

Flower *et al.* (1999) emphasised that, the economic importance of Mopane woodlands can only be meaningful if more ecological studies are done on the tree species thereby unlocking potential in Mopane worm farming. Above all, little nutritional information is known about the *C. mopane* leaves at different times of the year in which Mopane worm is harvested. Likewise, Ditlhogo *et al.* (1997) highlighted little information on growth rates of Mopane tree (on *which G. belina* depend) under various conditions, as major limitation in the ability to manage and utilise Mopane worms. In addition to that, Mopane worm geographical variability in outbreak occurrence may also lead to conflicts between community members (Ghazoul, 2006).

Gardiner *et al*, (2005) reported that, *G. belina*, and mopane woodland products are key resources to poor farmers and landless poor people across southern Africa. In line with that, De Foliart (1995) and Styles (1995) revealed substantial value in Mopane worm trade. For instance in South Africa alone, the commercial value of Mopane worm harvests can reach $3,000 per ha, amounting to annual sales of $1.6m. Also in Botswana, the Mopane worm harvest in a good year is estimated to be worth $3.3m, providing employment and income to 10,000 people. However, the irregular and largely unpredictable nature of Mopane worm outbreaks results in price fluctuations and uncertainty of supply, both undesirable outcomes for poor and risk inflicted farmers (Gardiner, 2005; Ghazoul, 2006).

II. Product Quality and Food Safety

Essentially, Mopane worm processing, packaging and storage practices are chiefly regarded as poor and most leading causes of their spoilage by micro-organisms or fungi. In this regard, thin plastic bags are often used and are easily punctured by remaining spines on the dried product leading to infestation by pests and uptake of water (Gardiner, 2005). Klunder *et al.* (2012) pointed out that, insects like many meat products, are rich in nutrients and moisture, providing a favourable environment for microbial survival and growth. Accordingly, adequate hygienic handling and correct storage of Mopane worm should be strongly addressed, in order to avoid and reduce potential hazards during consumption (Klunder *et al.*, 2012; Belluco *et al.*, 2013). According to Nyakudya, (2004), Mopane worm are traditionally kept in polypropylene woven bags in which maize or a similar product has been stored, plastic or metal buckets and clay pots. All these items are prone to contamination and spoilage (Allotey *et al.*, 1996; Nyakudya, 2004). Taylor (2003) indicated that later on during storage Mopane worm get infested and appropriately fumigated using Phostoxin gas. Nevertheless, Phostoxin gas is dangerous and only registered pest control operators are permitted to use it. In contrast, effort has been made to improve on Mopane worm shelf life as well as its hygienic processing mainly through solar radiation method (Dube and Dube, 2010).

Even though there is enough literature to support the high level of protein in *G. belina,* the insect has some challenges. According to Sekhwela, (1989) and Ohiokpehai *et al.*, (1996), *G. belina* contains chitin, a component of the outermost part of the worm, which forms 27% of the dry weight. Chitin physically blocks the access of digestive enzyme to hydrolyse protein, lipid, fat-soluble vitamins and minerals thus affecting their utilisation (Mahata *et al.*, 2008; FAO., 2010a.). In contrast, (Koide, 1998) stated that chitin and chitosan

can bind dietary lipids, thereby causing reduction in cholesterol and triglycerides in blood plasma due to reduced absorption of lipids in intestines. Majeti and Kumar (2000) also confirmed that chitosan is a fat trapper in the stomach, hence prevents absorption of trapped fat. However, experiments on silkworm pupa by (Zhang *et al.*, 2000; Paulino *et al.*, 2006) demonstrated the significant value of chitin as a source of fibre and calcium hence enabling production of protein concentrates from de-chitinised insects. Gardiner (2005) indicated that, Mopane leaves (on which *G. belina* feed on) are generally not favoured by vertebrate browsers and are used only in drought years implying that they likely contain plant defence compounds such as phenolic and tannins signifying presence of antinational factors.

The global growing consumer demands for safer and healthier foods have raised concerns over insects handling and processing practices, hygiene and overall food safety. However, FAO (2010b) regarded insects as "health foods" only when collected from forest areas when they are generally clean and free of chemicals. Belluco (2013) emphasised occurrence of chemical hazards in insects as dependent, mostly on habitat and plant feed contamination and can only be controlled by selected farming and dietary conditions. Among insect-related chemical hazards are cyanogenetic substances which can also be present in insects (*Lepidoptera* in which *G. belina* belongs). Blum (1994) reported that presence of these substances in insects cause inhibition of enzymes such as succinate dehydrogenase and carbonic anhydrase, thereby inhibiting some metabolic pathways for instance oxidative phosphorylation. This is due to the fact that cyanogenetic substances have a high affinity for ferrocytochrome oxidase (Blum, 1994).

Ingestion of caterpillars (to which *G. belina* belongs) is common in children, probably due to their natural interest. Lee and Hathaway (1998) reported children who had accidentally ingested caterpillars suffered from symptoms comprising drooling, difficulty swallowing, pain, and shortness of breath. FAO (2010a) insisted that, ingestion of caterpillars may provoke toxic reactions, even when symptoms suggest an underlying allergic reaction (Okezie *et al.*, 2010). However, few studies have been conducted on allergic reactions due to insect ingestion. Therefore, there is a need for further research to ascertain the risk of food allergy after insect consumption, though a thorough thoughtfulness is essential in differentiating toxic and allergic symptoms (Lee and Hathaway, 1998; Pitetti *et al.*, 1999). Importantly, ingestion of *G. belina* can cause anaphylactic shock. Okezie *et al.* (2010) reported the case of a 36 year old female who had two different episodes of anaphylactic shock after *G. belina* consumption, though no allergic reaction test was performed.

III. Conclusion

G. belina has high nutritional value and abundant in most parts of Zimbabwe making it a highly potential sustainable food source in human nutrition. The insect is a rich source of good protein including essential amino acids, fats and other nutritive elements, vitamins and carbohydrates for the human body (Capinera, 2004; Johnson, 2010; Xiaoming et al., 2010). Conclusively, *G. belina* average protein value is higher, (all calculations based on various sources) for instance it is approximately 55.41% (based on dry weight) as compared to current conventional sources from Glycine max (40.1 - 44.5%), Phaseolus vulgaris (15.1-15.4%), Archis hypogaea. L. (23.5-26.6%) and Vigna unguiculata (15.5-15.7%) (all calculations based on dry weight). In view of the above, *G. belina* appears to be a potentially equal protein substitute for proteins when used in FBFs formulations. Besides having the highest protein value per hundred gram of dry weight (g/100g), it is also an animal based nutrition source that can also provide all the essential proteins and fats that are not supplied by plants based foods (Capinera, 2004; Johnson, 2010; Xiaoming et al., 2010) (Ramos-Elorduy, 1997a). Above all, *G. belina* is considered as a cheap source of animal protein containing comparatively higher quantities of protein, fat, carbohydrate valuable minerals than beef and chicken (Moreki et al., 2012). On the other hand *G. belina* had found to be a key resource to poor farmers and landless poor people (Gardiner, 2005) who could exploit it to improve their livelihoods (Styles and Skinner, 1996; De Foliart, 1997). However, food hygiene issues and safety are of paramount importance to the viability of this sector if it is to attain global recognition (FAO., 2010a. ; FAO/WUR., 2013). Finally, *G. belina* utilisation as an alternative protein source in FBFs formulation is feasible in Zimbabwe, especially when commercially produced and harvested at large scale through participation of small holder community farmers. However, FBFs containing *G. belina* are not available and have not been formulated mainly because of lack of adequate studies on its feasibility accompanied by absence of process development for the production of FBFs containing the insect.

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Effects of Compost and Mineral Sulfur Fertilizers on Phosphorus Desorption at Wujiraba Watershed, Northwestern Highlands of Ethiopia

By Habtamu Admas, Heluf Gebrekidan, Bobie Bedadi & Enyew Adgo

Haramaya University, Ethiopia

Abstract- Phosphorus fixation, which is responsible for low availability of P, is one of the major problems of crop growth in acidic soils such as Nitisols. It is one of the most chronic problems for crop yield decline in Wujiraba watershed. Therefore, an incubation study was conducted for two months to investigate the effects of compost and S fertilizers on P desorption in strongly acid soils (pH/KCl 4.53) and low P content (Bray II P 4.8 mg kg^{-1}). After air drying, grinding and passing through 2 mm sieve, 200 g of soil was placed to each pot. The experimental treatments included three rates of compost (0, 5 and 10 t compost ha^{-1}) and S (0, 15 and 30 kg S ha^{-1}) fertilizers were laid down in CRD with three replications. At the end of the incubation period, the analyzed data result revealed highly significant ($P \leq 0.001$) difference in available P by interaction effects of compost and S fertilizers whereby the highest (22.8 mg kg^{-1}) was recorded in pots treated with high dose of compost (10 kg compost ha^{-1}) and nil S fertilizer rates which increased by 301% relative to the control.

Keywords: *acidic soil, compost, incubation, nitisols, p availability, p fixation, s fertilizer.*

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Habtamu Admas [α], Heluf Gebrekidan [σ], Bobe Bedadi [ρ] & Enyew Adgo [ω]

Abstract- Phosphorus fixation is one of the major problems of crop growth in acidic soils such as Nitisols. It is also one of the most chronic problems for crop yield decline in Wujiraba watershed. Therefore, an incubation study was conducted for two months in pots to investigate the effects of compost and S fertilizers on P desorption in strongly acid soils with low P contents. The experimental treatments included three rates of compost (0, 5 and 10 t compost ha) and S (0, 15 and 30 kg S ha) fertilizers which were laid down in CRD with three replications. At the end of the incubation period, the analyzed data result revealed highly significant ($P \leq 0.001$) difference in available P by interaction effects of compost and S fertilizers whereby the highest (22.8 mg kg) was recorded in pots treated with high dose of compost (10 kg compost ha) and nil S fertilizer rates that increased by 301% relative to the control. Unlike compost fertilizer, S amendment decreased available P and increased exchangeable Ac and Al contents of soil. Therefore, this work indicated a decline in P fixation and exchangeable Al with application of compost fertilizer which is a cost effective measure on strongly acid soils with P deficiency.

Keywords: acidic soil, incubation, nitisols, p deficiency, p fixation, yield decline.

I. Introduction

Soil acidity is the most important factor affecting plant growth and limiting crop production (Fageria, 2009; Achieng *et al.,* 2010) due to high concentration of Al and Mn, and deficiency of P, N, S and other nutrients (Zdenko, 2003; Wang *et al*., 2006; Abreha, 2013). It is common in regions where rainfall is high enough to leach appreciable amounts of exchangeable bases from soil surface (Achalu, *et al.,* 2012). Although acidification is a natural process, agricultural practices, environmental pollution, nutrient mining and other human activities have accelerated the process (Curtin and Syers, 2001).

It is estimated that 28.8% of African continent has acid surface soils (Eswaran et al., 1997; Hirpa *et al*., 2013). Soil acidification affected large areas of Ethiopian highlands (EATA, 2013) estimating 40% of the total arable l and of the country (Mesfin, 2007; Hirpa *et al* 2013). Soil acidity also becomes a serious threat to areas of the western, southern and central highlands of Ethiopia (Wassie and Boke, 2009; Abreha, 2013) where the study area is part of.

Although P is the most abundant elements and essential for plant growth (Fadly, 2005; Withers and Jarvie, 2008; Zhuo *et al*., 2009a), it is one of the least available plant nutrients in soil (Raghothama and Karthikeyan, 2005). Available P in soil is very low (< 10%) relative to its total amount (Wang *et al*., 2006; Adem *et al.,* 2009). Most of tropical soils are known to have low P status as it reacts with Al, Mn and Fe ions Chandrasekaran *et al*. (2010) that hinders crop production. High P adsorption in acid soils makes crops to utilize only 10 - 25% of P fertilizer applied (Bahl and Singh, 1986; Asmare, 2014).

Phosphorus deficiency remains a major constraint in rain fed upland farming systems (Fairhurst *et al*., 1999; Akande *et al.,* 2011) despite main crop production lands. The insolubility of P is due to its affinity to cations such as Ca^{2+}, Mg^{2+}, Fe^{3+} and Al^{3+} which are not amenable to plant uptake (Jose *et al.,* 2003). Aluminum toxicity is the most important plant-growth limiting factors in many acid soils, particularly those with pH < 5.5 (Kabambe *et al.,* 2012) as Al phytotoxicity results in rapid inhibition of root growth (Zdenko, 2003).

Ethiopian soils, particularly Nitisol, are reported to have low available P contents (Yihenew, 2002) due to impacts of P fixation by acidic cations, mining of P by crop harvest and little P sourced fertilizers application (Asmare, 2014). The high P adsorbing soils require massive application of P sourced mineral fertilizers, OM and sustainable land management practices although not practiced by most small scale farmers of Ethiopia due to its high cost, low attention for local amendments and more emphasis for current food insecurity than nutrient depletions, respectively.

Although OM improves P availability via organic; humic and fulvic acids (Minggang, *et al.,* 1997; Gourango, 2007), its application is very low at Wujiraba watershed. These organic acids are released during OM decomposition which are responsible in increasing negative charges (raising pH) on Al and Fe oxide surfaces and decreasing such metallic ions by competing for binding sites as well as solublizing P

Author α σ ρ: Haramaya University, School of Natural Resources Management and Environmental Sciences, Ethiopia.
e-mail: habtamuadmasu35@gmail.com
Author ω: Bahir Dar University, College of Agriculture and Environmental Science, Bahir Dar, Ethiopia.

mainly by producing CO_2 and forming H^2CO^3 (Kumari *et al.,* 2008; Nadar *et al.,* 2008; Paulo *et al.*, 2008).

Sulfate (SO^{42-}) retention is usually accompanied by a rise in pH of soil solution and improving P availability by releasing OH^- groups from the surface (Couto *et al.*, 1979; Mott, 1981) and increasing the ability of soils to retain basic cations (Bowden *et al.*, 1980). Although some researchers have found that gypsum increases the leaching of Al, Fe, Mn, it does not usually change soil acidity; while others reported that it did not improve the fertility of acid soils (Chalker-Scott's web page at http://www.theinformedgardener.com accessed on 18 February 2013) which is open for research work.

Soils of Wujiraba watershed are strongly acidic and P is the most deficient nutrients for crop growth with low application of P fertilizers and OM. Little research was done on P fixation problems in the study area. The effects of compost and S (gypsum) fertilizers on P desorption in acidic soils of northwestern highlands have not also yet been studied. Consequently, studying P desorption had paramount importance, and therefore, the objective of this study was to investigate the effects of compost and S fertilizers on soil P availability in acidic soils of Wujiraba watershed.

II. Materials and Methods

a) Description Of The Study Area

The study was conducted at Wujiraba watershed, located in Chilga District of North Gondar Zone in the Amhara National Regional State (Figure 1). The watershed is situated at about 60 km west of Gondar city and 760 km northwest of Addis Ababa (capital of Ethiopia). Geographically, the watershed lies at 12^0 32' 16''- 12^0 35' 20'' N latitudes and 37^0 03' 58''- 37^0 06' 23'' E longitudes with an area of 62.68 km^2 and elevations ranging from 1910 and 2267 masl.

