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African Journal of Agricultural Research

Full Length Research Paper

Influence of foliar spray with phenylalanine and nickel on growth, yield quality and chemical composition of genoveser basil plant

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Two field experiments were conducted during two successive seasons to study the effect of foliar application with Phenylalanine (zero, 50 and 100 ppm) and /or nickel (zero, 50 and 100 ppm) on growth, yield and essential oil components of genoveser basil plant (*Ocimum basilicum* L. var. Genoveser). Application of the combined treatment (100 ppm Phenylalanine + 50 ppm nickel) resulted in the maximum values of all growth parameters, oil content and estimated yield of herb, leaves and oil. The essential oil was analyzed using a gas liquid chromatography-mass spectrometer (GC-Ms). All treatments proved that linalool was the main compound followed by 1,8 cineol, α-bergamotene, Ʈ cadinol and α-cadinol respectively. These compounds representing about 78.64% of the total oil constituents of genoveser basil. Application of 100 ppm Phenylalanine + 50 ppm nickel increased the relative percent of linalool, α-bergamotene, Ʈ cadinol α-cadinol except 1,8 cineole which was decreased by this treatment.

Key words: Genoveser basil, phenylalanine, nickel, yield, essential oil constituents.

INTRODUCTION

Basil has been cultivated for a long time as a medicinal and aromatic plant in many countries. It belongs to the genus *Ocimum* (Lamiaceae) which contains nearly 150 species of herbs and shrubs from tropical regions of Asia, Africa, central and south America (Baily, 1942). Basil is an important medicinal plant and culinary herb. Genovese basil (*Ocimum basilicum* L. var. basilicum) is one of the most important varieties of the genus *Ocimum* that is well known by its diversity as a source of essential oils. Basil leaves can be used fresh or dried as a spice to add aroma and flavor to confectionary, dressings, salads, pizzas, meats and soups. Its extracts are also used in the manufacturing of pharmaceutical preparations, cosmetics and perfumes (Putievsky and Galambosi, 1999).

Basil traditionally has been used to treat headaches, coughs, diarrhea, constipation, warts, worms and kidney malfunction. Fresh leaves and flowers yield an essential oil of distinctive aroma that possesses various beneficial

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effects for example, antiseptic, carminative, antimicrobial, sedative, anticonvulsant, antitumor and antioxidative properties. It also possesses a wide range of biological activities since it has insect repellent, nematocidal, insecticidal and antifungal activities (Tilebeni, 2011).

Amino acids can directly or indirectly influence the physiological activities in the growth and development of plants. They are particularly important for cell growth stimulation. Also, amino acids might be as important for the metabolic processes as they are components of enzymes, and insufficient synthesis of the essential amino acids, may lead to stress effects on metabolism and growth (Aberg, 1961). Moreover, they protect the plants from ammonia toxicity as well as protect the plants against pathogens (Goss, 1973). Tugnoli and Bettini (2003) concluded that use of amino acids as foliar spraying makes the plant overcome the nutritional deficiencies that arise during growth.

According to several studies, the foliar application of Phenylalanine (Phe) caused an enhancement in plant growth during vegetative and flowering stages (Gamal et al., 1997) on *Cymbopgon citrates* herb, (El-Sherbiny and Hassan, 1987) on datura plants, (Moursy et al., 1988) on *Datura stramonium*, (Refaat and Naguib, 1998) on peppermint (*Mentha piperita*) and (Habba, 2003) on *Datura innoxia*.

Also, Bálványos et al. (2002), showed that 66 mg·L^{-1} Phe maximized growth and alkaloid (lobeline) production of hairy root cultures of *Lobelia inflata* L., meanwhile 250 mg·L^{-1} Phe increased growth parameters, photosynthetic pigments, capsaicin and dihydrocapsaicin content of pepper (*Capsicum annum* L.) (Rashad et al., 2002). Other amino acids have been shown to improve growth and yield of many plants. Foliar application of glutamine at 100 to 200 mg·L^{-1} significantly increased growth parameters as well as yield of onion and quality of bulbs (Amin et al., 2011). Similarly, (Youssef et al., 2004) on lemon basil plant, (Khattab and Helmy, 2003) on fennel plants (Khattab et al., 2011) and on lemon basil. Talaat and Youssef (2002) found a pronounced increase in vegetative growth of plants as a result of lysine and ornithine treatments.

On the other hand, Nickel (Ni) is an essential micronutrient for plant growth. It is a constituent of the enzyme urease, and in small quantities (0.01 to 5 μ g/g dry wt) is essential for many plant species to complete their life cycle but higher concentrations of this metal are toxic and may severely interfere with many physiological and biochemical processes of plants (Seregin and Kozhevnikova, 2006). Ni deficiency depressed urease enzyme activity (Eskew et al., 1983) and other enzymes responsible for nitrate reduction (Brown et al., 1990).

Concerning the role of Ni in higher plants nutrition, some researchers reported growth response of plants to Ni fertilization under field conditions (Takishima et al., 1988), or plants grown in nutrient solutions (Gerendas and Sattelmacher, 1999), or in tissue culture media furnished with urea as the sole N source (Gerendas and Sattelmacher, 1997). The earliest report of a growth response to Ni addition under controlled experimental conditions by Brown et al. (1987) indicated that Ni deficiency has a wide range of effects on plant growth, plant senescence, N metabolism and Fe uptake although, excessive Ni inhibits growth and development of plants. Teixeira da silva et al. (2012) reported that Ni has a role in plant growth and nitrogen uptake in crops fertilized with urea in calcareous soils.

As well as Aly (1999) revealed that the main aroma constituent of parsley leaves was 1,3,8-*p*-menthatriene, which forms about 62% of the essential oil and showed a 10 to 25% increase over that of control with 25 mg per kg soil or higher levels of Ni fertilization. It is suggested that low levels of Ni fertilization strongly improve not parsley leaf yield and quality but also the leaves became safer for human consumption.

Therefore, the objectives of this study were to evaluate the influence of foliar application of different concentrations of Phe and Ni on growth, yield and chemical constituents of genoveser basil under Egyptian environmental conditions.

MATERIALS AND METHODS

This investigation was carried out during the two consecutive seasons of 2011/2012 and 2012/2013 at the Experimental Farm of the Faculty of Agriculture, Cairo University, Giza, Egypt. The experimental area was a silt loamy soil of the following characters: sand, 25%; silt, 54%; loam, 21%; organic matter, 0.39%; total N, 1.12% total P, 0.088%; total K, 0.20%; total C, 0.23%; PH, 7.84 and EC (ds/m) 2.35 . The soluble ions (meq/L) were SO_4, 8.5; Ca^{+2}, 12.5 and HCO_3, 2.5.