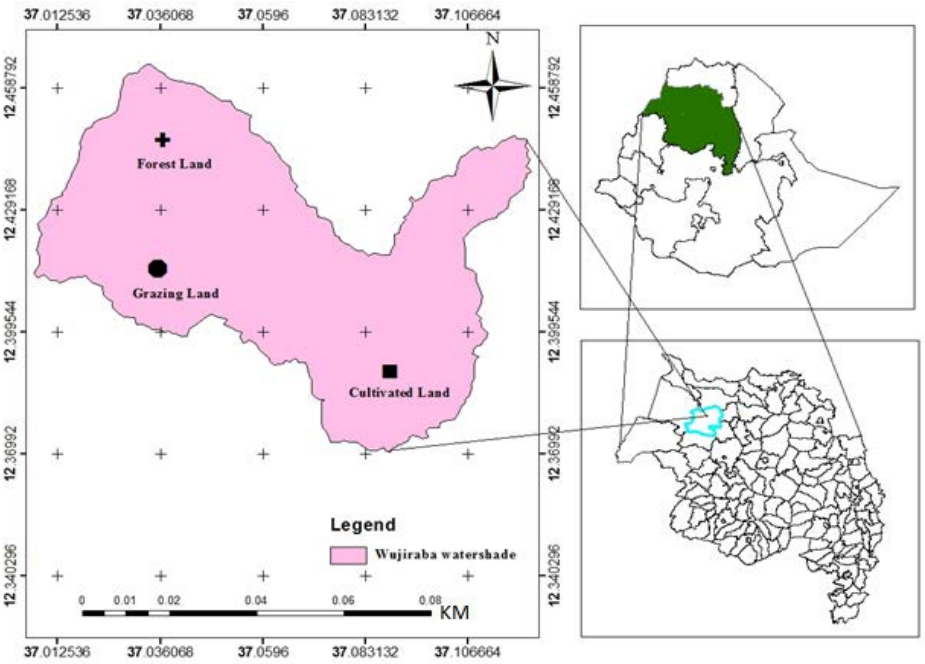

Figure 1 : Location map of the study area

Geologically, the study area is covered with thick trap series of volcanic rocks built-up in mid-Tertiary flood basalt pile and middle-Tertiary volcanic mountains of the Miocene and Pliocene–Quaternary basaltic volcanism. The soils of the study area were developed from the parent materials of volcanic origin, predominantly Tertiary basalt (Chorowicz *et al.,* 1998).

Wujiraba watershed is characterized by unimodal rainfall pattern with average annual rainfall of 1237 mm (Figure 2). The annual mean minimum and maximum temperatures were 13.6 and 23.7 ^{0}C, respectively. Natural vegetation of Wujiraba watershed is very low except some trees and grasses on reserved areas. The trees occurring on slopes, mainly churches, are remnants of once dense evergreen forest.

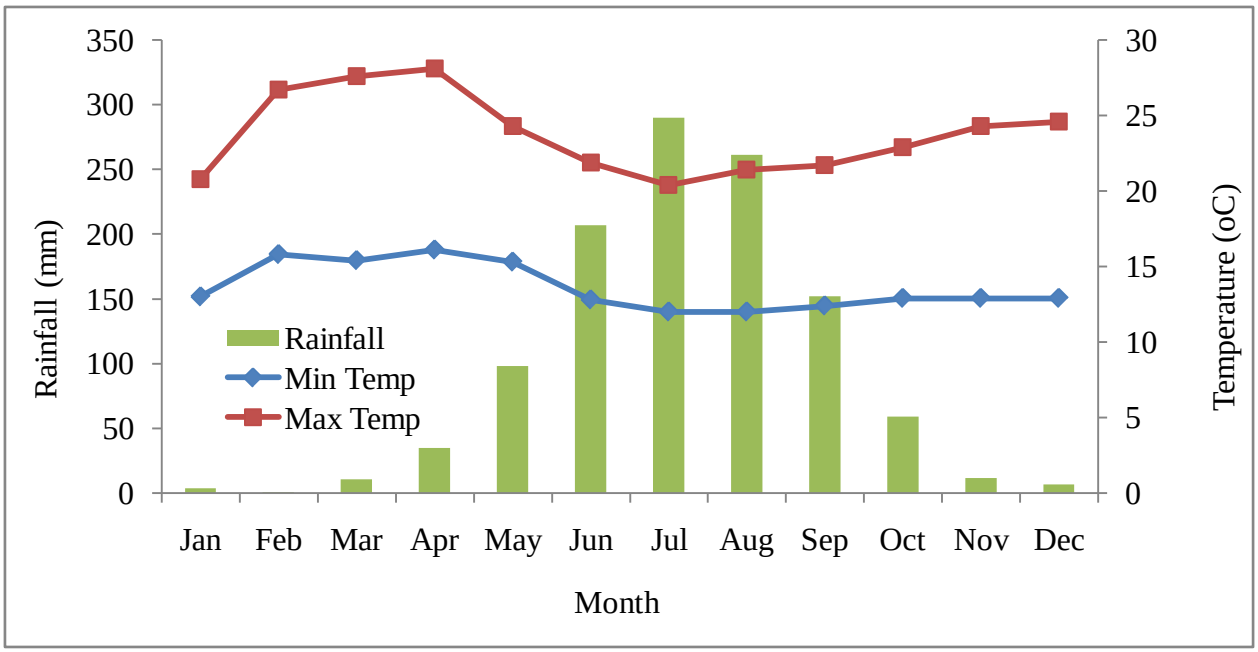

Figure 2 : Mean monthly rainfall and maximum and minimum temperatures of the study area

Economic activities of local community at Wujiraba watershed are primarily mixed farming system (crop production and animal husbandry). In the watershed, cultivated land accounts for 68.4% while grazing, settlement and forest together with area closure lands account 23.5, 5.3 and 2.8%, respectively (Chilga District Agriculture and Rural Development Office, 2012). The watershed is suitable for growing large variety of crops such as cereals, oil seeds, pulses, etc. Crops are grown in rotation by rain fed system.

b) Soil Sampling and Analysis

Six kilograms of composite surface (0 - 30 cm depth) acidic soils were collected from three blocks in cultivated land of soil group Nitisols (FAO, 2006) based on slope. Soil samples were collected by augur from thirteen sub-samples in each block and thoroughly mixed. Compost was prepared from local raw materials (clovers, grasses, leaves of trees, ashes, cow dung and urine, sheep and poultry manure and top soil) which are decomposable. It was prepared in pits with dimensions of 1.5 m length, 1.5 m width and 1 m depth and turned every month. Gypsum was also sieved in 2 mm sieve.

Before incubation study, collected soil and compost samples were prepared for physicochemical analyses. Soil and compost were air dried ground and passed through a 2 mm sieve except for total N and OC which were passed through 0.5 mm sieve. Analysis of samples was carried out at Bahir Dar Soil Testing and Fertility Improvement Laboratory and Amhara Design and Supervision Works Agency Soil Laboratory Centers based on their standard procedures.

Soils texture was analyzed by Bouyoucos hydrometer (Day, 1965). Bulk density was determined from undisturbed soil samples using core samplers (Rowell, 1997) while soil β_s was measured by psychnometer method (Barauah and Barthakulh, 1997). Total porosity was also calculated from values of β_b and β_s as: $f = \left(1 - \frac{\beta b}{\beta s}\right)100$.

Soil and compost pH was measured in 1:2.5 soils to KCl solution before incubation (Chopra and Kanwar, 1976) while after incubation, in suspension of 1:2.5 soils to water ratio. Total N was determined by micro-Kjedahl method (Jackson, 1958). Cation exchange capacity and exchangeable Ca, Mg, K and Na were extracted with 1 M NH_4OAc at pH 7 (Okalebo *et al.*, 1993). Organic carbon was determined by Walkley and Black method (Walkley and Black, 1934) while available P and S were determined by extraction with Bray II (Bray and Kurtz, 1945) and Turbidimetric methods (Kowalenko, 1985), respectively. Soil micronutrients of Fe, Mn, Cu and Zn were measured by atomic absorption spectrophotometer as described by Sahlemedhin and Bekele (2000). Exchangeable acidity was determined by saturating soil samples with 1M KCl solution and titrated with 0.02 M NaOH as described by Rowell (1994). From the same extract, exchangeable Al in soil samples was titrated with standard solution of 0.02 M HCl.

c) Experimental Design and Procedures for Incubation Study

Soil incubation study was conducted using compost and S fertilizers. For this study, composite soil samples, gypsum and compost were put in plastic pots. The treatments used were three rates of compost (0, 5 and 10 t compost ha^{-1}) and S fertilizer in the form of gypsum (0, 15 and 30 kg S ha^{-1}) that were laid down in CRD.

The experiment consists of nine treatment combinations with three replications. Twenty seven plastic pots were filled with 200 gm acidic soils each and thoroughly mixed with different compost and S fertilizer rates. Such soils with compost and gypsum were incubated for two months (April and May, 2013) at Gondar Agricultural Research Institute and subjected to uniform wetting at 60% FC adjusted every two days. Soil samples were taken at the end of incubation time (two months after), air dried ground and sieved through 2 mm sieve to determine pH, exchangeable Ac, Al and available P using the methods described above at Bahir Dar Soil Testing and Fertility Improvement Laboratory Center.

d) Statistical Analysis

Data were statistically analyzed as CRD by two ways analyses of variance using SAS software (SAS, 2002). Means were compared using LSD test by Fisher's test at 0.05. Correlation analyses were also carried out.

III. Results and Discussion

a) Initial Soil Properties and the Composition of Compost

The results for soil and compost laboratory analyses which were done before incubation study were presented in Tables 1 and 2. Soil was clayey in texture, moderate in f, very low in pH, low in OC, total N, available P and S, high in CEC, medium in exchangeable Ca, Mg and K contents.

Table 1 : Physicochemical properties of the experimental soil before incubation

Parameters Unit		Values
Texture (%)	Sand	12.34
	Silt	27.98
	Clay	59.68
$ß_b$ (g cm^{-3})		1.2
$ß_s$ (g cm^{-3})		2.36
f (%)		47.8
pH/KCl		4.53
OC (%)		1.6
Total N (%)		0.15
Available P (mg kg^{-1})		4.8
Available S (mg kg^{-1})		2.9
CEC (cmole+ kg^{-1})		32.6
Exchangeable Ac (cmol+kg^{-1})		2.5
Exchangeable Al (cmol+kg^{-1})		1.8
Exchangeable bases (cmole+ kg^{-1})	Ca	9.9
	Mg	2.1
	K	0.59
	Na	0.23
PBS (%)		41.61
Available micronutrients (mg kg^{-1})	Fe	6.8
	Mn	17.5
	Cu	2.1
	Zn	0.69

In this experiment, laboratory analyses results for nutrient contents of compost before incubation revealed that of OC (18.5%), total N (0.83%), available P (650.7 ppm) and S (17.8 ppm), CEC (94.4 cmolc kg^{-1}, exchangeable Ca (47.1), Mg (26.7), K (2.5) and Na (0.4 cmolc kg^{-1}) as well as NH_4^+ (332.1) and NO_3^- (259.6 ppm) with C: N ratio of 22:1. These nutrients could be emanated by the activities of microorganisms during the decomposition of compost.

Table 2 : Laboratory analysis results for nutrient contents of compost before incubation

Compost	pH/H_2O	CEC cmolc kg^{-1}	OC %	TN %	Av. P mg kg^{-1}	Av. S mg kg^{-1}	Ca cmolc kg^{-1}	Mg cmolc kg^{-1}	K cmolcg^{1}	Na cmolc kg^{-1}	NH_4^+ mg kg^{-1}	NO_3^- mg kg^{-1}
R1	7.2	96.4	19.11	0.81	646.32	17.5	47.62	26.08	2.54	0.37	312.0	269.6
R2	7.4	92.34	17.87	0.85	655.15	18.09	46.54	27.42	2.38	0.43	352.23	249.6

R1 and R2 = Replication 1 and 2

b) Effects of Compost and Sulfur Fertilizers on Soil pH

Soil pH is the most indicators of soil chemical properties and P availability. In this experiment, pH was significantly ($P \leq 0.05$) affected by the effects of compost and S fertilizer interactions (Table 3). The highest (5.57) pH was recorded in pots treated with 5 t compost ha^{-1} and nil S fertilizer rates while lowest (4.6) at nil compost and high dose of S fertilizers (30 kg S ha^{-1}). The experiment showed the increase of soil pH by compost and decrease by S fertilizer application. In this experiment, pH was positively correlated ($r = 0.34$) with available P but highly significantly ($P \leq 0.001$) and strongly negatively associated ($r = -0.67$ and -0.68) with exchangeable Ac and Al, respectively (Table 4).

c) Effects of Compost and Sulfur Fertilizers on Exchangeable Acidity and Aluminum

Exchangeable Ac and Al are the principal soil chemical properties that hinder crop growth in tropical soils. There was significant ($P \leq 0.01$) difference in exchangeable Ac by the combined effects of compost and S fertilizers (Table 3). The highest exchangeable Ac (2.88 cmol+kg^{-1}) was recorded in pots treated with fertilizer interactions of high dose of S (30 kg S ha^{-1}) and nil compost rates that showed an increase of 23.6% compared to the control. Significant ($P \leq 0.05$)) difference was also observed in exchangeable Al by the interaction effects of compost and S fertilizers (Table 3) whereby the highest (2.16 cmol+kg^{-1}) was observed again in pots treated with high doses of S Fertilizers (30 kg S ha^{-1}) and nil compost fertilizer rates that increased by 22% relative to the control. Nevertheless, the lowest exchangeable Al (1.37 cmol+kg^{-1}) was recorded in pots treated with high doses of compost fertilizers (10 tons compost ha^{-1}) and nil S fertilizer rates by showing a decrease of 22.6% relative to the control.

d) Effects of Compost and Sulfur Fertilizers on Phosphorus Availability

The extent of P desorption varied depending on the amounts and types of amendments used in incubation experiment. Available P content was highly significantly ($P \leq 0.001$) affected by compost and S fertilizer interactions (Table 3). The highest (22.8 ppm) available P was recorded in pots treated with high dose of compost (10 t compost ha^{-1}) and nil rates of S fertilizers that showed an increase of 301% relative to the control. The values of available P were increased with increasing compost but decreased with increasing S fertilizer rates. This experiment also revealed that the correlation of available P with exchangeable Ac and Al was highly significant ($P \leq 0.001$) and strongly negative ($r = -0.7$ and -0.69), respectively (Table 4).

Table 3 : Interaction effects of compost and S fertilizer on soil pH , exchangeable Ac, Al and available P

Treatment	pH/H_2O	Exchangeable Acidity (cmol+kg^{-1})	Exchangeable Al (cmol+kg^{-1})	Available P (mg kg^{-1})
C0S0	5.20ab	2.33bcd	1.77bc	5.70 c
C0S1	4.90bc	2.43abc	1.85abc	5.75 c
C0S2	4.60 c	2.88a	2.16a	5.46 c
C1S0	5.57 a	2.15bcd	1.56bcd	12.94 b
C1S1	4.87bc	2.41bc	1.82abc	12.50 b
C1S2	5.37 a	2.51ab	1.91ab	12.32 b
C2S0	5.54 a	1.87d	1.37d	22.80 a
C2S1	4.90bc	1.98cd	1.47cd	21.58 a
C2S2	5.41ab	2.00cd	1.54bcd	22.02 a
R^2	0.71	0.69	0.66	0.99

CV (%)	5.23	11.6	12.9	6.14
F-Test	*	**	*	***
LSD (0.05)	0.32	0.26	0.38	1.01

Means with the same letter are not significantly different; C0, C1, C2 = 0, 5, 10 t compost ha^{-1} and S0, S1, S2 = 0, 15, 30 kg S ha^{-1}

Table 4 : Pearson's correlation matrix for various soil pH, available P, exchangeable Ac and Al

	pH	Av P	Ex Ac	Ex Al
pH	1.0			
Av P	0.34	1.0		
Ex Ac	-0.67***	-0.7***	1.0	
Ex Al	-0.68***	-0.69***	0.98***	1.0

****Significant at P = 0.001; ** significant at P = 0.01; * significant at P = 0.05 levels; Av. P = available P; Ex A c= exchangeable acidity; Ex Al = exchangeable aluminum*

IV. Discussion

Soils of cultivated lands in the study area are clayey in texture, moderate in *f*, very low in pH, low in OC, total N, available P and high in CEC, medium in exchangeable Ca, Mg and K contents and affected by soil acidity and Al toxicity problems. These all might be due to low OM content, high leaching of basic cations and mining of nutrients, soil erosion as well as acidifying effects of mineral fertilizers. The high clay content of the soil in this study could increase P fixation due to its high surface area. Havlin *et al.* (1999) reported that P fixation tends to be more pronounced and ease of P release tends to be lowest in soils with higher clay content.

After the incubation study, soil pH was increased with increasing compost rate which might be due to being as the source of soil microorganisms that enabled the liberation of basic cations which substitute the acid cations (H^+, Al^{3+}, etc). Johannes (2000), Tesfay *et al.* (2006) and Sarwar *et al.* (2010) reported that compost has librated alkaline substances and cations such as Ca^{2+}, Mg^{2+}, K^+ which increase CEC and pH level that counteract soil acidification. Similarly, Erich *et al.* (2002) elucidated that the deprotonation of carboxylate group (COOH), phenolic and alcoholic hydroxyls (OH) reduce soil acidity. However, Eduardo *et al.* (2013) reported oppositely that different functional groups, that are part of the soil OM pool can release H^+, thereby, creating a more acidic environment.

However, pH was decreased with the increase in S fertilizer rates which might be due to the production of sulfuric acid (H_2SO_4) by the activity of thiobacillus bacteria that release H^+ ions. Al-Oud (2011) reported that S plays an important role in reducing soil pH through its transformation to sulfuric acid by S oxidizing bacteria. Shainberg *et al.* (1989) and Skwierawska *et al.* (2008) also noted that high content of S in the soil causes soil acidification and gypsum treatment decreased soil pH from 4.8 to 4.5 due to Ca^{2+} ions dissolution from gypsum and replacement by H^+ and Al^{3+} ions. Furthermore, Shainberg *et al.* (1989) reported that gypsum treatment decreased surface and subsurface soils pH from 4.8 to 4.5 and 4.8 to 4.1, respectively.

Exchangeable Ac and Al were increased with the increase in S fertilizer rates which might be due to acidifying effect of S fertilizers by reducing pH value. However, exchangeable Ac and Al were decreased by increasing compost fertilizer rates which might be due to increase in organic anions, rise in pH and basic cations by its oxidation. Hue (1992) and Abreha (2013) stated that adsorption of organic anions on hydrous Fe and Al surfaces, and release of hydroxyl ions from OM increase pH and reduce exchangeable Ac in soil solution. Yang *et al.* (2013) also reported that exchangeable Al concentration evidently decreased by fulvic acid production of compost decomposition. Huck *et al.* (2014) further revealed that reduction in exchangeable Ac and Al partly relates to the increase in soil pH by OM that precipitate exchangeable and soluble Al as insoluble Al hydroxides, thus reducing concentrations of Al in soil solution.

In this experiment, available P was increased with increasing compost fertilizer rates. This increase might be due to P solublizing/mineralizing effect of organic acids and phosphatase enzymes, shielding of compost on P adsorption sites, chelation of Al and Fe with complexing agents and its subsequent removal from a soil as well as a rise in soil pH. Erich *et al.* (2002), Myungsu *et al.* (2004), Ano and Ubochi, 2007 and Jen *et al.* (2008) found that application of compost can enhance the availability of soil P and even fixed P can be made available to plants after solubilization by soil microorganisms bsides complexation of soluble Al and Fe by organic molecules. Phosphorus solubilizing bacteria and fungi can increase soil P availability by acid phosphatase enzyme that affects P acquisition and P use efficiency in plants (Song and kaeppler, 2001; Petra *et al.*, 2007; Adem *et al.*, 2009. Similarly, Al-Oud (2011) and Carine *et al.* (2006) reported that compost

amendments enriched with microorganisms have the ability to increase OC, N and S nutrients. Sharif *et al*. (2010) also stated that humic acid is produced through decay/oxidation of OM by microbial action that can break Fe or Al bond P in acidic soil and release P in soil solution. Besides, Gaard (1996) and Geissen and Guzman (2006) revealed that especially in tropical countries where P is strongly adsorbed by Fe and Al oxides, increase in OM leads to P mobilization and reduction in its adsorption.

Nevertheless, available P was decreased with increasing S fertilizer rates which might be due to liberation of sulfuric acid. Simon (2002) and Brauer, *et al.* (2005) in their incubation studies reported that gypsum in soils made P less available by tying it up as insoluble Ca phosphates, and heavy gypsum application can even tie up it more. However, opposite results were reported by Taalab *et al*. (2008) in Nubaria-Egypt on P availability who stated that extractable P was significantly increased when various P sources were combined with S fertilizer.

V. Conclusions

Application of compost fertilizer increased while S decreased pH and P availability in acidic soils. Although exchangeable Ac and Al were decreased with increasing compost rate, they were increased with increasing S fertilizers. Large application of compost fertilizer could alleviate the problem of P fixation but S rather exacerbated its adsorption. The increase in P desorption with increasing compost rate could be the result of its capacity in raising soil pH, chelating on Al and Fe as well as solublizing/mineralizing by organic acids which made it an alternative input for acid soil management. Thus, application of high OM such as compost could significantly increase while S fertilizers decrease P desorption in acidic soils. Hence, regular application of compost or other alternative sources of OM to small holder farms in the highlands of Ethiopia (affected by soil acidity) could result in improving P availability while S fertilizers aggravate P fixation.

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The Ability of Sludge from Wastewater Treatment Systems of Paper Plant to Improve Soil Fertility and Crop Growth

By Nguyen Xuan Cu
VNU-University of Science, Viet Nam

Abstract- In Vietnam, the sludge from wastewater treatment systems in general and from the paper mill in particular is quite large. Particularly, an estimated 14,500 tons of sludge are generated annually from only the paper industry. However, at present mainly these sludge are applied forms of burial in landfills. It has caused difficulties for the construction of the landfill and waste of resources. Therefore, this study aims to investigate the possibility of using sludge as fertilizer to soil and crop improvement, and contribute to environmental protection.

The results show that sludge from wastewater treatment systems of paper plant has high organic matter content (28.76% of organic C), rich in N (1.07%) and other nutrients such as P, Ca, Mg that should be used as fertilizer to improvement of soil fertility, and contribute increasing crop production. In this research, the sludge has a positive impact on soil properties, especially contributed significantly improve the amount of available nitrogen and soil humus. The high sludge applied generally produced greater biomass and crop yields.

Keywords: *sludge of paper plant, soil fertility, crop improvement.*

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Keywords: sludge of paper plant, soil fertility, crop improvement.

I. Introduction

Sludge means materials in the form of slurry formed from wastewater treatment systems of paper plant are usually natural dry and burial in the landfill as solid waste. Due containing multiple organisms identified to participate in the process of decomposition of organic matter in the wastewater treatment systems, the sludge from the paper plants also called biosolids. Worldwide annual sludge is huge. For example in Texas, there is about 650 thousand tons of dry sludge was brought for burial in landfills. This is wasteful and costly expenses for the construction of the landfill (Texas Environmental profile, 2009).

In recent years, the use of sludge from paper mills to improve soil was also noted studies, it is likely to supply organic matter and mineral nutrients for crops. In the US, every year there are 5-6 million tons of this type of sludge is removed from the wastewater treatment plants, of which about 60% is used for fertilizing soil in farms and golf courts. This solution is considered to be effective in both economic and environment, and is much better than bringing to the landfill. Scientists in Ontario (Canada) has carried out experiments to evaluate the use of paper mill sludge applied to agricultural land (Industry and Environment office, 1981). The results of the experiments showed that sludge has the effect of increasing growths and yields of various crops (Bellamy et al., 1995; Harrison et al., 2014),

However, because the sludge usually contains a lot of heavy metals, thus ensuring that the use of sewage sludge applied to soils also needs to be tightly controlled. Some studies in US indicated that if applied at high volume 50 tons/acre would be harmful to plants (US-Environmental Protection Agency, 1979).

In Vietnam, the sludge from the wastewater treatment systems in general and from the paper plants in particular are quite large. Particularly, an estimated 14,500 tons of sludge are generated annually from only the paper industry. However, at present mainly these sludge are applied forms of burial. It has caused difficulties for the construction of the landfill and waste of resources. Therefore, studying the effects sludge as fertilizer to soil properties and crop production are important and contribute to environmental protection. For these, the study aims to evaluate the effects of applying sludge from waste water treatment systems of paper plant to humus accumulation in soil and crop yields of peanuts. Field experiments were carried out on hilly land in Phu Tho Province, Vietnam.

II. Materials and Methods

Field experiments were arranged on the hillside (Acrisols) growing peanuts in Phu Tho province. Phu Tho located in the Northern midlands of Vietnam, with a tropical monsoon climate. The average temperatures is about 22,5°C (the lowest and highest of 6°C and 39°C). The average annual rainfall of 1724 mm (the lowest and highest of 1241mm and 2185mm). However approximately 70% of annual rainfall happened in rainy season during April to October.

Originally sludge taken from the wastewater treatment systems of Bai Bang paper mill, Phong Chau district, Phu Tho province used to fertilize the soil growing peanuts (*Arachis hypogaea* L.). Peanut is a

Author: Department of Pedology and Soil Environment, VNU-University of Science; Nguyen Trai, Hanoi, Vietnam. e-mail: cunx@vnu.edu.vn

food plant with rich in energy and nutrients and have important economic implications in the midlands of Vietnam.

The purpose of the experiment was to study the effects of sludge applied to soil properties and yield of crops. The experiment included four treatments is a randomized block design, and repeated three times. These including the control without sludge applied (Trt.1), and other three treatments corresponding to the amount of sludge applied 10 tons (Trt.2), 20 tons (Trt.3) and 30 tons (Trt.4) per ha. The area of each plot is $20m^2$ and the background of 200 kg/ha of mixture NPK fertilizer (5:10:3) based on the average amount of local people applying to the crop. Peanuts are sown immediately after tillage and sludge applied during the rainy season.

The plant and soil samples were taken before treatment and periodically at 30 days, 60 days, 90 days and 110 days (before harvest time) after seeds sowing. Mixture soil samples were taken at the surface layer of 0-20cm, and the data of plants samples were determined based on 5 plants randomly chosen in each treatment.

III. Results and Discussion

a) Some properties of sludge and soil research

Some properties of soil and sludge used in the experiment are shown in Table 1. Overall the soil fertility is very poor in plant nutrients. While the amount of these in the sludge are much higher, especially organic matter and nitrogen, calcium and magnesium. These are important factors that affect the soil properties and plant nutrition.

The data in Table 1 shows the sludge has pH value of 10.8 and exchangeable Ca^{2+} of 7.54 Cmol/kg, and exchangeable Mg^{2+} of 10.2 Cmol/kg that are much higher than in the soil. Therefore, the amendment of sludge will be a measure needed to supplement Ca and Mg to soil, renovating the acidity, reduce the toxicity of Al^{3+}, and enhance the activities of soil microorganisms.

Soil acidity is an important factor of soil fertility. It affects the physical, chemical, and biological processes in soil and also affect plant growth (Chantigny, 2003). Because of low pH values in this soil, the application of sludge to reduce soil acidity is the significant, especially in the case of peanuts.

In term of nitrogen, the data in Table 1 also shows higher nitrogen content of the sludge of 1.07% while the nitrogen content in soil only 0.09%. Thus, it can be calculated the total nitrogen content in sludge close to 12 times higher than in the studied soil. Similarly, total phosphorous content in sludge is 6 times higher than in the soil. So the sludge from wastewater of paper plant really is additional source of nitrogen and phosphorus to the soil and plant nutrition.

Table 1 : The properties of studied soil and sludge samples

Sample	pH	Total content (%)					Humus acids (% of total C)			Ch/Cf
		C	N	C/N	P_2O_5	K_2O	Humic	Fulvic	Total	
Sludge	10.8	28.76	1.07	27/1	0.66	0.12	29.03	25.67	54.7	1.13
Soil	5.1	1.21	0.09	13/1	0.11	0.15	17.10	21.92	34.4	0.78

One of the most advantages of sludge is very high in organic matter and humus acids (humic and fulvic acids) as well. The content of total C accounted for 28.76%, more than 23 times higher than in the soil research. Moreover, the sludge also has high ratio of C/N (27/1) compared with low ration of C/N in soils (13/1). So the addition of sludge will be of great effects to adjust the ratio C/N in the soil.

From the results presented above it can be say that sludge considered a good material with high potential to improve soil and provide nutrient elements for plants. The use of sludge as fertilizer with adequate levels will have a positive impact on the physical, chemical and biological properties of soil. So the sludge can be applied for soil and crop improvement, and contribute minimizing environmental pollution.

However, at present in Vietnam, sludge from all waste water treatments always considered as hazard wastes. But from the date in Table 1 shows the contents of heavy metals in low concentration: 14.57 ppm As; 0.11 ppm Cd; 22.11 ppm Pb; 16.25 ppm Cu; 131.55 ppm Zn; 178.55 ppm Mn and 0.19 ppm Hg. Therefore, the use of the sludge as fertilizer to soil may have no negative impact on soil environment. Moreover, they also have some additional trace elements needed for plant nutrition.

b) Effect of sludge applied to soil properties

The results of soil organic matter in soil are shown in Table 2. Due to sludge contains high organic matter so the sludge has an important role to improve the soil organic matter. From this experiment, after 30 days of application, the levels of total of soil organic carbon (SOC) has increased from 1.21% in the origin soil up to 1.25%, 1.44%, 1.67% and 1.91% corresponding to application of 0 tons, 10 tons, 20 tons and 30 tons of sludge/ha.

Table 2 : Effect of sludge to SOC in the experiment

Treatment	After 30 days	After 60 days	After 90 days	After 110 days
Trt.1	1.25	1.48	1.48	1.51
Trt.2	1.44	1.60	1.55	1.67
Trt.3	1.67	1.77	1.97	1.99
Trt.4	1.91	1.98	1.99	2.02

The SOC increases rapidly when increasing amounts of sludge fertilizer at all time research. Buts at each level of sludge applied, SOC increase faster during 90 days of sludge applied, and then tend to rise more slowly. The reason can be explained by the increase quickly in biomass of peanut roots and soil microorganisms in the early stages and then being more and less stable during the late stages of growing season. Moreover, due to high C/N ratio in sludge (27/1) this changes the ratio of C/N in soil to favor humus accumulation in soil.

Along with the enhanced levels of organic matter, the applied sludge has an important role to improve the quality of soil humus. That means the total content of humic and fulvic acids in the soil has increased rapidly in all the treatments with sludge fertilizer over time. At 110 days of the experiment, the total humus acids in SOC increased from 47.43% in no sludge applied to 58.04%, 70.13% and 72.68% corresponds to the amount of sludge increased to 10 tones, 20 tones and 30 tones per ha (Table 3).

Table 3 : Effect of sludge to soil humus

Treatment	After 30 days		After 60 days		After 90 days		After 110 days	
	% SOC	Ch/Cf	% SOC	Ch/Cf	% SOC	Ch/Cf	% SOC	Ch/Cf
Trt.1	39,02	0,78	43,13	0,81	44,48	0,76	47,43	0,79
Trt.2	46,15	0,67	48,71	0,89	52,02	0,82	58,04	0,86
Trt.3	53,40	0,76	54,50	0,92	61,17	0,84	70,13	0,92
Trt.4	55,85	0,84	56,69	0,94	69,32	0,96	72,68	0,97

The data in table 3 also show that the sludge fertilizer not only increases SOC but also improve the quality of soil humus. Although the proportion of humic and fulvic acids indicated the sludge has created favorable conditions for the formation of humic acid. But, low ratios of humic acids/fulvic acids (Ch/Cf) in all the treatments demonstrate the rate of humic acid accumulation is slower than the rate of fulvic acid accumulation. This result is consistent with previous studies on the composition of soil humus in Vietnam by Nguyen Xuan Cu. It is concluded that the fulvic acids are predominant than humic acid in most of soil types in Vietnam (Nguyen Xuan Cu, 2005).

c) Effect of sludge applied to crop growth

- Effect of sludge applied to the height of peanut plant in the experiments

The results show different effects of sludge applied to plant growth depending to the rate of sludge applied (Table 4). In general, the height of peanut plants in all treatment grow rapidly over time.

After 60 days sowing, plant heights range about 7.2 - 8.3cm and increase more than 3 times at 90 days. The highest value of plant height is observed at 110 days after sowing, range about 41.3 - 46.7cm. At this time, the difference on the plant height of peanuts between levels of sludge applied are also more significant.

Table 4 : The growth of peanuts in the experiment

Treatment	Plant height (cm)			Plant biomass (quintal/ha)			Pods yield	
	60 days	90 days	110 days	60 days	90 days	110 days	pods/plant	quintal/ha
Trt.1	7.2	26.7	41.3	1.76	22.00	68.50	12	40.0
Trt.2	7.7	27.7	43.7	2.62	23.50	78.00	13	51.0
Trt.3	8.1	28.6	44.0	2.86	27.00	84.00	14	57.5
Trt.4	8.3	29.3	46.7	3.27	29.00	97.50	16	62.0

- Effect of sludge applied to plant biomass

Compared with the height of plants, the effect of sludge to biomass is more clearly. The biomass increase with increasing the amounts of sludge applied in all treatments and all observation time, especially during the first 60 days of growth. At 60 days, the biomass in the treatment applied 30 tons of sludge/ha (Trt.4) increase form 1.76 to 3.27 quintal/ha, increased 1.86 times, compared with the control (Trt.1). While this rate is only 1.32 times at 90 days and 1.42 times at 110 days after sowing.