Seeds of genoveser basil (*Ocimum basilicum* L. var. Genoveser) were obtained from Enza Zaden com. Seeds were sown in open seed beds during the second week of February in both seasons. After 40 days from sowing, the seedlings were transplanted into the field at rows (60 cm between rows) 25 cm apart between plants. During soil preparation, 150 kg/fed. superphosphate (15.5 % P_2O_5) was applied. After transplanting, 200 kg ammonium nitrate (33.5 % N) and 100 kg potassium sulfate (48 % K_2O) per fed. were added. The mineral fertilization was divided into two equal portions during the growing season; the first portion was added as mentioned before while the second one was applied after two weeks from the first cut. All agricultural practices were carried out as usually recommended for basil production in Egypt.

Nickel sulphate (as a source of Ni) was added as foliar application at rates of Zero, 50 and 100 ppm, while Phe (as a source of amino acids) was sprayed at levels of Zero, 50 and 100 ppm. Both of them were sprayed qquadrupled during the growing season once a month. The first one was applied after one month of transplanting. All spraying treatments were applied at the early morning and spreading agent “Masrol” was added to the foliar nutrient solution (1mL/L) to reduce surface tension. The experiment was designed as split plot in three replicates with Phe as main plots and Ni as subplots.

Genoveser Basil plants were cut twice during the growing season and then left for seed setting. The first cut was done during the second week of July and the second one in the middle of October in both seasons. For each cutting, 10 plants were randomly selected for determining and recording plant height (cm), plant diameter

Table 1. The influence of foliar application of Phenylalanine and nickel on growth parameters of genoveser basil at the first and second cuts in the first season.

Parameter→ Effective factor↓	Plant height (cm	Plant diameter (cm)	Plant fresh weight (g)	Plant dry weight (g)	Leaves fresh weight (g)		Leaves dry weight (g)
				First cut			
	Zero	56.5^{b}	37.6^{c}	392.8^{b}	110.0^{b}	147.7^{b}	26.0^{b}
Phe	50 ppm	62.6^{a}	42.5^{b}	488.6^{a}	137.4^{a}	183.7^{a}	32.3^{a}
	100 ppm	63.2^{a}	44.0^{a}	493.9^{a}	141.6^{a}	185.7^{a}	32.7^{a}
	Zero	57.2^{c}	40.0^{b}	401.9^{c}	112.5^{c}	151.1^{c}	26.6^{c}
Ni.	50 ppm	64.5^{a}	43.0^{a}	526.1^{a}	150.6^{a}	197.8^{a}	34.8^{a}
	100 ppm	60.1^{b}	41.0^{b}	447.2^{b}	125.8^{b}	168.2^{b}	29.6^{b}
				Second cut			
	Zero	55.4^{c}	38.3^{b}	388.6^{c}	108.8^{c}	146.1^{c}	25.7^{c}
Phe	50 ppm	62.6^{b}	42.3^{a}	495.2^{b}	138.7^{b}	186.2^{b}	32.8^{b}
	100 ppm	64.10^{a}	44.0^{a}	505.4^{a}	141.5^{a}	190.0^{a}	33.4^{a}
	Zero	56.4^{c}	39.3^{b}	417.4^{c}	116.9^{c}	156.9^{c}	27.6^{c}
Ni	50 ppm	64.9^{a}	42.9^{a}	525.9^{a}	147.3^{a}	197.7^{a}	34.8^{a}
	100 ppm	61.0^{b}	42.5^{a}	445.9^{b}	124.8^{b}	167.6^{b}	29.5^{b}

Values within each column followed by the same letter were not statistically significant at 5 level. Phe = phenylalanine: Phe 0 = 0; Phe 1 = 50 ppm; Phe 2 = 100 ppm. Ni = nickel: Ni 0 = 0; Ni 1 = 50 ppm; Ni 2 = 100 ppm.

(cm), fresh and dry weights of plant (g), leaves (g) and flowers (g). The yields of fresh and dry herb (ton/fed; fed: Local area in Egypt = $4200m^2$), leaves (ton/fed.) and flowers (ton/fed.) were also estimated.

Representing samples of air dried herb of each replicate at each cut in both seasons were subjected to hydro-distillation for 3 h using Clevenger apparatus to extract and to determine essential oil percent according to Egyptian Pharmacopoeia (1984). The resulted essential oil was separately dehydrated over anhydrous sodium sulphate and kept in silica vials with Teflon-sealed caps and stored at 2°C in the absence of light till GLC analysis. The percentage of extracted essential oil was determined and recorded on the basis of oil volume to herb dry weight (ml/100g dry herb). Essential oil yield (L/fed.) was also calculated by multiplying oil percent with dry yield.

The essential oil constituents were analyzed and determined in the oil samples of the first cut of the second season. The dehydrated oil of each treatment was subsequently analyzed using a gas liquid chromatography-mass spectrometer (GC-MS) to evaluate oil quality. The gas chromatography–mass spectrometry (GC-MS) analysis of the essential oil samples was carried out using gas chromatography-mass spectrometry instrument stands at the Department of Medicinal and Aromatic Plants Research, National Research Center, Egypt with the following specifications. Instrument: a TRACE GC Ultra Gas Chromatographs (THERMO Scientific Corp., USA), coupled with a THERMO mass spectrometer detector (ISQ Single Quadruple Mass Spectrometer). The GC-MS system was equipped with a TG-WAX MS column (30 m x 0.25 mm i.d., 0.25 μm film thickness). Analyses were carried out using helium as carrier gas at a flow rate of 1.0 ml/min and a split ratio of 1:10 using the following temperature program: 40°C for 1 min; rising at 4.0°C/min to 160°C and held for 6 min; rising at 6°C /min to 210°C and held for 1 min. The injector and detector were held at 210°C. Diluted samples (1:10 hexane, v/v) of 0.2 μL of the mixtures were always injected. Mass spectra were obtained by electron ionization (EI) at 70 eV, using a spectral range of m/z 40 to 450. Most of the compounds were identified using mass spectra (authentic chemicals, Wiley spectral library collection and NIST library).

The collected data were subjected to the analysis of variance of split-plot design in Randomized Complete Block Design (RCBD) arrangement according to Snedecor and Cochran (1990) using MSTAT-C V.2.1 software package (Freed et al., 1989). Differences among means were compared for each trait by least significant difference test (L.S.D.) at 5% level of significance (Steel et al., 1997).

RESULTS AND DISCUSSION

Growth parameters of genoveser basil as affected by foliar application of different levels of Phe and Ni are shown in Tables 1, 2, 3 and 4 at the first and the second cuts of the two seasons. Phe applied at 50 or 100 ppm concentration showed positive effect on all the growth parameters (Table 1). The highest values were obtained as a result of Phe application at 100 ppm followed by 50 ppm for all tested parameters in first and second cuts. The increments in plant height, plant diameter, plant fresh and dry weights, leaves fresh and dry weights compared to control reached 11.8, 17.0, 25.7, 28.7, 25.7 and 25.8% respectively, for the first cut of the first season and 15.7, 14.9, 30.1, 30.1, 30.0 and 30.0% consecutively, for the second cut.

With regard to Ni application it significantly augmented all growth parameters of genoveser basil at both 50 and 100 ppm concentrations. There was a progressive increase

Table 2. The influence of foliar application of phenylalanine and nickel on growth parameters of genoveser basil at the first and second cuts in the second season.