Along with increasing plant height, the plant biomass are accumulated over time, most evident is the time at 60 days after sowing. The deference here is that the plant height tends to rise slowly while biomass of peanuts tend to rise faster after 2 months from sowing. At 110 days, the biomass increased more than 3 times compared to 90 days, and ranging between 68.5 – 97.5 quintal/ha. Thus it can be said that the sludge applied has a positive effect stimulates the growth of peanuts and significantly increase plant biomass.

- Effect of sludge applied to pod yields in the experiment

As mentioned above, sludge has good effects on soil properties, promoting the growth and productivity of peanuts. The results in Table 4 show the pod yields are positively correlated with the amount of sludge applied to soils. The observation on plant growth in the treatments with sludge applied also recognized the root systems of peanuts is better to form nodules, flowering and fruit setting rate.

The average number of pods per plant has increased from 12 to 13; 14 and 16 pods per plant when the amounts of sludge increased from 0 to 10; 20 and 30 tons per ha. Similarly, pods yield increased from 40 to 51; 57.5 and 62 quintal/ha, accounted increasing respectively 128; 144 and 155% compared to control.

In brief, the results presented above clearly show the positive effects of sludge from paper plants to soil and crop improvement, and contributing to protect the environment.

IV. Conclusions

Sludge from wastewater treatment systems in Bai Bang paper plant has high organic matter content (28.76% of organic C), rich in N (1.07%) and other nutrients such as P, Ca, Mg that should be used as fertilizer to improve soil and crop production.

Sludge have a positive impact on soil properties, increase the amount of available nitrogen in the soil, especially significantly improve the quality and content of soil humus. Plants grown and develop better in sludge applied soil, and give higher yields. Specifically, with the amount of sludge applied 10; 20 and 30 tons per ha increased the pod yields of peanuts by 128; 144 and 155% compared to control without application of sludge.

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Comparative Study on the Breeding Performance of Two Different Strains (XY Male and YY Male) of Nile Tilapia (*Oreochromis niloticus*)

By Amitav Roy, Abdullah-Al Mamun, Shuva Bhowmik, Md. Tamim Hasan & Priyanka Rani Majumdar

Noakhali Science and Technology University, Sonapur, Bangladesh

Abstract- The study was conducted to know the breeding performance of two strains (YY and XY male tilapia) of *Oreochromis niloticus* in Bismillah Agro production hatchery of Noakhali Sadar in Noakhali district, Bangladesh from May to August, 2012.The length, weight of the brood fishes and gonad weight, fecundity, egg fertilization rate, hatching rate, fry survival rate and larval growth in both strains were assessed. YY male showed the highest length and weight during three stocking months. Average fertilization rate and hatching rate were higher in YY male derived than that of XY male derived egg. Higher average larval survival rate and larval growth was observed in YY male derived progeny than that of XY male derived. Production of male population was higher in YY male than XY male tilapia. The result of the present study concluded that YY male tilapia outperformed than XY male in all cases of breeding performance.

Keywords: *Oreochromis niloticus , yy male, xy male, breeding performance.*

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Comparative Study on the Breeding Performance of Two Different Strains (XY Male and YY Male) of Nile Tilapia (*Oreochromis niloticus*)

Amitav Roy [α], Abdullah-Al Mamun [σ], Shuva Bhowmik [ρ], Md. Tamim Hasan [ω] & Priyanka Rani Majumdar[¥]

Abstract- The study was conducted to know the breeding performance of two strains (YY and XY male tilapia) of *Oreochromis niloticus* in Bismillah Agro production hatchery of Noakhali Sadar in Noakhali district, Bangladesh from May to August, 2012.The length, weight of the brood fishes and gonad weight, fecundity, egg fertilization rate, hatching rate, fry survival rate and larval growth in both strains were assessed. YY male showed the highest length and weight during three stocking months. Average fertilization rate and hatching rate were higher in YY male derived than that of XY male derived egg. Higher average larval survival rate and larval growth was observed in YY male derived progeny than that of XY male derived. Production of male population was higher in YY male than XY male tilapia. The result of the present study concluded that YY male tilapia outperformed than XY male in all cases of breeding performance.

Keywords: Oreochromis niloticus, yy male, xy male, breeding performance.

I. Introduction

The Nile tilapia, Oreochromis niloticus (Linnaeus) is widely cultured species in many tropical and subtropical countries of the world (Lin *et al.,* 2008; Authman *et al.,* 2009).It is currently ranked second only to carps in global production and is likely to be the most important cultured fish in the 21st century (Ridha, 2006). It is one of the popular and commercial species which fulfills the animal protein demand of people where wild capture fisheries are being depleted because of their faster growth rate, tolerance to harsh environment, ease of breeding and culture technique (Mandal *et al.,* 2009; Palipoch *et al.,* 2011). Major problems in tilapia culture arethe reduction of growth rates of females due to their early sexual maturity that diverts energy from growth to reproduction and the excessive reproduction that leads to various sizes of small fish production and overcrowding condition (Lèveque, 2002; Chakraborty *et al.,* 2011). The most effective solution to this problem is to produce, grow and culture all-male tilapia because males grow significantly faster, larger and more uniform in size than females (Bwanika *et al.,* 2007). In 1994 Bangladesh Fisheries Research Institute (BFRI) imported GIFT (Genetically Improved Farmed Tilapia) Tilapia for research of genetic improvement by a project of World Fish Center. Nowadays all progressive farmers are used to prefer GIFT culture compared to Indian major carps for more profit. Another alternative is GMT (Genetically male tilapia) which is useful and advantages over GIFT due to its fertility and ability to produce all males resulting great potential of growth. This genetic technology for producing all- or nearly all-male progeny in the Nile tilapia is known as the "YY male technology" and the producing YY male progeny are known as "super males" (Mair *et al.,* 1997). Thus, the main objective of this study was to find out more desirable and profitable strain between two different strains of (XY Male and YY Male) of Nile Tilapia (Oreochromis niloticus) by comparing their breeding performance.

II. Materials and Methods

Two different strains of tilapia such as: SRT (Sex Reversed Tilapia) and GMT (Genetically Male tilapia) were selected for the experiment.

a) Experimental site and species

The study was conducted in Bismillah Agro production hatchery of NoakhaliSadar in Noakhali district, Bangladesh (Fig. 1). Two different strains of tilapia – GIFT (Genetically Improved Farmed Tilapia) and GMT (Genetically Male tilapia) were experimental species. The fish under study have following genomes: XX females, XY males; and YY super males. In this study, the breeding of YY supermale and BFRI XY male were occurred with BFRI XX females separately in Bismillah Agro production hatchery.

b) Collection of brood fish

The YY supermale was collected from Philippine and GIFT brood fishes were collected from BFRI, Mymensing. The average arrival size of imported 50 fry

Author α σ ¥: Department of Fisheries and Marine Science, Noakhali Science and Technology University, Sonapur, Bangladesh.
e-mail: priyanstu@gmail.com
Author ρ: Department of Fisheries Technology, Bangladesh Agricultural University, Mymensingh, Bangladesh.
Author ω: Department of Oceanography, University of Dhaka, Dhaka, Bangladesh.

of YY male was 11mm (0.1 g) which were reared for 3.5 months uptoattaining 200-250g as average size.The average arrival size of BFRI XY and XX tilapias were 22mm and 3 g which were reared for 3 months upto attaininganaverage size of 120 g.Six Experimental hapaswhich were similar in shape and size, with an area of 5m x 6m x 2 m hapasof 1.5-mm mesh size were used for stocking of the three strains.

c) Stocking of brood fish in experimental hapas

Amongtotal 252 broods, 42 were YY supermale, 42 were GIFT XY male and the rest 168 were GIFT XX female broods and the stocking ratio was 1:2 (male: female). In this study two treatments were T1 (XY male) and T2 (YY male) and each had three replicates (Table 1).

Table 1: Experimental setup

Treatment Category	Replication	Number of Tank	Sexes	Stocking density
T1(XY Male)	R1	Tank 1	XX/XY	36
	R2	Tank 2	XX/XY	36
	R3	Tank 3	XX/XY	36
T2(YY Male)	R1	Tank 4	XX/YY	36
	R2	Tank 5	XX/YY	36
	R3	Tank 6	XX/YY	36

Figure 1 : Image from Google Earth showing the location of Bismillah Agro production Hatchery

d) Brood stock test study

Comparative study was conducted to assess the maturation time of XX female broods. 30 GIFT females crossed by two types of male brood (XY male and YY male) were randomly selected for gonad weight test. The each sample was dissected after applying anesthetics and gonads from each sample were wiped out intact. Only the mature ovaries were selected for weight test. The mature ovaries were weighed by a sensitive electrical balance.

e) Fecundity test Study

Fecundity is the egg producing capability of the female fish. Fecundity is calculated by actual counting and volumetric methods. For fecundity estimation, Gonads were collected by cutting the abdomen of female fish. These gonads were placed in the 10% formalin solution, which helped to harden the eggs. As a result eggs were separated and were counted.

f) Comparative egg fertilization rate

Comparativeegg fertilization rate was found by counting the viable eggs. 30 GIFT femaleswere randomly selected from each treatment. Fertilized eggs were collected from the mouth of the sampled females. For calculating percent fertilization, eggs were carefully taken on a petridish containing water and the number of fertilized and unfertilized eggs were counted under a binocular microscope (x 10) (Adebayo, 2006).Ratio of the average collected eggs and eggs present in the gonad represent the egg fertilization rate.

Fertilization Rate = (Number of fertilized eggs / Total number of eggs counted) x 100

g) Comparative hatching rate

Adult female mouths were checked for eggs every seven days. The fertilized eggs were collected from the female mouths and kept in the incubation jars for hatching. Hatching period was 65-72 hours. About 10000 eggs were placed in each hatching tray. After

hatching, the number of hatchlings within each batch was carefully counted and the hatching rate was calculated using the following equation according Adebayo (2006).

Hatching Rate = (Number of eggs hatched / Total number of eggs in a batch) x 100

h) Comparative larval survival rate study

The hatchlings from two different strains of tilapia were kept in six different nursery hapas and were observed for 21 days to count the larval survival rate. Survival rate was estimated by following equation (Adebayo, 2006).

Survival Rate = (Number of hatchlings alive upto larvae stage / Total number of hatchings) x 100

i) Comparative larval growth observation

Larval growth was observed for 28 days in order to measure the length and weight. 30 different larvae were randomly sampled from each treatment.

j) Sex determination study

Finally the rate of male obtained from these comparative treatments and replications were observed. This determination was done by using two techniques:

Aceto-carmine technique: Microscopic examination on the gonads was performed by staining the gonad of the fish. 30 females were randomly sampled and sacrificed for collecting gonad. Collected gonads were mounted on a glass slide and few drops of aceto-carmine stain are added.

The gonad mounts are examined under a compound microscope. The male gonad is composed of fine granular like structure of spermatogonia and the female is characterized with the structure of circular oogonia. The technique proved to be efficient.

Manual sexing: This technique is based on the number of opening in the urinogenital papillae. The male were sorted out by finding a single opening where the female was sorted by finding two separate openings. The accuracy of this method ranges from 80% to 90% (Penman and McAndrew, 2000).

III. Results and Discussion

a) Average Total length observation

Average total lengthwas measured by using scale and gauge. The highest average length was found in YY male than XY male and XX female at three months-May (22.1±2.60 cm), June (23.5±3.18 cm) and July (25.6±0.322 cm) (Fig. 2). It was found from three different replications for each month that the total length were increased with the time (from May to July, 2012).The highest length of YY male, XY male and XX female were found in July (25.6±0.322 cm, 25.4±0.73 cm and 23.7±2.63 cm respectively) and lowest in May (22.1±2.60 cm, 18.5±0.36 cm and 17.8±1.45 respectively).

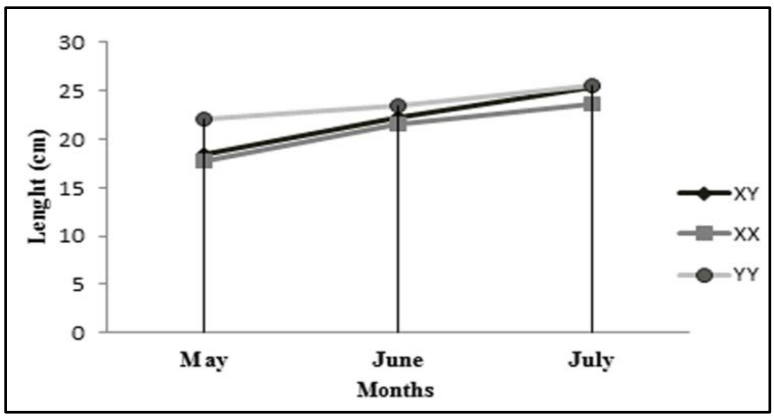

Figure 2 : Monthly variation in length of XX, XY and YY tilapia

Legend to Figure 2 : The highest average length was found in YY male than XY male and XX female during whole rearing periods (from May to July).

b) Average weight observation

Average total weightwas measured by using electrical balance. The highest average weight was found in YY male than XY male and XX female at three months-May (105.7 g), June (115.4 g) and July (129.6 g) (Fig. 3). As like as the length, the total weight of these fishes were increased with the time (from May to July, 2012).The highest weight of YY male, XY male and XX female were found in July (129.6 g, 110.2 g and 115.4 g respectively) and lowest in May (105.7 g, 75.2 g and 70.3 g respectively). Khan et al. (2014) reported that mono sex (YY) group achieved significantly higher weight gain and length than mixed-sex (XX/XY) strain of tilapia under both treatments 35% and 40% CP level.

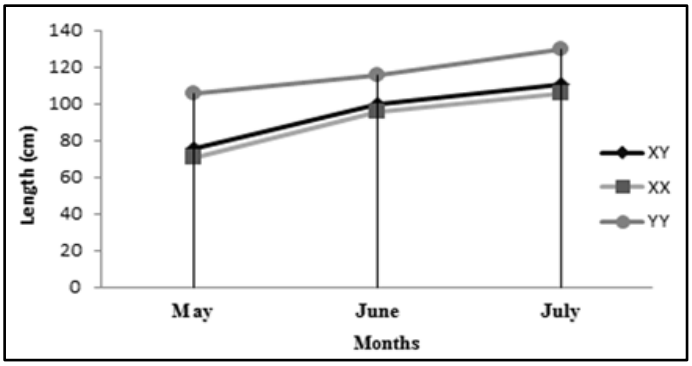

Figure 3 : Monthly variation in weight of XX, XY and YY tilapia

Legend to Figure 3: The highest average weight was found in YY male than XY male and XX female during whole rearing periods (from May to July).

c) Gonad weight and fecundity in GIFT female

Approximately, 752.7 eggs were counted when the gonad weight was 3.45 gram in average from the R1 replication. During the R2 replication approximately 769.8 eggs were counted and the gonad weight was 3.57 in average. In R3 replication the average numbers of eggs were 801.7 and the gonad weight was 3.61 gram in average (Table 2). It was found that the fecundity of XX female increases with the increasing weight of the gonad. Highest eggs production was seen during July with the higher weight of the gonads. Velasco (2003) reported that the fecundity fluctuates widely from a few hundred to several thousand eggs, depending on the size and age of the female. It is reported that as the weight of GIFT strain Oreochromisniloticus increases to a range of 180-498 g, the number of eggs decreases. It means that absolute fecundity in this species is inversely correlated with the weight of sexually mature females.

Table 2 : Relationship between gonad weight and fecundity in GIFT tilapia

No.	R1		R2		R3	
	Gonad weight (g)	Number of eggs	Gonad weight (g)	Number of eggs	Gonad weight (g)	Number of eggs
1.	3.25	735	3.48	791	3.45	775
2.	3.75	810	3.25	718	3.39	759
3.	3.15	710	3.09	675	3.54	785
4.	3.38	723	3.20	712	3.48	754
5.	3.50	794	3.78	823	3.75	851
6.	3.98	834	3.53	797	3.68	791
7.	3.91	825	3.42	784	3.78	868
8.	3.34	710	4.03	820	3.43	765
9.	3.05	685	3.99	798	3.52	791
10.	3.18	701	3.93	780	4.12	878
Average	3.45	752.7	3.57	769.8	3.61	801.7

d) Comparative egg fertilization rate observation

The higher average egg fertilization rate (83%) was found in YY crossed GIFT tilapia. On the other hand, the average estimated egg fertilization rate in XY crossed GIFT tilapia was 77% (Table 3). According to Dey (2000), the GIFT strain showed about 15 - 25% higher yield than the genetically superior existing strains introduced in 1978 and 1988, the hybrid strain of China, and the Chitralada strain of Thailand respectively.

Table 3 : Comparative egg fertilization rate in GIFT tilapia crossed by XY male and YY male

Treatment Category	R1	R2	R3	Average
T1 (XY male)	78%	75%	77%	77%
T2 (YY male)	82%	81%	85%	83%

e) Comparative hatching rate observation

The higher averagehatching rate was found in eggs of YY male crossed GIFT tilapia (47.66%)than XY male crossed GIFT tilapia (46%)(Table 4).Edwin and Ronald (1988) suggested that greater mechanical stress on the egg membrane may result in premature hatching. Therefore, it seems possible that the observed egg mortality was likely to have been associated with mechanical injuries making the eggs susceptible to bacterial or fungal infection. One of the main advantages which artificial incubation offers is the possibility of reducing egg losses compared with maternal incubation (Shamsuddinet al., 2012). However, in nature, oral incubation is a gentle and delicate process. Eventually, in this study, the eggs were kept in continuous circulation in artificial incubation. Although the incubators provide a somewhat smooth and gentle surface, this agitation could cause mechanical stress on the eggs which could result in physical damage to the eggs. Hatching jar was used for the hatching of the eggs.

Table 4 : Comparative hatching rate in GIFT tilapia crossed by XY male and YY male

Treatment	Replication	Number of fertilized eggs	Hatched egg	Hatching rate	Average Hatching rate
T1 (XY male)	R1	20350	9768	48%	46%
	R2	21211	9548	45%	
	R3	22127	9957	45%	
T2 (YY male)	R1	22800	10944	48%	47.66%
	R2	23666	10649	45%	
	R3	24100	11568	48%	

f) Comparative larval survival rate observation

The higher averagelarval survival rate was found in YY male derived larva (85%) rather than XY male derived larva (72.3%) tilapia (Table 5).

Table 5 : Comparative larval survival rate in GIFT tilapia crossed by XY male and YY male

Treatment	Replication	Hatched egg	Survived larva up to 21 days	Survival rate	Average Survival rate
T1 (XY male)	R1	9768	7326	75%	72.3%
	R2	9548	6684	70%	
	R3	9957	7169	72%	
T2 (YY male)	R1	10944	9302	85%	85%
	R2	10649	9318	87.5%	
	R3	11568	9486	82%	

g) Comparative larval growth observation

It was found the growth of YY male derived larvae were higher than XY male derived larvae. The average length of YY male derived larvae in 3rd, 15th and 28th days were 1.4, 3.69 and 11.6 mm respectively which were higher than XY male derived larvae (1.033, 3.01 and 9.7 mm respectively) (Fig. 4). The average weight of YY male derived larvae in 3rd, 15th and 28th days were 0.0126, 0.53 and 1.03 g respectively which were higher than XY male derived larvae (0.0116, 0.327and 0.59 g respectively) (Fig. 5).

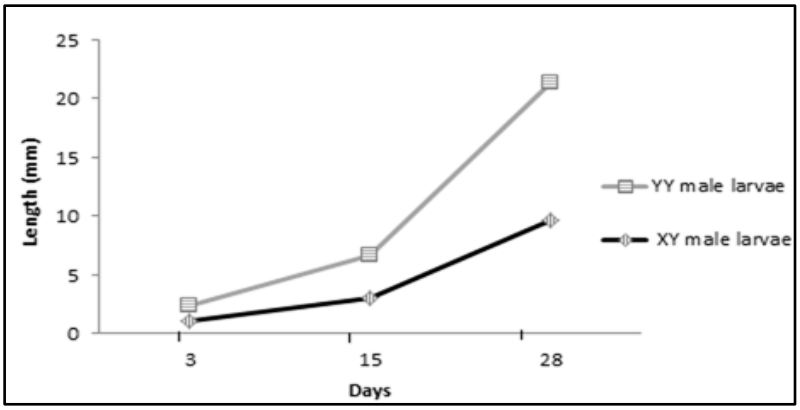

Figure 4 : Comparative length rate of XY and YY male derived larvae

Legend to Figure 4: The average length of YY male derived larvae in 3rd, 15th and 28th days were higher than the length of XY male derived larvae.

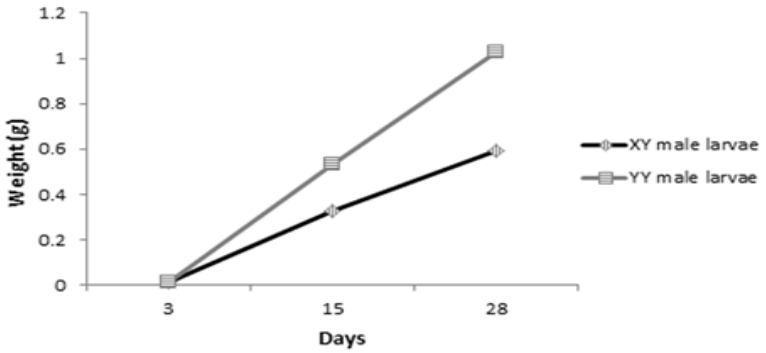

Figure 5 : Comparative weight rate of XY and YY male derived larvae

Legend to Figure 5: The average weight of YY male derived larvae in 3rd, 15th and 28th days were higher than the weight of XY male derived larvae.

h) Percent (%) of male tilapia

Aceto-carmine squash method was used to carry the sex determination study along with manual sexing technique. In the present study, 100% male population was obtained from the YY male crossed GIFT tilapia whereas only 50% male population was obtained from the XY male crossed GIFT tilapia.

IV. Conclusion

Farming of the tilapia has a great potential in Bangladesh and it will be a prime culture species in the near future for freshwater and brackish water ecosystems. The way tilapia aquaculture is expanding at small, medium to commercial scale; it will not be long before the tilapia contributes to the bulk of aquaculture production. It will also be a major source of employment. It can be confidently said that in the near future Bangladesh will be one of the leading countries in Asia in tilapia production.

V. Acknowledgement

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Effects of Water Stress on Morpho-Phenological Changes in Wheat Genotypes

By Md. Mahfuz Bazzaz, Abullah-Al-Mahmud & Md. Shawquat Ali Khan
International Potato Center, Bangladesh

Abstract- The experiment was conducted with eleven wheat genotyps at the research field of Agronomy Department of the Bangabandhu Sheikh Mujibur Rahman Agricultural University from November 2011 to March 2012 to know the morpho-phenological changes in wheat and to identify water stress tolerant wheat genotypes. The experiment was carried out in a split-plot design comprising two water regimes in main plot and eleven wheat genotypes (BARI Wheat 25, BARI Wheat 26, Sourav, BAW 1157, BAW 1158, BAW 1159, BAW 1161, BAW 1165, BAW 1167, BAW 1169 and BAW 1170) were placed randomly in sub-plot with three replications. Water deficit condition caused an overall reduction in morphological and phenological attributes. The maximum reduction in plant height, peduncle length, flag leaf length and flag leaf area was by 25, 39, 27 and 57% in the genotypes BAW 1167, BAW 1167, BAW 1157 and BAW 1170, respectively under water deficit condition.

Keywords: *wheat genotypes, morpho-phenological changes, water stress.*

GJSFR-D Classification : *FOR Code: 820507*

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Effects of Water Stress on Morpho-Phenological Changes in Wheat Genotypes

Md. Mahfuz Bazzaz [α], Abullah-Al-Mahmud [σ] & Md. Shawquat Ali Khan [ρ]

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Keywords: wheat genotypes, morpho-phenological changes, water stress.

I. Introduction

Wheat, next to rice is the staple food of the people in Bangladesh grown over an area of 3.74 million hectare with an annual production of about 1 million metric tons with an average of 2.60 t ha^{-1} (Anonymous, 2011). This production is less than that of other countries because about one third of the total area under wheat in Bangladesh falls in the rainfed regions where water stress can limit plant growth and productivity either because of unexpected dry periods or due to very low or no rainfall (Khaliq *et al.,* 1999). Every year Bangladesh experiences a dry period of seven months from November to May when rainfall is normally low. During this period about 2.7 million hectares of land in Bangladesh is vulnerable to annual drought. Water having paramount importance in the plants, is essentially required at every stages of plant growth from seed germination to plant maturation. Crop plants require adequate water to grow at an optimum rate. Cultivated crops can't show its full genetic potential for yield due to certain environmental limitations especially water stress.

Water deficit inhibits cell enlargement more than cell division and reduces plant growth. Drought reduces leaf expansion (Alves and Setter, 2004), accelerates leaf senescence (de Souza *et al.,* 1997) and leads to death of leaf tissue. Water deficit may influence the phenology of the plant, for instance, it may push forward the flowering in wheat or delay the flowering in rice (Parchin *et al.,* 2011). Kiliç and Yağbasanlar (2010) observed that drought stress accelerated all the phenological growth stages, the normal growth and development periods, dry matter production and final yield.

Monsoon rains provide 80% annual precipitation in Bangladesh, and when this is reduced, water deficit becomes a significant problem. Most of the farmers in Bangladesh grow wheat with irrigation due to scarcity of water. Moreover, it is well known that the ground water table in Bangladesh is declining day by day. As a result wheat faces water deficit at later stages that reduces grain yield drastically. Research on plant response to water stress is becoming increasingly important, as most climate change scenarios suggest an increase in aridity in many areas of the globe (Petit *et al.,* 1999). Drought tolerant genotypes may only partially solve this problem. Little studies have been done in Bangladesh on these to identify wheat, which may act as supporting aspect for increasing wheat production in the country. Therefore, the present study was undertaken to know the morpho-phenological changes in wheat and to identify water stress tolerant wheat genotypes.

II. Materials and Methods

a) Experimental Site, Soil and Climate

The experiment was carried out at the research field of the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur from November, 2011 to March, 2012 on an upland soil. It is

Author α: Agronomy Division, Bangladesh Agricultural Research Institute, Rajbari, Dinajpur, Bangladesh.
e-mail: mbazzaz72@yahoo.com
Author σ: Tuber Crops Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh.
e-mail: A.Mahmud@cgiar.org
Author ρ: Agronomy Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh.
e-mail: shawquatshahadat@yahoo.com

located at the center of Madhupur Tract (240 05′ North latitude and 90016′ East longitude) at an elevation of 8.4 m above the sea level. The soil of the experimental field belongs to Salna series of Shallow Red-Brown Terrace soil type (AEZ 28) with silty clay texture in surface and silty clay loam in sub-surface region of the soil (Brammer, 1971), (Shaheed, 1984). The experimental site is situated in the sub-tropical region characterized by heavy rainfall during the months from July to September and scanty or no rainfall in the rest of the year.

b) Test Crop

Eleven wheat genotypes including most of the popular varieties, some advanced lines and some lines from abroad collected from Wheat Research Centre of Bangladesh Agricultural Research Institute, Nashipur, Dinajpur, Bangladesh were used in the present study.

c) Land Preparation

The land was well prepared by repeated ploughing and cross-ploughing with a power tiller followed by laddering for breaking the clods, leveling the lands and collecting the stubbles. The individual plots were prepared by making ridges (8-10 cm high) around the each plot to restrict the lateral run off of fertilizer with irrigation water.

d) Experimental Design And Treatments

The experiment was carried out in a split-plot design comprising two water regimes in main plot and 11 wheat genotypes selected from previous experiment were placed randomly in sub-plot with three replications. The water regimes were (1) Non-stress (four irrigations were applied at crown root initiation, booting, anthesis and grain filling stages), and (2) Water stress (irrigation was stopped after crown root initiation stage i.e. 20 days after sowing and the crop was protected from rainfall by rainout shelter). The nine water deficit tolerance (BARI Gom 26, Sourav, BAW 1157, BAW 1158, BAW 1159, BAW 1161, BAW 1165, BAW 1169 and BAW 1170) and two susceptible (BARI Gom 25 and BAW 1167) wheat genotypes based on yield reduction were selected for the present experiment. The unit plot size was consisted of 6 rows each of 2.5 m long having a row to row distance of 20 cm.

e) Sowing of Seeds, Fertilizer Application and Intercultural Operation

Wheat seeds at the rate of 120 kg ha^{-1} were sown in line by hand on November 24, 2011. Seeds were placed continuously in lines by making narrow and shallow furrows with iron rod and covered with soil by hand. After sowing of seeds light irrigation was given to ensure uniform germination of seeds. Fertilizers were applied @ 100-60-40-20-1 kg ha^{-1} N-P_2O_5-K_2O-S in the form of urea, triple super phosphate, muriate of potash and gypsum, respectively. Two-third of urea and total amount of other fertilizers were applied during final land preparation. The rest amount of urea was top dressed at crown root initiation stage (20 days after sowing) followed by first irrigation. Intercultural operations were done uniformly in each plot to ensure normal growth of the crop. Weeding and mulching were done simultaneously in the experimental plot for two times, firstly at 15 days after sowing (DAS) and secondly, at 35 DAS. Thinning was also done at 14 DAS.

f) Data Collection

The data related to morphological and phenological parameters were recorded as described below.

g) Morphological Parameters

Plant height was recorded from the average of ten selected plants at maturity stage. Plant height (cm) was measured by a meter scale from soil surface to the tip of the spike excluding awns and averaged. Leaf area of the fully expanded flag leaf was collected from five selected plants at anthesis stage and measured in square centimeters using a calibrated automatic leaf area meter (Delta-T Devices Ltd., Burwell Cambs, UK). Then the measured data were expressed as means of three replications. The peduncle length of five main tillers was recorded by meter scale from the top joint up to the base of the spike in cm.

At harvest, three replicated plants per treatment were used to measure the root volume and root dry weight. The roots were collected from a depth of 0-20 cm and carefully cleaned with running tap water. The root volume was determined volumetrically with the help of a 100 ml measuring cylinder. The cylinder was filled up with 50 ml of tap water and then the total roots of a plant immersed into the water. The raised level of water due to immersion of the roots was recorded. The difference between final and initial volume was considered as root volume. Finally the root dry weight was measured after the samples were oven dried at 70oC for 72 hours.

h) Phenological Attributes

Days to heading was recorded by counting the number of days from the date of sowing till when 80% heads (eye estimation) were found completely visible in each row of the plot. Days to physiological maturity were calculated from sowing to the day when the peduncle and the spike on the tagged main stem became completely yellow. Grain filling duration was calculated by the number of days from heading to physiological maturity during the growing season for each genotype.

i) Statistical Analysis

The data were analyzed by MSTAT-C statistical package program. The difference between the treatments means were compared by least significant difference (LSD) test (Gomez and Gomez, 1983). Functional relationships among different parameters as affected by water deficit stress were established through

correlation and regression analysis by using Excel program.