Parameter→ Effective factor↓	Plant height (cm	Plant diameter (cm)	Plant fresh weight (g)	Plant dry weight (g)	Leaves fresh weight (g)		Leaves dry weight (g)
			First cut				
	Zero	56.9^{b}	39.0^{b}	402.7^{c}	109.7^{b}	151.4^{c}	26.7^{b}
Phe	50 ppm	63.3^{a}	43.4^{a}	498.0^{b}	143.9^{a}	187.2^{b}	33.3^{a}
	100 ppm	64.4^{a}	44.2^{a}	509.0^{a}	140.7^{a}	191.4^{a}	33.7^{a}
	Zero	57.5^{c}	39.5^{c}	412.2^{c}	115.4^{b}	155.0^{c}	27.3^{c}
Ni.	50 ppm	65.2^{a}	44.8^{a}	541.3^{a}	148.5^{a}	203.6^{a}	36.1^{a}
	100 ppm	61.9^{b}	42.3^{b}	456.1^{b}	130.3^{b}	171.5^{b}	30.2^{b}
			Second cut				
	Zero	59.8^{b}	37.9^{b}	385.7^{b}	107.8^{b}	145.0^{b}	25.5^{b}
Phe	50 ppm	64.7^{a}	45.0^{a}	495.0^{a}	138.6^{a}	186.1^{a}	32.2^{a}
	100 ppm	64.4^{a}	44.6^{a}	503.3^{a}	140.9^{a}	189.2^{a}	33.3^{a}
	Zero	59.7^{c}	40.0^{c}	413.3^{c}	115.7^{c}	155.4^{c}	27.4^{c}
Ni	50 ppm	66.8^{a}	45.0^{a}	525.1^{a}	146.9^{a}	197.5^{a}	34.2^{a}
	100 ppm	62.4^{b}	42.5^{b}	445.6^{b}	124.8^{b}	167.5^{b}	29.5^{b}

Values within each column followed by the same letter not statistically significant at 5 level. Phe = phenylalanine: Phe 0 = 0; Phe 1 = 50 ppm; Phe 2 = 100 ppm. Ni = nickel: Ni 0 = 0; Ni 1 = 50 ppm; Ni 2 = 100 ppm.

in growth values with increasing Ni concentration up to 50 ppm then the values significantly declined but they were still superior to the control for all tested parameters (Table 1). The maximum values were obtained as a result of Ni application at 50 ppm.

The increments in plant height, plant diameter, plant fresh and dry weights, leaves fresh and dry weights over control were 12.8, 7.5, 30.9, 33.9, 30.9 and 30.8% respectively, at the first cut and also 15.1, 9.2, 26.0, 26, 26 and 26.1% consecutively, at the second cut for the first season. The data within hand in Table 2 indicated that foliar application of Phe significantly augmented all growth parameters of genoveser basil in comparison with control in the second season.

All growth parameters in the first cut except plant and leaves fresh weights did not significantly increase by increasing Phe level from 50 to 100 ppm but they were still superior to the control, for the first and second cuts in the second season. The highest values of growth parameters were obtained as a result of the highest Phe of 100 ppm. The increments in aforementioned parameters over control were 13.2, 13.3, 26.4, 28.3, 26.4 and 26.2% consecutively, in the first cut and also 7.7, 17.7, 30.5, 30.7, 30.5 and 30.6% respectively, in the second cut. The increase in growth parameters as a result of Phe application may be related to its acting as building blocks of proteins and serving in number of additional functions in regulation of metabolism, transport and storage nitrogen (Davies, 1982). Amino acids play an important role for cell growth stimulation (Nahed et al., 2010).

Furthermore, they can serve as a source of carbon and energy and synthesize other organic compounds, such as protein, amines, purine, alkaloids, vitamins, enzymes, terpenoids and others (Goss, 1973; Abd El-Aziz and Balbaa, 2007). These results are in harmony with those obtained by Moursy et al. (1988) on *Datura stramonium*, Refaat and Naguib (1998) on peppermint (*Mentha piperita*), Habba (2003) on *Datura innoxia*, Balbaa and Talaat (2007) on rosemary plants and Talaat et al. (2013) on ammi visnaga. Also, the results corroborate with the findings of Gamal et al. (1997) on *Cymbopgon citrates* herb who reported Phe caused an enhancement in plant growth during vegetative and flowering stages.

The data in Table 2 emphasized that all growth parameters in the second season significantly augmented by foliar application of Ni in both cuts in comparison with control. The same tendencies were observed in the second season as that of the first season. The highest values of plant height, plant diameter, and plant fresh and dry weights, leaves fresh dry weights were obtained as a result of Ni application at 50 ppm in both cuts. The increments of all previous parameters over control were13.4, 13.4, 31.3, 28.7, 31.4, and 32.2% respectively, for the first cut and 11.9, 12.5, 27.1, 27, 27.1 and 24.8% consecutively, for the second cut. Increasing Ni concentration to 100 ppm significantly decreased all previous parameters but they were still superior to the

Table 3. The impact of foliar application of phenylalanine and nickel on growth and yield parameters of genoveser basil at the first and second cuts in the first season.

Parameters→ Effective factor↓		Flowers fresh weight (g)	Flowers dry weight (g)	Oil content (%)	Dry herb yield (ton/*fed.)	Oil yield (L/*fed.)
First cut						
Phe	Zero	149.2^{b}	50.7^{b}	0.331^{c}	2.442^{b}	8.134^{c}
	50 ppm	185.6^{a}	63.1^{a}	0.402^{a}	3.052^{a}	12.333^{a}
	100 ppm	187.7^{a}	63.8^{a}	0.373^{b}	3.147^{a}	11.759^{b}
Ni.	Zero	152.6^{c}	51.9^{c}	0.334^{c}	2.499^{c}	8.477^{c}
	50ppm	199.9^{a}	68.0^{a}	0.381^{b}	3.348^{a}	12.804^{a}
	100 ppm	169.9^{b}	57.8^{b}	0.391^{a}	2.794^{b}	10.946^{b}
Second cut						
Phe	Zero	147.7^{c}	50.2^{b}	0.348^{c}	2.419^{c}	8.472^{b}
	50 ppm	188.2^{b}	61.7^{a}	0.423^{a}	3.080^{b}	13.063^{a}
	100 ppm	192.1^{a}	65.3^{a}	0.402^{b}	3.146^{a}	12.716^{a}
Ni	Zero	158.6^{c}	51.7^{c}	0.358^{b}	2.597^{c}	9.462^{c}
	50 ppm	199.9^{a}	67.9^{a}	0.408^{a}	3.273^{a}	13.492^{a}
	100 ppm	169.4^{b}	57.6^{b}	0.407^{a}	2.774^{b}	11.297^{b}

Values within each column followed by the same letter not statistically significant at 5 level. Phe = phenylalanine: Phe 0 = 0; Phe 1 = 50 ppm; Phe 2 = 100 ppm. Ni = nickel: Ni 0 = 0; Ni 1 = 50 ppm; Ni 2 = 100 ppm; *fed: Local area in Egypt = 4200 m^2.

control.