III. Results and Discussions

a) Morphological Changes In Wheat Genotypes

i. Plant Height

Different morphological characters such as plant height, flag leaf length and peduncle length were affected due to water deficit (Table 1). The plant height ranged from 76.31 to 90.27 cm and from 62.00 to 81.52 cm under control and water deficit, respectively. The tallest plant was obtained in the genotype BAW 1167 and the shortest in BAW 1158 under non-stress condition. The plant height was reduced under water deficit and the reduction was highest in BAW 1167 (25%) followed by BAW 1161 (22%) and BAW 1157 (21%) and the lowest reduction was recorded in the genotype Sourav (8%) followed by that in BAW 1159 (8%) and BARI Gom 26 (9%). The decrease in plant height might be due to decrease in relative turgidity and dehydration of protoplasm which is associated with a loss of turgor and reduced expansion of cell and cell division. Manivannan *et al.,* (2007) also mentioned that the reduction in plant height could be attributed to decline in the cell enlargement and more leaf senescence in the plant under water stress. The plant height in wheat reduced from 77 cm to 61.66 cm when irrigation was skipped at tillering stage of crop growth (Mushtaq *et al.,* 2011). These results are in agreement with the findings of Bayoumi *et al.,* (2008) who observed that drought caused reduction in plant height by 14.7 percent.

ii. Flag Leaf Length

The length of the flag leaf in different wheat genotypes was significantly affected by variable water regimes. The flag leaf length ranged from 22.00 to 28.28 cm and from 15.99 to 20.65 cm under control and water stress condition, respectively (Table 1). The maximum flag leaf length was recorded in the genotype BAW 1167 and the minimum in BAW 1158 in irrigated condition, while the maximum and minimum flag leaf length was recorded in the genotype BAW 1161 and BAW 1165, respectively under water stress condition. The highest reduction in flag leaf length was observed in the genotype BAW 1167 (39%), while the least reduction was obtained in the genotype BAW 1158 (11%) due to water stress. These results are in agreement with the findings of Sangtarash (2010) who found that flag leaf length was significantly affected by water stress in wheat.

iii. Peduncle Length

The peduncle length was also significantly affected by variable water regimes. The peduncle length ranged from 14.98 to 21.15 cm and from 12.17 to 13.35 cm under irrigated and water stress condition, respectively (Table 1). However, the longest peduncle was measured in the genotype BAW 1159 and the shortest in BAW 1161 under non-stress condition, while under water stress condition the longest peduncle was observed in BAW 1170 and the shortest in BAW 1167. The highest reduction in peduncle length was found in the genotype BAW 1157 (27%), while the minimum reduction was obtained in the genotype BARI Gom 25 (13%) due to water stress. These results are in harmony with the findings of Sangtarash (2010) who found that water stress in wheat significantly reduced the peduncle length. Kazmi *et al.,* (2003) reported similar result that water stress imposed to wheat significantly reduced the peduncle length (36%). The highest (30.04 cm) and the lowest (17.04 cm) peduncle length produced in well watered and severe water stress respectively were reported by Moghaddam *et al.,* (2012).

Table 1 : Plant height, flag leaf length and peduncle length in wheat genotypes under water stress condition

Genotypes	Plant height (cm)		% decrease	Flag leaf Length (cm)		% decrease	Peduncle length(cm)		% decrease
	Non-stress	Stress		Non-stress	Stress		Non-stress	Stress	
BARI Gom 25	87.60	71.37	19	25.43	17.9	30	17.75	15.38	13
BARI Gom 26	87.63	79.40	9	26.95	19.32	28	18.09	15.61	14
Sourav	88.27	81.52	8	25.25	18.57	26	20.91	17.34	17
BAW 1157	78.35	62.00	21	23.73	17.22	27	17.61	12.89	27
BAW 1158	76.31	64.73	15	22.00	19.62	11	18.39	15.61	15
BAW 1159	82.67	76.03	8	24.75	20.65	17	21.15	17.21	19
BAW 1161	80.45	63.00	22	24.33	15.99	34	14.98	12.31	18
BAW 1165	79.65	69.13	13	23.83	18.94	21	19.39	16.17	17
BAW 1167	90.27	68.07	25	28.28	17.35	39	16.25	12.17	25

BAW 1169	89.93	77.10	14	22.93	18.5	19	18.19	15.57	14
BAW 1170	77.21	68.40	11	25.7	17.22	33	20.33	17.38	15
LSD (5%)	3.94			1.71			1.31		
CV (%)	4.34			6.78			6.67		

iv. *Flag Leaf Area*

The flag leaf area in wheat varied markedly among genotypes under variable water regimes (Fig. 1). Under control condition, the maximum flag leaf area was exhibited by the genotype BARI Gom 25 (46.87 cm^2) and the lowest in BAW 1169 (28.61 cm^2). But, the flag leaf area drastically reduced in all genotypes due to water stress stress which ranged from 53 to 30 cm^2. However, the genotype BAW 1167 exhibited the maximum reduction in flag leaf area which was followed by the genotypes BARI Gom 25 and BAW 1157 and the minimum reduction was in BAW 1158 which was followed by those in BARI Gom 26 and BAW 1169. These results are in harmony with those reported by El-Danasory (2005), Kazmi *et al.,* (2003) and Khakwani, *et al.,* (2012) who concluded that the flag leaf area was significantly reduced by water stress. Alves and Setter (2004) showed that both cell expansion and production of cells contributed to a loss in leaf area depending on the developmental stage at which the leaf was stressed.

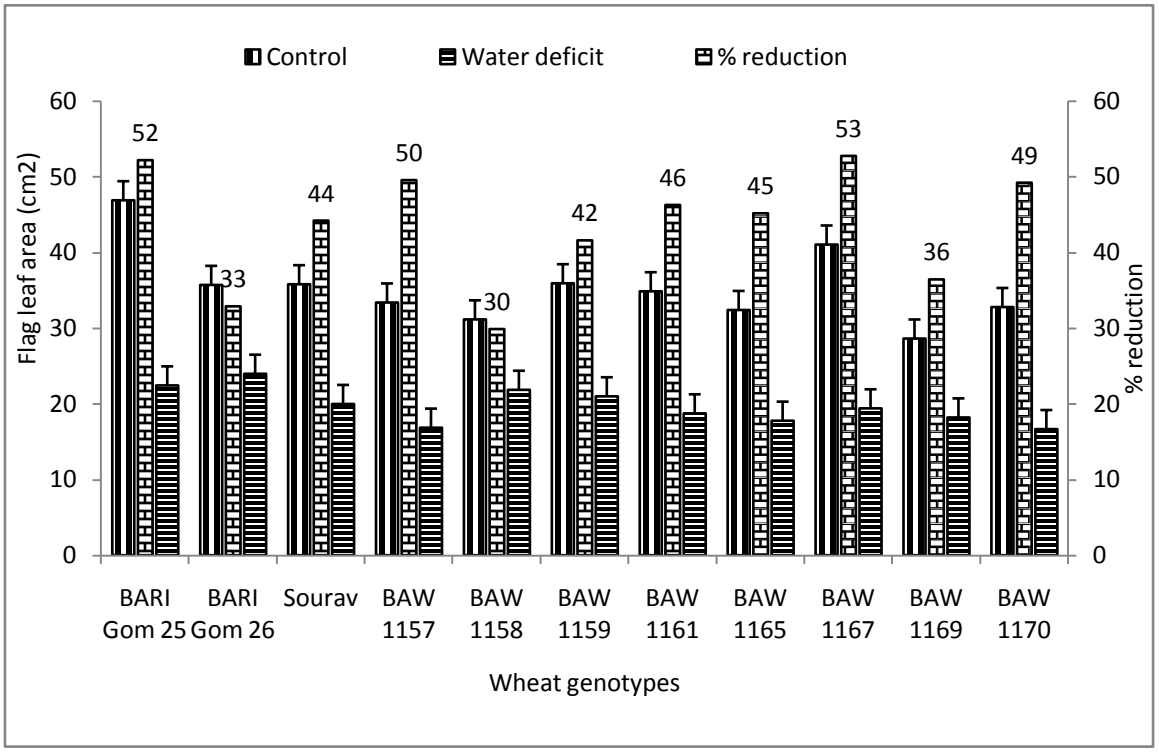

Figure 1 : Flag leaf area in wheat genotypes under non-stress and water stress conditions. Vertical bars indicate LSD at 5% level of significance

v. *Root Volume and Dry Weight*

The present study showed a significant difference in root dry weight and root volume among the genotypes under water stress condition (Fig. 2 and 3). The root volume ranged from 0.46 to 0.61 mm and from 0.37 to 0.52 mm $plant^{-1}$ under non-stress and water stress condition, respectively. The highest root volume was obtained in the genotype BARI Gom 26 (0.52 mm $plant^{-1}$), while the lowest in BAW 1167 (0.37 mm $plant^{-1}$). However, the highest reduction in root volume was recorded in genotype BAW 1167 (33.93%), whereas the lowest in BARI Gom 26 (7.14%). The root dry weight in 11 wheat genotypes followed the similar trend observed in root volume, and varied from 2.27 to 3.10 g plant-1 and from 1.81 to 2.81 g $plant^{-1}$ under non-stress and water stress conditions, respectively. The higher root dry weight was recorded in the genotype BAW 1159 (2.81 g $plant^{-1}$) and the lowest in BAW 1167 (1.81 g $plant^{-1}$). Similar results were also reported by Gesimba *et al.,* (2004) who found that the drought tolerant genotypes had significantly more roots in the crown region, while the susceptible genotypes had fewer roots. Reduction in

root volume under osmotic stress originates not only from growth inhibition but also from a loss of turgidity, as reported in wheat (Benlaribi *et al.,* 1990; Ali Dib and Monneveux, 1992).

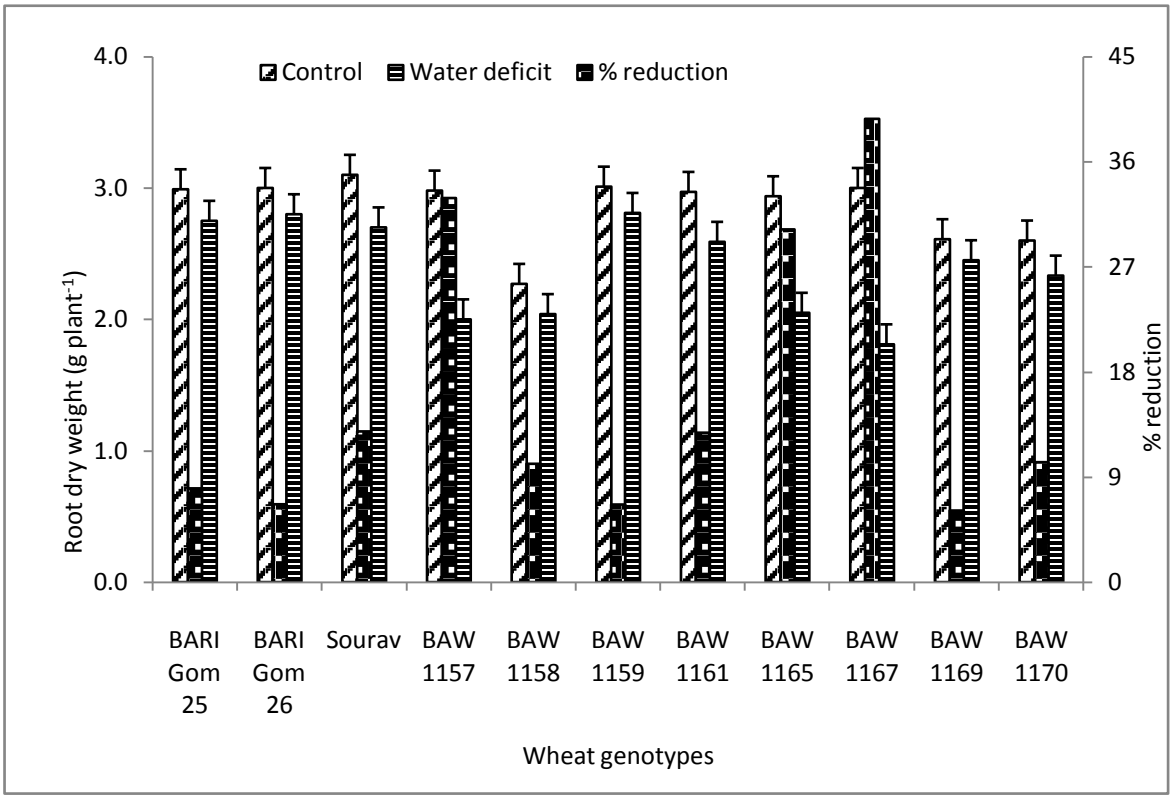

Figure 2 : Root dry weight in wheat genotypes under non-stress and water stress conditions. Vertical bars indicate LSD at 5% level of significance

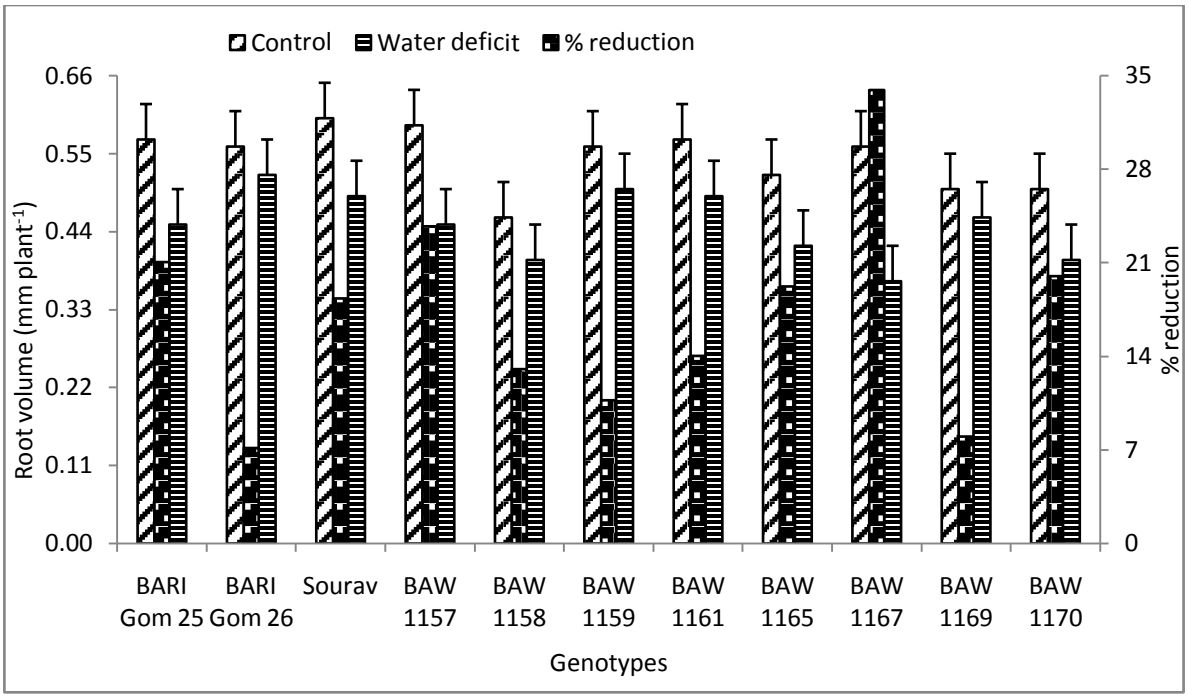

Figure 3 : Root volume in wheat genotypes under non-stress and water stress conditions. Vertical bars indicate LSD at 5% level of significance

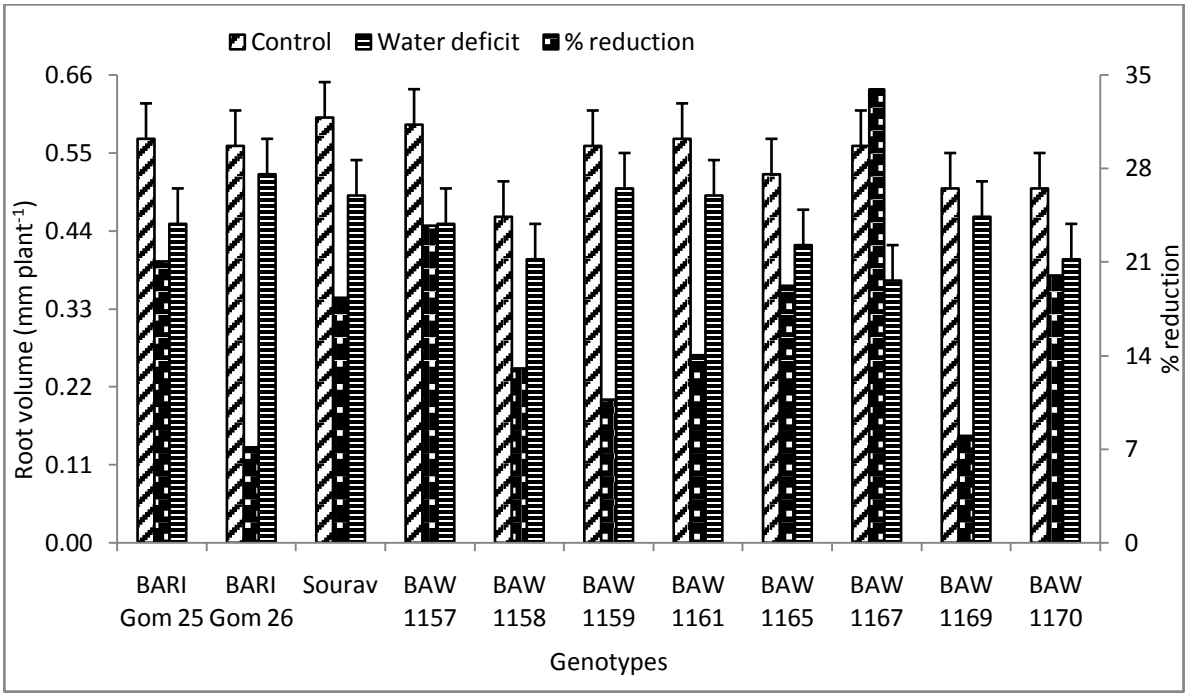

Figure 3 : Root volume in wheat genotypes under non-stress and water stress conditions. Vertical bars indicate LSD at 5% level of significance

b) Phenological Parameters

i. *Days to Heading, Physiological Maturity and Grain Filling Duration*

The phenological traits such as Days to heading, days to physiological maturity and days to grain filling duration were reduced significantly under water stress condition (Table 2). The number of days to heading ranged from 66 to 70 and from 59 to 69 under non-stress and water stress conditions, respectively. But the heading was 7 days earlier in the genotypes BAW 1158 and BAW 1170, whereas 1 to 3 days earlier in the genotypes BAW 1169, BARI Gom 26 and Sourav over control. The physiological maturity ranged from 106 to 111 and from 91 to 106 days under water stress and water stress condition, respectively. However, the higher earliness for physiological maturity was observed in the genotype BAW 1167 (18 days), whereas only 4 to 6 days earlier for physiological maturity was observed in BAW 1169, BARI Gom 26 and Sourav as compared to control. The most important phenological trait, days to grain filling, varied significantly and ranged from 37 to 41 and from 28 to 38 days under non-stress and water stress conditions, respectively. The maximum number of days for grain filling was recorded in the genotype BARI Gom 26 (38 days), while the minimum period for grain filling was observed in the genotype BAW 1167 (28 days). Similar results were also reported by various researchers that drought reduced the number of days to heading (Kiliç and Yağbasanlar, 2010; Bayoumi et al., 2008; Sial *et al.,* 2009; Khakwani *et al.,* 2012; Kılıç *et al.,* 1999), days to maturity (Kiliç and Yağbasanlar, 2010; Saleem *et al.,* 2007) and grain filling period (Kiliç and Yağbasanlar, 2010; Sial *et al.,* 2009). Drought decreases the seed-filling duration, leading to smaller seed size (Frederick *et al.,* 1991; de Souza *et al.,* 1997).