Similar finding about Ni effect were reported by Seregin and Kozhevnikova (2006) who mentioned that the small quantities of Ni (0.01 to 5 µg/g dry wt.) is essential for many plants to complete their life cycle but higher concentrations of this metal are toxic and may severely interfere with many physiological and biochemical processes of plants. The earliest report of a growth response to Ni application indicated that Ni deficiency has a wide range of effects on plant growth, plant senescence, N metabolism and Fe uptake (Brown et al., 1987; Teixeira da silva et al., 2012). As well the study of Aly (1999) showed that low levels of Ni fertilization particularly 50 mg/kg soil increased parsley leaf yield and quality without affecting leaf chlorophyll and Fe contents. It was evident from the previous researches that the beneficial effect of Ni on growth could be explained by the fact that Ni (Ni) is a constituent of the enzyme urease and in small quantities is essential for many plant species to complete their life cycle.

Data presented in Table 3 indicated that foliar spray with different levels of Phe significantly augmented some growth and yield parameters in both cuts in the first season. The highest values of flowers fresh and dry weights per plant and dry herb yield were obtained as a result of Phe application at 100 ppm in both cuts. Nevertheless, the differences in earlier mentioned parameters between 50 and 100 ppm did not reach the level of significant. The increments of flowers fresh and dry weights, oil content, dry herb yield and oil yield over control were 25.8, 25.8, 12.7, 28.9 and 44.6% respectively, for the first cut and 30.1, 30.1, 15.5, 30.1 and 50.1% for the second cut. Concerning Ni effect it was found that foliar application of 50 pm Ni resulted in the highest values of flowers fresh and dry weights, oil content, yields of

dry herb and oil in both cuts for the first season, except oil content in the first cut. The rate of increments of previous parameters over control were 31, 31.0, 14.1, 34.0, and 51.0% consecutively, for the first cut and 26.0, 31.3, 14, 26.0, and 42.6% respectively, for the second cut.

Data of the second season presented in Table 4 behaved similarly as that of the first season. It showed that foliar application with Phe or Ni significantly increased all tested parameters in comparison with control for both cuts. The highest values of flowers fresh and dry weights were obtained by foliar spray with 100 ppm Phe in both cuts. Meanwhile, the highest values of oil content, dry herb yield and oil yield were produced by foliar spray with 50 ppm Phe in both cuts. The increments in flowers fresh and dry weights, oil content, herb yield and oil yield over control were 25.8, 26.5, 11.8, 28.4 and59.4% respectively for the first cut and also 30.5, 30.3, 9.7, 30.6, and 43.7% consecutively for the second cut.

These results were found to be in harmony with those obtained by Gamal et al. (1997) who reported that foliar application of amino acids (ornithine and Phe)

Table 4. The impact of foliar application of Phenylalanine and nickel on some growth parameters, oil content and yields of dry herb and oil of genoveser basil at the first and second cuts in the second season.

Parameters→ Effective factor↓		Flowers fresh weight (g)	Flowers dry weight (g)	Oil content (%)	Dry herb yield (ton/*fed.)	Oil yield (L/*fed.)
First cut						
Phe	Zero	153.7[c]	52.0[c]	0.363[c]	2.436[b]	7.982[b]
	50 ppm	189.2[b]	64.3[b]	0.431[a]	3.197[a]	13.844[a]
	100 ppm	193.4[a]	65.8[a]	0.406[b]	3.127[a]	12.727[a]
Ni.	Zero	157.3[c]	53.2[c]	0.354[c]	2.563[c]	9.242[b]
	50ppm	205.7[a]	69.9[a]	0.431[a]	3.300[a]	14.299[a]
	100 ppm	173.3[b]	58.9[b]	0.414[b]	2.897[b]	11.012[b]
Second cut						
Phe	Zero	145.0[b]	49.9[b]	0.371[c]	2.396[b]	8.957[c]
	50 ppm	186.1[a]	63.9[a]	0.447[a]	3.079[a]	13.819[a]
	100 ppm	189.2[a]	65.0[a]	0.407[b]	3.130[a]	12.872[b]
Ni	Zero	155.4[c]	53.4[c]	0.371[c]	2.572[c]	9.689[c]
	50 ppm	197.5[a]	67.9[a]	0.435[a]	3.261[a]	14.318[a]
	100 ppm	167.5[b]	57.6[b]	0.419[b]	2.771[b]	11.641[b]

Values within each column followed by the same letter not statistically significant at 5 level. Phe = phenylalanine: Phe 0 = 0; Phe 1 = 50 ppm; Phe 2 = 100 ppm. Ni = nickel: Ni 0 = 0; Ni 1 = 50 ppm; Ni 2 = 100 ppm; *fed: Local area in Egypt = 4200 m^2.

significantly increased plant growth of lemongrass, Khattab and Helmy (2003) also reported that foliar spray with amino acids significantly increased vegetative growth and fruit yield of fennel plants. Furthermore Khattab et al. (2011) found that foliar application of cysteine significantly augmented all growth parameters of lemon basil.

As for Ni, it was obvious from data in Table 4 that Ni application at 50 ppm followed by 100 ppm gave the highest values. Flowers fresh weight, flowers dry weight, oil content and yield of dry herb and oil significantly increased with the application of Ni (50 ppm) by about 30.8, 31.4, 21.8, 28.8, and 54.7% over the control in the first cut respectively and 27.1, 27.2, 17.3, 26.8, and 47.8% in the second cut consecutively. These results were found to be in harmony with those of Helmy et al. (2002) who found that low level of Ni fertilization (40 mg/kg soil) increased coriander leaf yield and quality. Teixeira da silva et al. (2012) reported that excessive Ni inhibits growth and development of plants, induces leaf chlorosis and wilting and reduce plant yields.

The influence of various concentrations of Phe and Ni on growth parameters in the first season are shown in Table 5 and Figures 1 and 2. Data within hand obviously showed that foliar application of Phe (100 ppm) and Ni (50 ppm) had highly positive effect on plant height, plant diameter, plant fresh and dry weights, leaves fresh and dry weights, yield of fresh and dry leaves followed by 50 ppm Phe and 50 ppm Ni in comparison with control in the first and second cuts except plant diameter in the second cut.

Meanwhile the combined treatment of 100 ppm Phe and 100 ppm Ni reduced aforementioned parameters, except plant diameter in the second cut. Foliar application of 100 ppm Phe + 50 ppm Ni increased plant height, plant diameter, plant fresh and dry weights, leaves fresh and dry weights over control by about 30.96, 33.71, 76.33, 87.26, 75.6 and 74.88% in the first cut respectively, while in the second cut the increments were 39.71, 31.41, 78.85, 78.87, 78.93 and 78.89% respectively.