Table 2 : Days to heading, days to physiological maturity and grain filling duration in wheat genotypes under non-stress and water stress conditions

Genotypes	Days to heading			Days to physiological maturity			Grain filling duration		
	Non-stress	Water stress	Earliness over control	Non-stress	Water stress	Earliness over control	Non-stress	Water stress	Earliness over control
BARI Gom 25	69	63	6	109	94	15	40	31	9
BARI Gom 26	69	66	3	109	104	5	40	38	2

Sourav	70	67	3	110	104	6	40	37	3
BAW 1157	69	63	6	106	91	15	37	28	9
BAW 1158	66	59	7	106	92	14	40	33	7
BAW 1159	69	64	5	109	99	10	40	35	5
BAW 1161	69	63	6	109	94	15	40	31	9
BAW 1165	70	65	5	109	98	11	39	33	6
BAW 1167	70	65	5	111	93	18	41	28	13
BAW 1169	70	69	1	110	106	4	40	37	3
BAW 1170	68	61	7	106	93	13	38	32	6
LSD (5%)	2.20			1.54			2.22		
CV (%)	2.82			1.28			5.25		

ii. *Correlation Between Yield and Phenological Traits*

The correlation between yield and phenological traits such as days to heading, days to physiological maturity and days to grain filling showed a marked variation under water stress as shown in Table 3. A significant positive correlation was found between grain yield under water stress condition and days to heading ($P<0.05$), days to physiological maturity ($P<0.01$) as well as days to grain filling period ($P<0.01$). But under non-stress condition, no significant correlation was found between grain yield and above traits. Moreover, among the phenological traits, the days to physiological maturity showed very strong and positive correlation with grain yield which was followed by that in days to grain filling period and days to heading. The relationship between grain yield and days to heading indicates that the yield can vary by 71% due to the variation in days to heading. On the other hand, the relationship between grain yield and days to physiological maturity as well as days to grain filling suggests that the yield can vary by 89% and 86% due to the variation in days to physiological maturity and days to grain filling periods, respectively. The days to heading also showed a significant positive correlation with days to physiological maturity ($P<0.01$) and days to grain filling period ($P<0.05$). Similarly, the days to physiological maturity showed a significant positive correlation with days to grain filling period (($P<0.01$). A positive and significant correlation was observed between grain yield and grain filling period, while a negative and significant correlation was observed between grain yield and number of days to heading as reported by Kiliç and Yağbasanlar (2010). Likewise, the negative correlation between yield under stress and flow¬ering date has frequently been found (Dodig *et al.,* 2010).

Table 3 : Correlation between grain yield and days to heading, days to physiological maturity and grain filling duration in wheat under non-stress and water stress conditions

Trais	Yp	Ys	Heading (days)	Physiological maturity (days)	Grain filling period (days)
Yp	1.00				
Ys	0.23	1.00			
Heading (days)	0.29	0.714*	1.00		
Physiological maturity (days)	0.24	0.893**	0.84**	1.00	
Grain filling period (days)	0.17	0.862**	0.61*	0.95**	1.00

p < 0.05, p**< 0.01, Yp= grain yield under control, and Ys= grain yield under water deficit*

IV. Conclusion

The results of this study indicated that all the parameters in morpho-phenology of eleven wheat genotypes reduced remarkably under water stress condition. The highest reduction in plant height, peduncle length, flag leaf length and flag leaf area was by 25% in BAW 1167, 39% in BAW 1167, 27% in BAW 1157 and 57% in BAW 1170 and the lowest reduction was by 8% in Sourav, respectively under water stress condition. The highest reduction in root volume and root dry weight under water deficit was recorded in the genotype BAW 1167, while the lowest in BARI Gom 26 and BAW 1169. The maximum number of days for grain filling under water stress condition was recorded in the genotype BARI Gom 26 which was at par with Sourav and BAW 1169, while the minimum in the genotype BAW 1167. From this experiment, it was concluded that the

genotypes BARI Gom 26 and BAW 1169 are water stress tolerant and BAW 1167 is susceptible.

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Tuber Yield, Tuber Quality and Plant Water Status of Potato under Drought and Well Watered Condition

By Abullah-Al-Mahmud, Mohammad Hossain, Md. Mahfuz Bazzaz, Md. Shawquat Ali Khan, Md. Altaf Hossain & M.S. Kadian

International Potato Center, Bangladesh

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Keywords: drought susceptibility index, relative water content, xylem exudation rate and spad value.

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Tuber Yield, Tuber Quality and Plant Water Status of Potato under Drought and Well Watered Condition

Abullah-Al-Mahmud[α], Mohammad Hossain [σ], Md. Mahfuz Bazzaz [ρ], Md. Shawquat Ali Khan [ω], Md. Altaf Hossain[¥] & M.S. Kadian [§]

Abstract- Four CIP potato clones with one check variety Asterix were grown during 2010-11 and 2011-12 at horticulture research farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University to observe the effect of water stress on yield and tuber quality of potato. The present study revealed that the tuber yields of all the genotypes were reduced by different degrees of drought. Genotype CIP 393371.58 and CIP 396244.12 performed better in severe drought condition produced higher yield per plant. The highest percent of small sized and deformed tuber was found in the CIP 391004.18 and Asterix under severe drought condition, whereas the normal sized tuber was found in CIP 396244.12 and CIP 393371.58. These two genotypes also maintained more relative water content (RWC) with higher xylem exudation rate under water stress condition than the susceptible genotypes. On the basis of tuber yield and plant water status under drought condition, the genotypes CIP 393371.58 and CIP 396244.12 could be drought tolerant.

Keywords: drought susceptibility index, relative water content, xylem exudation rate and spad value.

I. Introduction

Potato is a cool loving crop, needs regular water supply for its normal growth and development. Potatoes grown all over the world are characterized as drought sensitive (Deblonde & Ladent, 2001; Lahlou et al., 2003; Onder et al., 2005 and Hassanpanah, 2009). RWC is a measure of plant water status, which represents also variation in water potential, turgor potential and osmotic adjustment. RWC is closely related with cell volume; it may more closely reflect the balance between water supply to the leaf and transpiration rate (Schonfeld et al., 1988). This influences the ability of plant to recover from the stress and consequently affects yield and yield stability (Lilley and Ludlow, 1996). Relative water content (RWC) is an integrative indicator (Parsons and Howe, 1984), and was used effectively to detect drought resistance in French bean (Choudhury, 2009), wheat (Sarker et al., 1999), and mustard (Kumar and Singh, 1998). Xylem exudation rate is known as the flow of sap out of the cut end of a stem against the gravitational force. Thus, the exudation rate can be used as an indicator to measure the severity of water deficit. Water stressed plants showed a marked reduction in xylem exudation rate compared to well-watered condition (Aziz, 2003; Chowdhury, 2009). Water deficit is a common phenomenon for potato production, which leads to reduction in tuber quality and yield. Because of the vulnerability of potato to drought (Hassanpanh et al., 2008) arranging adequate water is very important for improving potato quality and increasing quantity. Interrupted water supply leads poor plant growth and reduced tuber number (Hassanpanah et al., 2008) and can decrease tuber yield up to 69% subject to the periods and strength of the stress (Schafleitner et al., 2007).

A well-watered crop is more capable of giving higher yields. Deficit water in irrigation reduces potato yield. The percent of reduction in potato yield may also vary from genotype to genotype. According to some authors, to obtain maximum yields soil moisture should not drop below 50% of crop available water in the soil, although it may vary 25 to 75%. These differences can be explained by climatic, plant and soil characteristics (Van loon, 1981). As water stress in potato is a common phenomenon and its effect has a good impact on growth & development, it is essential to find out how much a tolerant or a susceptible variety can withstand water stress for prolonged period and what is the impact on the water status in plant system. Therefore, the present study was under taken to determine effects of severe and moderate drought on plant water status and tuber yield of potato.

II. Materials and Methods

a) Site and Season of the Experiment

- The experiment was conducted at the Horticultural Research Farm, BSMRAU, Gazipur, Bangladesh

Author α: International Potato Center, Bangladesh.
e-mail: A.Mahmud@cgiar.org, Mahmud.tcrc@gmail.com
Author: σ International Potato Center, Bangladesh.
e-mail: Mohammad.hossain@cgiar.org
Author ρ: Agronomy Division, Bangladesh Agricultural Research Institute, Rajbari, Dinajpur, Bangladesh. e-mail: Mbazzaz72@yahoo.com
Author ω: Agronomy Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh.
e-mail: Shawquatshahadat@yahoo.com
Author¥: Tuber Crops Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh.
e-mail: Altafmy@yahoo.com
Author§: International Potato Center, New Delhi, India.
e-mail: M.Kadian@cgiar.org

during winter season of 2010-11 and 2011-2012. The experimental site is situated in a sub- tropical climate zone and characterized by no rainfall during December to March and plenty during the rest of the year and this area is moderately drought prone, and face drought both winter and late winter season (Ramamasy and Baas, 2007). Air temperature and humidity, precipitation, evaporation, soil temperature and ground water table were recorded throughout the crop period (Table 1).

Table 1 : Climatological data of 2010 11 and 2011 12 crop season

Month	Air Temperature (°C)			Soil Temperature (°C),Depth			Humidity (%)	Rain Fall (mm)
	Max.	Min.	Ave.	10 cm	20 cm.	30 cm		
2010-11								
November	26.60	22.43	24.52	26.03	26.57	26.93	80.47	8.44
December	19.90	15.45	17.68	20.81	21.26	21.61	89.05	0.00
January	15.20	11.58	13.39	16.90	17.33	17.72	90.80	0.00
February	23.85	19.08	21.47	20.85	21.30	21.66	89.89	8.43
March	31.16	26.09	28.62	22.71	23.22	23.59	76.70	29.84
2011-12								
November	27.76	23.76	25.76	26.55	26.91	27.33	85.66	0.00
December	24.80	16.58	20.69	22.72	23.17	23.56	90.70	5.19
January	22.32	11.53	16.93	18.85	19.34	19.84	89.81	0.00
February	27.31	13.24	20.28	20.03	20.45	20.83	87.66	0.00
March	32.58	20.68	26.63	23.53	23.97	24.42	83.94	3.10

b) Planting materials, date of planting and Crop management

Four CIP clones (CIP 391004.18, CIP 393371.58, CIP 396031.119 and CIP 396244.12) and high yielding variety Asterix were used in this experiment. Apparently diseases free, uniform (28-40 mm) sized well sprouted potato were selected as planting material for the experiment. Seed tubers were planted on 25th November, 2010 and 17th November, 2011. Plant spacing was 60 x 25cm. Fertilizers were applied @ 160-44-132-15 kg ha^{-1} of N, P, K and S, respectively. Full amount of P, K and S and 50% of N were applied as basal and the remaining amount of urea was top dressed at 30 days after planting. Intercultural operations such as weeding, earthing up were done manually. Effective crop protection measures were taken according to Dey *et al.*, (2007).

c) Design and treatments of the experiment

The experiment was laid out in the field following strip plot design with three replications. Three drought treatments were applied (T1= severe drought and T2=moderate drought and T3= well-irrigated control). In severe drought plots, only one irrigation was applied at 30 DAP for good crop stand, but no irrigation was applied thereafter until harvest. In moderate drought plot, irrigation was applied twice at 30 and 45 DAP, but no water was applied thereafter till harvest. The control plot was irrigated four times at 30, 45, 60 and 75 DAP.

d) Harvesting and data collection

Selected plants were harvested at 90 DAP. Data were collected on i) Tuber yield (g/plant), ii) % tuber grades (by number) from randomly selected 10 plants.

e) Measurement of plant water status

Relative water content of leaves for each genotype was measured at 60 DAP at 8:00 am. Fully developed 4th and 5th leaf from the top were used for RWC measurement. Relative water content was calculated according to Kumar and Singh (1998). Xylem exudation rate was measured at 60 DAP stage 8:00 am in the morning 5cm above stem base. At first, dry cotton was weighed. A slanting cut on stem was made with a sharp knife. Then the weighed cotton was placed on the cut surface. The exudation of sap was collected from the stem for 1 h at normal temperature. The final weight of the cotton with sap was taken. The exudation rate was calculated by deducting cotton weight from the sap containing cotton weight and expressed per h basis as follows-

$$\text{Xylem exudation rate} = \frac{(\text{Weight of cotton} + \text{sap}) - (\text{Weight of cotton})}{\text{Time (h.)}}$$

f) Statistical analysis

Data on different attributes recorded for two years were analyzed by 'CROSTAT 7.2' statistical package. Appropriate standard errors (S.E.) of the means were also calculated.

III. Results and Discussions

a) Tuber yield per plant

The main effect of drought, genotype and drought-genotype interaction effect for tuber yield per plant was varied significantly (Table 2). Tuber yield of different potato genotypes under different drought conditions were ranged from 169.13 to 488.60 g plant^{-1} in 2010-11 and 155.50 to 357.88 g plant-1 in 2011-12. In severe drought condition, the highest yield was observed in CIP 396244.12 (219.73 g and 203.50 g with a mean of 211.62 g) which was similar to CIP 393371.58 (215.80 g and 160.38 g with a mean of 188.09 g) and the lowest from CIP 391004.18 (169.13 g and 155.50 with a mean of 162.32 g). In moderate drought condition, no significant difference was observed among the genotypes in 2010-11. It might be due to rainfall at later stage of growth (Table 1). Asterix produced significantly the highest tuber yield (315.88 g) in 2011-12 which was similar to CIP 396244.12 (283.38 g), CIP 393371.58 (274.94 g) and CIP 391004.18 (261.66 g). CIP 396031.119 produced the lowest yield (242.61 g) per plant. Tuber yield significantly increased in all genotypes in well watered control condition and ranged from 386.90 g to 488.60 g in 2010-11 and 327.38 to 357.88 g in 2011-12. Among the genotypes, CIP 396244.12 produced the highest mean tuber yield in the year 2010-11 and Asterix in 2011-12. In severe drought and moderate drought conditions, mean yield reduction were 54.80% and 20.49% in 2010-11 and 50.70% and 19.33% in 2011-12, respectively. Under severe stress conditions CIP 396244.12 and CIP 393371.58 performed better, but in moderate stress condition Asterix gave the highest yield followed by CIP 396244.12 and CIP 393371.58. Therefore, CIP 393371.58 and CIP 396244.12 have good yield potentials under both stress conditions. The present findings are in agreement with the findings of Struik and Voorst, 1986; Deblonde and Ladent, 2001; Heuer and Nadler, 1998 and Hassanpanh, 2010. Deblonde et al., (1999) also reported that severe drought treatment adversely affected tuber yield.