Data reported in Table 6 emphasized that the same trend was observed in the second season, wherein foliar fertilization with Phe and Ni significantly increased all tested parameters in comparison with control in both cuts. Once again foliar application with 100 ppm Phe + 50 ppm Ni resulted in the highest values of growth parameters followed by 50 ppm Phe + 50 ppm Ni for both cuts. The increases in height, plant diameter, plant fresh and dry weights, leaves fresh and dry weights when applying 100 ppm Phe + 50 ppm in comparison with control were estimated at 35.3, 36.6, 78.1, 78.1, 78.2 and 77.6% for the first cut respectively, and also 25.3, 38.0, 80.0, 80.4, 80.3, and 80.4% for the second cut consecutively. Furthermore, the amino acids are not only building blocks of proteins but also precursors for a myriad of other molecules that serve important functions in plants. Amino acids are involved in the synthesis of other organic compounds, such as protein, amines,

Table 5. The influence of the interaction between foliar application of Phenylalanine and nickel on growth parameters of genoveser basil at the first and second cuts in the first season.

Parameters→ treatments↓	Plant height (cm)	Plant diameter (cm)	Plant fresh weight (g)	Plant dry weight (g)	Leaves fresh weight (g)	Leaves dry weight (g)
1st cut						
Phe0Ni0	52.0 ^{f}	34.7 ^{e}	322.3 ^{g}	90.3 ^{e}	121.7 ^{g}	21.5 ^{g}
Phe0Ni1	60.7 ^{cd}	38.3 ^{d}	474.3 ^{d}	132.8 ^{c}	178.3 ^{d}	31.4 ^{d}
Phe0Ni2	55.3 ^{e}	39.8 ^{d}	381.6 ^{f}	106.9 ^{d}	143.5 ^{f}	25.3 ^{f}
Phe1Ni0	60.7 ^{cd}	43.1 ^{b}	468.3 ^{d}	131.1 ^{c}	176.1 ^{d}	31.0 ^{d}
Phe1Ni1	64.6 ^{b}	44.3 ^{ab}	535.7 ^{b}	150.0 ^{b}	201.4 ^{b}	35.4 ^{b}
Phe1Ni2	62.2 ^{c}	40.2 ^{cd}	461.7 ^{d}	131.1 ^{c}	173.6 ^{d}	30.5 ^{d}
Phe2Ni0	58.9 ^{d}	42.3 ^{bc}	415.0 ^{e}	116.2 ^{d}	156.1 ^{e}	27.5 ^{e}
Phe2Ni1	68.1 ^{a}	46.4 ^{a}	568.3 ^{a}	169.1 ^{a}	213.7 ^{a}	37.6 ^{a}
Phe2Ni2	62.6 ^{bc}	43.2 ^{b}	498.3 ^{c}	139.5 ^{bc}	187.4 ^{c}	33.0 ^{c}
2nd cut						
Phe0Ni0	49.6 ^{g}	34.7 ^{c}	329.7 ^{g}	92.3 ^{g}	123.9 ^{g}	21.8 ^{g}
Phe0Ni1	60.7 ^{d}	40.6 ^{b}	449.0 ^{e}	125.7 ^{e}	168.8 ^{e}	29.7 ^{e}
Phe0Ni2	56.9 ^{f}	39.7 ^{b}	387.0 ^{f}	108.4 ^{f}	145.5 ^{f}	25.6 ^{f}
Phe1Ni0	60.6 ^{de}	42.2 ^{ab}	482.3 ^{c}	135.1 ^{c}	181.3 ^{c}	31.9 ^{c}
Phe1Ni1	64.8 ^{b}	42.4 ^{ab}	539.0 ^{b}	150.9 ^{b}	202.7 ^{b}	35.7 ^{b}
Phe1Ni2	62.3 ^{c}	42.4 ^{ab}	464.3 ^{d}	130.0 ^{d}	174.6 ^{d}	30.7 ^{d}
Phe2Ni0	59.1 ^{e}	40.9 ^{b}	440.3 ^{e}	123.3 ^{e}	165.6 ^{e}	29.1 ^{e}
Phe2Ni1	69.3 ^{a}	45.6 ^{a}	589.7 ^{a}	165.1 ^{a}	221.7 ^{a}	39.0 ^{a}
Phe2Ni2	63.9 ^{bc}	45.5 ^{a}	486.3 ^{c}	136.2 ^{c}	182.9 ^{c}	32.2 ^{c}

Values within each column followed by the same letter not statistically significant at 5 level. Phe = phenylalanine: Phe 0 = 0; Phe 1 = 50 ppm; Phe 2 = 100 ppm. Ni = nickel: Ni 0 = 0; Ni 1 = 50 ppm; Ni 2 = 100 ppm.

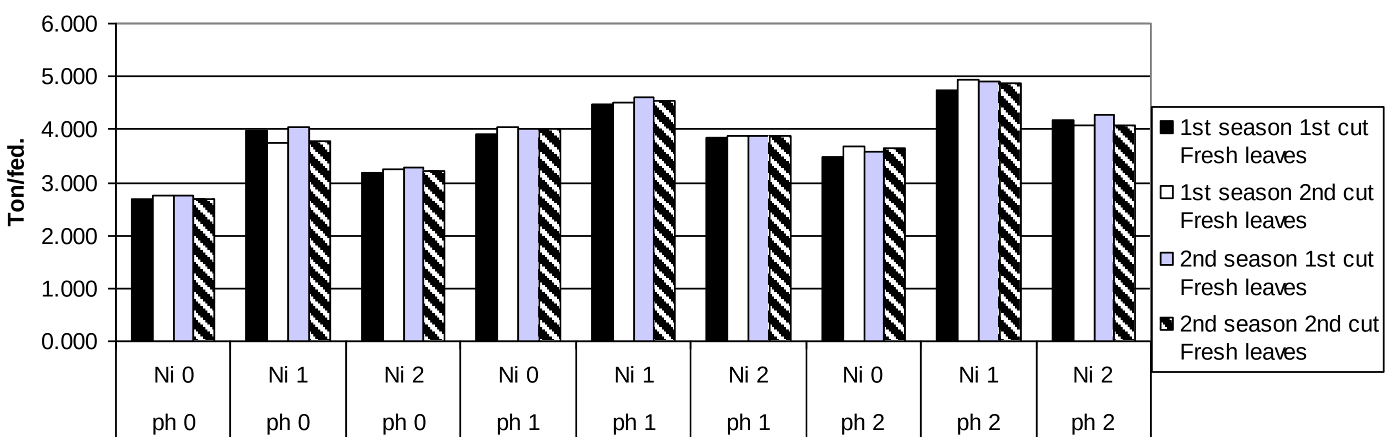

Figure 1. The influence of the interaction between foliar application of phenylalanine and nickel on yields of fresh leaves of genoveser basil at the first and second cuts in the first and second seasons.

alkaloids, vitamins, enzymes, terpenoids and plant hormones that control various plant processes (Glawischnig et al., 2000; Ibrahim et al., 2010). The result within hand are in agreement with those obtained by Gamal et al. (1997) who reported that foliar spraying of Phe (100 ppm) or ornithine (50 ppm) led to significant increases in the number of leaves and tillers per plant, fresh and dry weights of *Cymbopgon citrates* herb

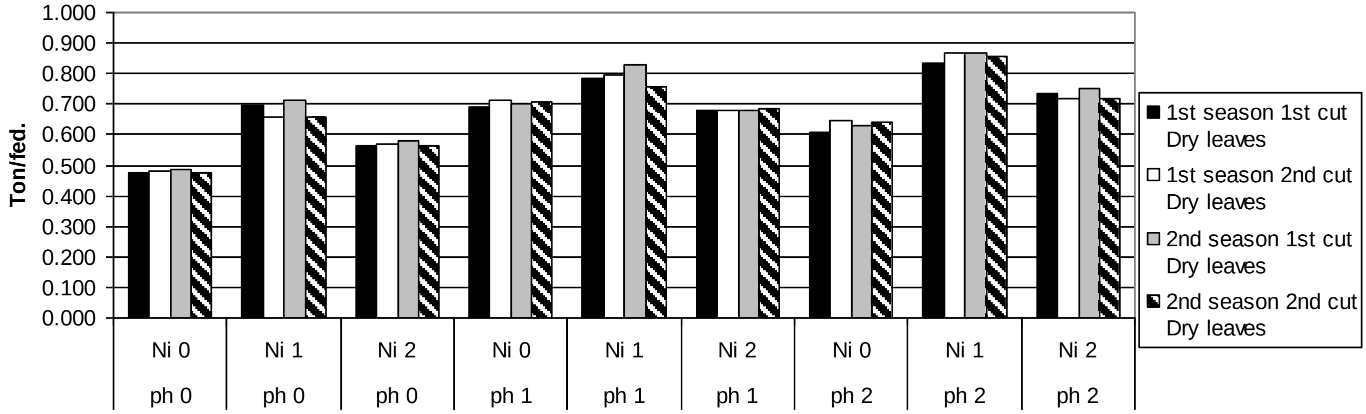

Figure 2. The influence of the interaction between foliar application phenylalanine and nickel on yields of dry leaves of genoveser basil at the first and second cuts in the first and second seasons.

Table 6. The impact of interaction between foliar application of Phenylalanine and nickel on growth parameters of genoveser basil at the first and second cuts in the second season.

Parameters→ treatments↓	**Plant height (cm)**	**Plant diameter (cm)**	**Plant fresh weight (g)**	**Plant dry weight (g)**	**Leaves fresh weight (g)**	**Leaves dry weight (g)**
1st cut						
Phe0Ni0	51.0^{g}	35.0	330.3h	92.5^{g}	124.2h	21.9h
Phe0Ni1	61.3^{de}	41.7^{d}	485.0^{d}	126.5^{de}	182.4^{d}	32.1^{d}
Phe0Ni2	58.3^{f}	40.5^{d}	392.7^{g}	109.9^{f}	147.6^{g}	26.0^{g}
Phe1Ni0	61.7^{de}	43.0^{bcd}	479.3^{d}	134.2^{cd}	180.2^{d}	31.7^{de}
Phe1Ni1	65.3^{b}	45.0^{b}	550.7^{b}	154.2^{b}	207.1^{b}	37.4^{b}
Phe1Ni2	63.0^{cd}	42.1^{cd}	464.0^{e}	143.3^{c}	174.5^{e}	30.7^{e}
Phe2Ni0	59.8^{ef}	40.5^{d}	427.0^{f}	119.6^{ef}	160.6^{f}	28.3^{f}
Phe2Ni1	69.0^{a}	47.8^{a}	588.3^{a}	164.7^{a}	221.3^{a}	38.9^{a}
Phe2Ni2	64.3^{bc}	44.4^{bc}	511.7^{c}	137.8^{c}	192.4^{c}	33.8^{c}
2nd cut						
Phe0Ni0	55.3^{e}	35.0^{f}	323.3^{f}	90.5^{f}	121.6^{f}	21.4^{g}
Phe0Ni1	65.0^{bc}	40.3^{d}	450.3^{d}	125.5^{d}	169.3^{d}	29.8^{de}
Phe0Ni2	59.0^{d}	38.3^{e}	383.3^{e}	107.3^{e}	144.1^{e}	25.4^{f}
Phe1Ni0	63.7^{c}	43.8^{c}	480.0^{c}	134.4^{c}	180.3^{c}	31.7^{cd}
Phe1Ni1	66.0^{b}	46.4^{b}	541.7^{b}	151.7^{b}	203.7^{b}	34.1^{b}
Phe1Ni2	64.3^{bc}	44.8^{bc}	463.3^{bc}	129.7^{bc}	174.2^{bc}	30.7^{cde}
Phe2Ni0	60.0^{d}	41.2^{d}	436.7^{d}	122.3^{d}	164.2^{d}	28.9^{e}
Phe2Ni1	69.3^{a}	48.3^{a}	583.3^{a}	163.3^{a}	219.3^{a}	38.6^{a}
Phe2Ni2	64.0^{c}	44.3^{c}	490.0^{c}	137.2^{c}	184.2^{c}	32.4^{bc}

Values within each column followed by the same letter not statistically significant at 5 level. Phe = phenylalanine: Phe 0 = 0; Phe 1 = 50 ppm; Phe 2 = 100 ppm. Ni = nickel: Ni 0 = 0; Ni 1 = 50 ppm; Ni 2 = 100 ppm.

as well as El-Sherbiny and Hassan (1987) on datura, Khattab et al. (2011) on lemon basil where different amino acids enhanced plant growth and yield. Similarly, Talaat and Youssef (2002) found a pronounced increased in vegetative growth of basil plant as a result of lysine and ornithine treatments.

Concerning the effect of Ni it was reported by Chand et al. (2012) that Ni and Pb applied at 25:25 produced

Table 7. The influence of interaction between phenylalanine and nickel on some growth and yield parameters of genoveser basil at the first and second cuts in the first season.

Parameters→ treatments↓	Flowers fresh weight (g)	Flowers dry weight (g)	Oil content (%)	Dry herb yield (ton/*fed.)	Oil yield (L/*fed.)
1st cut					
Phe0Ni0	122.3g	41.6g	0.284g	2.003e	5.690e
Phe0Ni1	180.2d	61.3d	0.325f	2.950c	9.590d
Phe0Ni2	145.0f	49.3f	0.384bc	2.373d	9.123d
Phe1Ni0	177.9d	60.5d	0.364de	2.913c	10.610c
Phe1Ni1	203.6b	69.2b	0.445a	3.333b	14.833a
Phe1Ni2	175.4d	59.6d	0.397b	2.910c	11.557bc
Phe2Ni0	157.7e	53.6e	0.354e	2.580d	9.130d
Phe2Ni1	216.0a	73.4a	0.372cd	3.760a	13.990a
Phe2Ni2	189.4c	64.4c	0.392bc	3.100bc	12.157b
2nd cut					
Phe0Ni0	125.8g	42.6g	0.297f	2.050h	6.087e
Phe0Ni1	170.6e	58.0cd	0.350e	2.767e	9.777cd
Phe0Ni2	147.1f	50.0f	0.397cd	2.410g	9.553d
Phe1Ni0	183.3c	55.5d	0.395cd	3.000c	11.857b
Phe1Ni1	204.8b	69.6b	0.452a	3.353b	15.150a
Phe1Ni2	176.4d	60.0c	0.422b	2.887d	12.183b
Phe2Ni0	167.3e	56.9cd	0.381d	2.740f	10.443c
Phe2Ni1	224.1a	76.2a	0.424b	3.670a	15.550a
Phe2Ni2	184.8c	62.8c	0.402c	3.027c	12.153b

Values within each column followed by the same letter not statistically significant at 5 level. Phe = phenylalanine: Phe 0 = 0; Phe 1 = 50 ppm; Phe 2 = 100 ppm. Ni = nickel: Ni 0 = 0; Ni 1 = 50 ppm; Ni 2 = 100 ppm; *fed: Local area in Egypt = 4200 m^2.