Table 2 : Interaction effects of drought and genotype on tuber yield/plant

Genotype	Yield (g plant-1)							
	2010-11				2011-2012			
	T1	T2	T3	Mean	T1	T2	T3	Mean
CIP 391004.18	169.13	316.90	386.90	290.98	155.50	261.66	346.72	254.63
CIP 393371.58	215.80	363.56	419.10	332.82	160.38	274.94	327.38	254.23
CIP 396031.119	175.33	318.40	393.00	295.58	158.94	242.61	331.33	244.29
CIP 396244.12	219.73	361.73	483.43	354.96	203.50	283.38	345.33	277.40
Asterix	201.33	365.70	488.60	351.88	164.02	315.88	357.88	279.26
Mean	196.26	345.26	434.21		168.47	275.69	341.73	
Statistics	LSD0.05		S.Em ±		LSD0.05		S.Em ±	
Drought (T)	23.17		7.73		25.45		8.49	
Genotype (G)	29.92		9.98		32.86		10.96	
T x G	51.82		17.28		56.91		18.98	

T1= Severe drought, T2=Moderate drought and T3= Well watered control

b) Drought susceptibility index

Drought susceptibility index (DSI) was calculated for all the genotypes and presented in the (Fig. 1). The DSI for tuber yield per plant was the lowest in CIP 396244.12 (0.92) followed by CIP 393371.58 (0.94) in the severe drought condition. The highest DSI for yield per plant was recorded in Asterix (1.07), followed by CIP 391004.18 (1.05).Similarly, under moderate drought condition, the lowest DSI was found in CIP 393371.58 (0.72) followed by Asterix (0.98). The highest DSI was found in CIP 396031.119 (1.13) followed by CIP 396244.12 (1.11) High yielding genotype Asterix showed high DSI under severe drought condition as well as very much sensitive to water stress condition. On the other hand, clone CIP 393371.58 showed minimum DSI for yield both in severe (0.94) and moderate (0.72) drought condition.

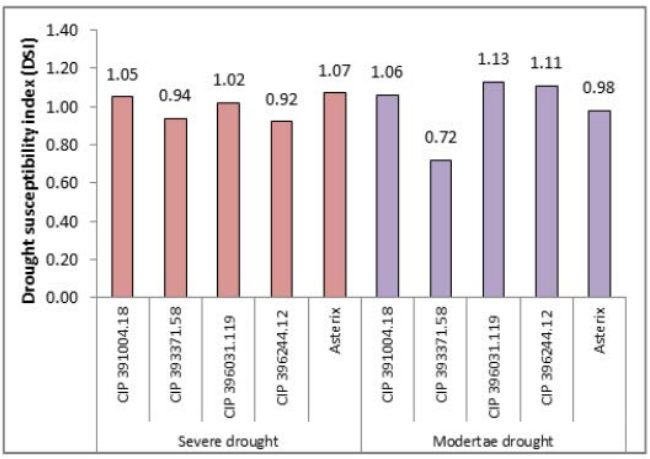

Figure 1 : Drought susceptibility index of potato genotypes under severe and moderate drought condition (Mean of 2010-11 and 2011-12)

c) Tuber grade (% by number)

Tubers of all the treatment combinations were graded into four different groups according to tuber diameter viz. under size (<28mm), Grade- A (28-40mm), Grade-B (40-55mm) and Over size (>55mm). Marked variation on tuber grade (% by no.) was observed among the all treatment combinations (Table-3). In severe drought treatment, CIP 391004.18 produced the highest proportion of under sized tuber (48.48%) followed by CIP 396031.119 (43.69 %) and Asterix (35.66%). The maximum A-grade tuber was produced by CIP 393371.58 (59.35%) followed by CIP 396244.12 (49.68%), Asterix (49.74%) and CIP 391004.18 (48.34%), while CIP 396031.119 produced lowest (39.42%). However, in B-grade tuber, large variation observed which ranged from 2.78 to 33.95 %, CIP 391004.18 produced the lowest, and CIP 396244.12 produced the highest. No oversized (>55mm) tubers were found in severe drought treatment. In moderate drought treatment CIP 396031.119 produced the highest proportion of under sized tuber (28.30%) followed by CIP 391004.18 (27.80 %) and Asterix (27.11%). CIP 396244.12 (12.84%) was the lowest. The highest proportion of A-grade tubers were produced in CIP 391004.18 (61.01%) followed by Asterix (56.78%), and CIP 393371.58 (52.75%) while CIP 396244.12 produced the lowest (45.48%). Larger variation was observed in B-grade tuber which ranged from 11.19 to 38.01% where CIP 391004.18 produced the lowest and CIP 396244.12 produced the highest. CIP 393371.58 and CIP 396244.12 produced 1.97 and 3.67 % over sized tuber, respectively but none were found in CIP 391004.18, CIP 396031.119 and Asterix. In well watered control treatment, % under sized and A-grade tubers decreased, but B-grade and oversized tubers increased. The highest B-grade tubers were found in CIP 396244.12 (44.87%), followed by CIP 393371.58 (38.67%), CIP 396031.119 (33.39%) and Asterix (30.21%), where the lowest was found in CIP 391004.18 (24.50%). The highest oversized tubers were produced by Asterix (10.20%) followed by CIP 396244.12 (6.33%), CIP 396031.119 (5.67%) and CIP 393371.58 (5.33%), and the lowest (2.39 %) was in CIP 391004.18.

Table 3 : Tuber grade (% by number) of five potato genotypes under different drought conditions

Treatment	Genotype	% under size	% seed size		% over size
		<28 mm	A-Grade (28-55 mm)	(B-Grade) 40-55 mm	<55 mm
Severe drought	CIP 391004.18	48.88	48.34	2.78	0.00
	CIP 393371.58	22.12	59.35	18.53	0.00
	CIP 396031.119	43.69	39.42	16.89	0.00
	CIP 396244.12	16.37	49.68	33.95	0.00
	Asterix	35.66	49.74	14.61	0.00
Moderate drought	CIP 391004.18	27.80	61.01	11.19	0.00
	CIP 393371.58	14.33	52.75	30.95	1.97
	CIP 396031.119	28.30	47.17	24.53	0.00
	CIP 396244.12	12.84	45.48	38.01	3.67
	Asterix	27.11	56.78	16.12	0.00
Well watered condition	CIP 391004.18	30.37	42.74	24.59	2.39
	CIP 393371.58	15.74	40.25	38.67	5.33
	CIP 396031.119	24.31	36.64	33.39	5.67
	CIP 396244.12	17.91	30.89	44.87	6.33
	Asterix	22.26	37.33	30.21	10.20

d) Plant water status

i. *Relative water content*

Relative water content (RWC) of leaves of five potato genotypes varied significantly due to treatment effects (Figure 2). The lowest RWC of leaves was observed in severe drought condition (75.08%) followed by moderate drought (85.86%). In severe drought condition, the RWC of leaves among the genotypes varied from 72.09 to 77.06%. The lowest was found in CIP 391004.18 and the highest was in CIP 396244.12 followed by CIP 393371.58 (75.11%). In moderate drought condition, the RWC of leaves varied from 83.58 to 87.16 % where the lowest was found in CIP 391004.18 and the highest was in CIP 396244.12 followed by CIP 393371.58 (86.52%). In well watered condition, the RWC of leaves varied from 89.30 to 91.20

% where the lowest was found in CIP 391004.18 and the highest was in Asterix followed by CIP 396031.119 (90.9%). It was observed that the genotype CIP 396244.12 and CIP 393371.58 maintained more RWC than the rest three in severe and moderate drought conditions. Similar findings were reported by Begum and Paul, 1993, Paul and Aman, 2000 and Omae et al., 2005, Chandrasekar et al., 2000 and Choudhury, 2009.

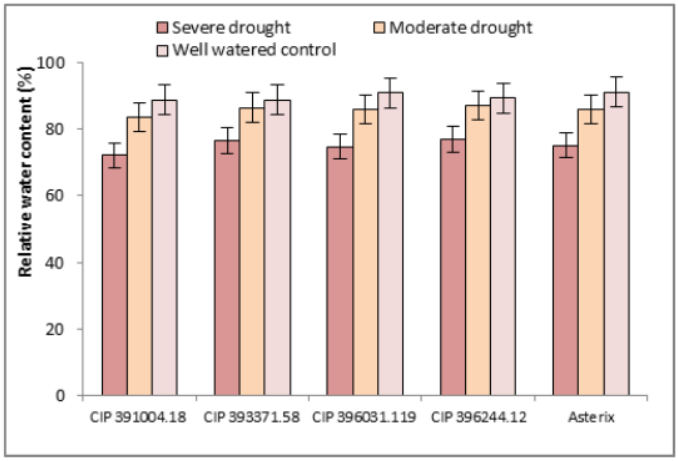

Figure 2 : RWC of five potato genotypes at different drought treatment (Mean of 2010-11and 2011-12).Bar represent mean ± S.E. of 3 replications

ii. *Xylem exudation rate*

Xylem exudation rates of five potato genotypes measured in the morning (9:00am) at 60 DAP stages varied significantly due to treatment effects (Figure 3). The lowest rate was observed in severe drought treatment followed by moderate drought treatment in all genotypes. In severe drought condition, the xylem exudation rate varied from 37 to 117 mg hr^{-1} where, the lowest was found in CIP 391004.18 and the highest was in CIP 396244.12. In moderate drought condition, it varied from 92 to 207 mg hr^{-1} where the lowest was found in CIP 391004.18 and the highest was in CIP 396244.12. Again in well watered condition it varied from 199 to 316 mg hr-1 where the lowest was found in CIP 391004.18 and the highest was in Asterix followed by CIP 396244.12 (298 mg hr-1.). Both in severe and moderate drought conditions, the higher xylem exudation rate was observed in CIP 396244.12 and CIP 393371.58 Similar results in different crops were reported by Islam, 2008 in mungbean and Choudhury, 2009 in French bean.

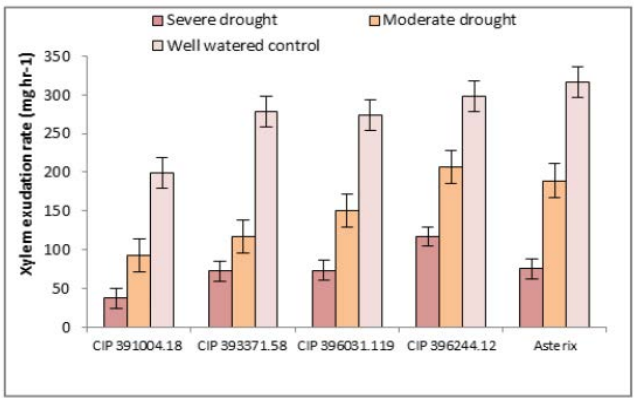

Figure 3 : Xylem exudation rate of five potato genotypes at different drought treatment (Mean of 2010-11and 2011-12). Bar represent mean ± S.E. of 3 replications

iii. *SPAD value*

SPAD (Soil-Plant Analysis Development) value was measured at 60 DAP and found significant variation among the treatments. Mean values of SPAD in severe drought, moderate drought, and well watered conditions were 39.89, 43.58, and 50.98. In severe drought condition, the SPAD values of the genotypes varied from 37.66 to 45.90 where the lowest was in CIP 391004.18 and the highest was in CIP 396244.12. In moderate drought condition, the SPAD values varied from 35.43 to 48.06 where the lowest was in CIP 391004.18 and the highest was in CIP 396244.12. In well watered condition, the values varied from 45.86 to 53.60 where the lowest was in CIP 391004.18 and the highest was in Asterix.

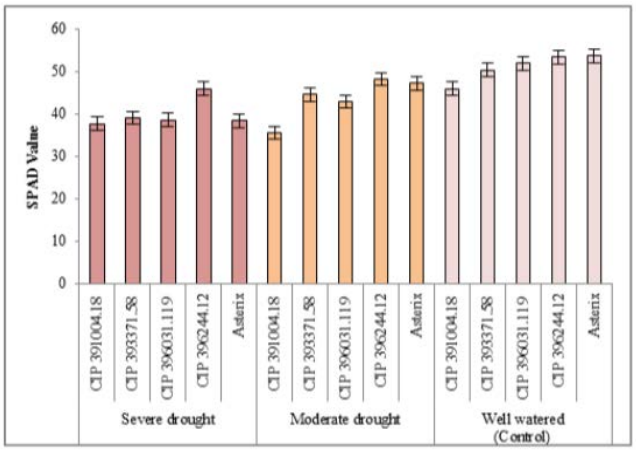

Figure 4 : SPAD value of five potato genotypes at different drought treatment (Mean of 2010-11and 2011-12). Bar represent mean ± S.E. of 3 replications

IV. Discussions

Potato yield greatly depends on its canopy structure as well as on yield contributing attributes like

tuber number per plant, average tuber size and tuber yield per plant. All these attributes affected by deficit irrigation during the production period which ultimately lowered the yield. Growth and yield of potato grown under water stress conditions reduced as a result of stress induced changes of physiological and bio-chemical process (Huffacker et al., 1970). It was clear that drought cause leaf area reduction with leaf fall. Leaf falling and leaf area reduction under drought condition causes reduction of photosynthetic area of the potato plants (Mahmud, 2012) which lowering the rate of photosynthesis. The number of shoots per plant is determined by the size of the tuber (Wurr, 1974), soil condition and soil moisture at planting, although pathogens (black scurf) and pests may have an effect. It may also be influenced by the length and conditions of the pre sprouting period (Allen, 1978). Haverkort et al. (1990) reported that the later dry period does not affect the number of stolons and tubers. Potato plants are especially sensitive to water stress during stolonization and tuberization stages (Steckel and Gray, 1979). The main cause of tuber reduction in water stress condition was the reduction of the number of stolons per plant, and not through a reduction of the number of tubers per stolon (Haverkort et al., 1990). Once stolons are initiated, they yield tubers regardless of a subsequent water stress period. Similar results were reported by Deblonde and Ladent, 2001 and Schafleitner et al., 2007. It was clear from the results that deficit water supply during tuber formation stage reduced the tuber number and size. Irrigated condition favored larger sized tuber formation (Mackerron and Jefferies, 1988; Struik and Voorst, 1986 and Onder et al., 2005).

Genotypes with high DSI were high yielder as well as very much sensitive to water stress. But, oppositely genotypes with low DSI were low yielder and tolerant to water stress. So, potato genotypes with comparatively low DSI and moderate to high yield for better productivity under water stress situation might be selected. Tera´n and Singh (2002) reported that water stress resistant lines had relatively low DSI while the water stress susceptible lines had high DSI values.

RWC in severe and moderate drought conditions which is a good indicator of drought tolerance. Reasons might be the cause of more xylem exudations and production of high amount of osmo-regulatory compounds like proline, sugar etc. Higher exudation rates under drought condition indicated that plants have deep root system and can uptake more water and can tolerate drought condition. It is directly associated with the flow of transpiration stream. Lower SPAD values indicated the reduction of chlorophyll in the leaf due to drought imposition. Leaf chlorophyll content is well correlated with leaf nitrogen status, and photosynthetic capacity. Therefore, the productivity of a crop can be predicted by examining the SPAD values.

V. Conclusion

Tuber yield and grades were seriously affected by drought. The lowest reduction in tuber yield was found in genotypes (CIP 396244.12 and CIP 393371.58). Small sized and deformed tubers were higher under severe drought condition in the genotypes CIP 391004.18 and Asterix, whereas the highest percent of normal sized tubers was found in the genotypes CIP 396244.12 and CIP 393371.58. These two genotypes maintained more RWC with higher xylem exudation rate and higher SPAD values under water stress condition than others which indicated the capacity of the genotypes to thrive well in the water deficit environment.

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- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
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- Significant conclusions or questions that track from the research(es)

Approach:

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- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
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Approach:

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- If use of a definite type of tools.
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The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

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	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
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References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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