40% higher fresh herbage and root of *Mentha arvensis* L. while 50:50 ppm exhibited negative effect on the herb and yield. On the other hand, Teixeira da silva et al. (2012) proved that Ni deficiency affects plant growth, plant senescence, nitrogen metabolism and iron uptake and it may play a role in disease resistance, but also excessive Ni inhibits and development of plants.

Results in Table 7 showed that foliar application of Phe and Ni significantly augmented all tested parameters of genoveser basil and yield of herb and oil in the first season. Except oil content, the combined treatment between 100 ppm Phe and 50 ppm Ni induced the maximum values of all tested parameters in both cuts. Plants received combined foliar spray of 100 ppm Phe and 50 ppm Ni surpassed control plants in the flowers fresh and dry weights, oil content, yield of dry herb and yield of oil by 76.6, 76.4, 30.9, 87.7 and 145.9% for the first cut respectively and by 78.1, 78.9, 42.8, 79.0 and 155.5% for the second cut. On the other hand, the combined treatment of 50 ppm Phe and 50 ppm Ni induced the maximum values of oil content in both cuts.

Similar trend was observed in data presented in Table 8 and Figures 3 and 4. It was found that foliar fertilization with combined Phe and Ni significantly increased plant growth, flowers fresh and dry weights, oil content, dry herb yield, oil yield, yields of fresh and dry flowers. The highest values of oil content and oil yield were noticed with the application of 50 ppm Phe + 50 ppm Ni in both cuts of the second season. The combined foliar application of 100 ppm Phe and 50 ppm Ni enlarged the flowers fresh and dry weights, oil content, yield of dry herb and yield of oil over control by 75.4, 78.0, 44.5, 78.2, and 157.5% for the first cut respectively and by 80.3, 80.4, 36.6, 80.2, and 146.7% consecutively, for the second cut.

Amino acids may be playing an important role in plant metabolism and protein assimilation which is necessary for cell formation and consequently increase fresh and dry matter. In addition, Fowden (1973) reported that amino acids acting as the building blocks of proteins can serve in number of additional functions in regulation of metabolism, transport and storage nitrogen. On the other hand, Waller and Nowacki (1978) suggested that the regulatory effects of certain amino acids, like Phe andornithine on plant development are through their influence on gibberellins. The results within hand are in agreement with those obtained by Youssef et al. (2004) on lemon basil, Talaat and Youssef (2002) on basil,

Table 8. Effect of interaction between foliar application of phenylalanine and nickel on some growth and yield parameters of genoveser basil at the first and seconds cut in the second season.

Parameters→ treatments↓	Flowers fresh weight (g)	Flowers dry weight (g)	Oil content (%)	Dry herb yield (ton/*fed.)	Oil yield (L/*fed.)
1st cut					
Phe0Ni0	127.5^{h}	42.7^{h}	0.292^{g}	2.055^{g}	5.997^{e}
Phe0Ni1	184.3^{d}	62.7^{d}	0.387^{ef}	2.811^{de}	10.90^{cd}
Phe0Ni2	149.2^{g}	50.7^{g}	0.410^{cd}	2.443^{f}	7.050^{e}
Phe1Ni0	182.1^{d}	61.9^{d}	0.377^{f}	2.982^{cd}	11.237^{cd}
Phe1Ni1	209.2^{b}	71.2^{b}	0.483^{a}	3.426^{b}	16.557^{a}
Phe1Ni2	176.3^{e}	59.9^{e}	0.432^{b}	3.184^{c}	13.740^{abc}
Phe2Ni0	162.3^{f}	55.2^{f}	0.395^{de}	2.657^{ef}	10.493^{d}
Phe2Ni1	223.6^{a}	76.0^{a}	0.422^{bc}	3.661^{a}	15.440^{ab}
Phe2Ni2	194.4^{c}	66.1^{c}	0.400^{de}	3.063^{c}	12.247^{bcd}
2nd cut					
Phe0Ni0	121.6^{f}	41.8^{f}	0.325^{f}	2.013^{f}	6.537^{d}
Phe0Ni1	169.3^{d}	58.2^{d}	0.376^{e}	2.790^{d}	10.513^{c}
Phe0Ni2	144.1^{e}	49.5^{e}	0.412^{d}	2.383^{e}	9.820^{c}
Phe1Ni0	180.3^{c}	62.0^{c}	0.422^{cd}	2.987^{c}	12.600^{b}
Phe1Ni1	203.7^{b}	70.0^{b}	0.484^{a}	3.367^{b}	16.310^{a}
Phe1Ni2	174.2^{bc}	59.8^{bc}	0.435^{bc}	2.883^{cd}	12.547^{b}
Phe2Ni0	164.2^{d}	56.4^{d}	0.365^{e}	2.717^{d}	9.930^{c}
Phe2Ni1	219.3^{a}	75.4^{a}	0.444^{b}	3.627^{a}	16.130^{a}
Phe2Ni2	184.2^{c}	63.3^{c}	0.412^{d}	3.047^{c}	12.557^{b}

Values within each column followed by the same letter not statistically significant at 5 level. Phe = phenylalanine: Phe 0 = 0; Phe 1 = 50 ppm; Phe 2 = 100 ppm. Ni = nickel: Ni 0 = 0; Ni 1 = 50 ppm; Ni 2 = 100 ppm; *fed: Local area in Egypt = 4200 m^2.

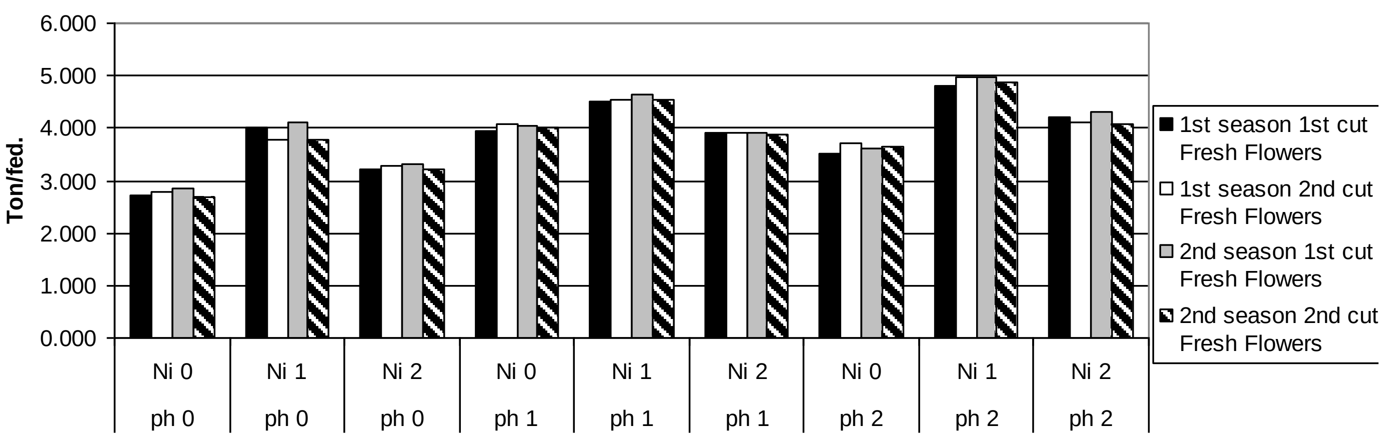

Figure 3. The influence of foliar application with different levels of phenylalanine and nickel on yields of fresh flowers of genoveser basil at the first and second cuts in the first and second seasons.

where they found that foliar application with different amino acids significantly enhanced plant growth, oil content and yields of herb and oil.

Similar findings were obtained in tobacco (Darwish and Reda, 1975), Datura (El- Bahr et al., 1990), *Hyoscyamus muticus* L. (Reda et al., 1999), *Iberis amara* L. (Attoa et al., 2002) and chrysanthemum (El-Fawakhry and El-Tayab, 2003) where different amino acids augmented plant growth during vegetative and flowering stages, and produced a high quality of inflorescences. Studies have proved that amino acids can directly or indirectly influence the physiological activities in the growth and development

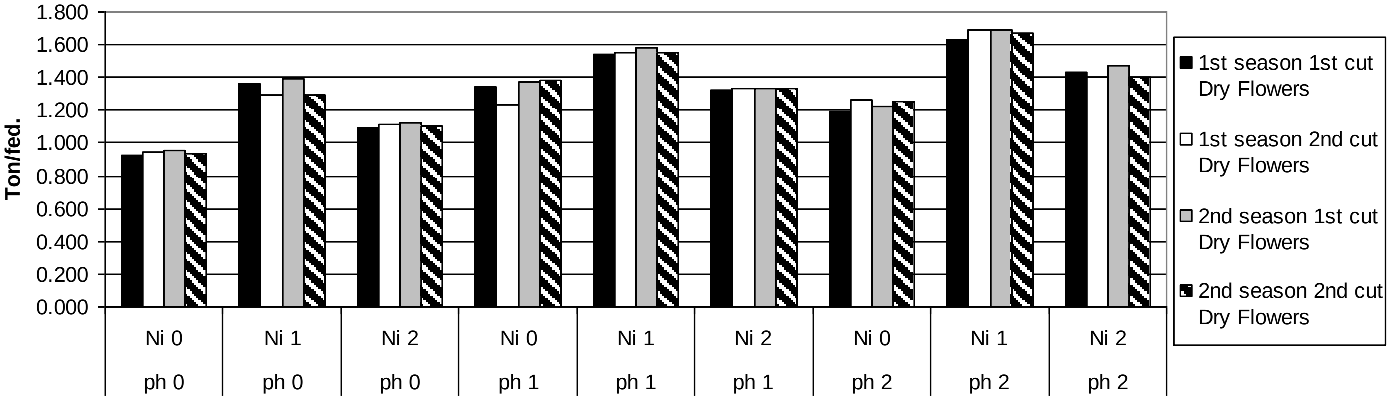

Figure 4. The influence of foliar application with different levels of phenylalanine and nickel on yields of dry flowers of genoveser basil at the first and second cuts in the first and second seasons.

of plants.

These results could be explained by the fact that amino acids can serve as a source of carbon and energy when carbohydrates become deficient in the plant; amino acids are determinate, releasing the ammonia and organic acid from which the amino acid was originally formed. The organic acids then enter Kreb's cycle, to be broken down to release energy through respiration (Goss, 1973).

Concerning the effect of Ni, the illustrated results are in agreement with what was obtained by Prasad et al. (2008) who reported that $Ni_2SO_4{\cdot}7H_2O$ caused a significant increase in herb yield by 21.6% more than the control. Also Aly (1999) suggested that low levels of Ni fertilization particularly 50 mg/kg clay soil, strongly improve not parsley leaf yield and quality but also the leaves became safer for human consumption. Also, Helmy et al. (2002) found that low levels of Ni fertilization 40 mg/kg soil, increased coriander leaf yield, oil content and quality. The latter effect of Ni on growth may be due to the fact that Ni is a constituent of the enzyme urease and in small quantities is essential for many plant species to complete their life cycle.

In terms of essential oil constituents of genoveser basil, thirty compounds were identified. These compounds were listed in Table 9 in an ascending order. All treatments showed that the major oil constituent was linalool with mean relative percent (37.18%). The second main compound was 1,8 cineole with mean relative percent (16.4%) followed by α-bergamotene (14.71%). As well as the fourth and fifth compounds, Ʈ cadinol and α-cadinol had mean relative percent of 6.82 and 3.53% respectively. These compounds represented 78.64% of the oil constituents of genoveser basil.

A major differences between the oil constituents from plants treated with Phe were observed in the contents of linalool, 1,8 cineole, α-bergamotene, Ʈ cadinol and α-cadinol. Plants sprayed with 50 ppm Phe without Ni showed an increase in linalool content with a corresponding decrease in the rest of aforementioned compounds. While those sprayed with 100 ppm Phe decreased linalool content compared to control. The rest of the other components in the oil were unaffected by treatments. On the other hand, application of 100 ppm Ni + 50 ppm Phe increased the relative percent of linalool, α-Bergamotene, Ʈ cadinol and α-cadinol, except 1,8 cineole which decreased by this treatment. Meanwhile foliar spraying with 100 ppm Ni +100 ppm Phe decreased linalool and 1,8 cineol in comparison with control, except α-bergamotene, Ʈ cadinol and α-cadinol which they increased by aforementioned treatment.

Similarly, some other authors showed that amino acid treatments resulted in numerous differences in the components of the essential oil **(**Khattab et al., 2011) who reported that increasing cysteine from 50 to 100 ppm increased hydrocarbons on the cost of oxygenated compounds in the lemon basil oil. Also, Khattab and Helmy (2003) pointed out that almost all concentrations of ornithine or cysteine increased the relative percent of anethole in the fennel oil.

Conclusion

No differences could be observed in the amount of the main components between control and other Ni treatments. In contrast of this study results, Aly (1999) revealed that parsley leaf oil constituents responded positively to Ni fertilization. Also, Prasad et al. (2008) reported that the content of linalool, geraniol and 10-*epi*-eudesmol in the geranium oil significantly increased after the application of $Ni_2SO_4{\cdot}7H_2O$ while geranial and β-bourbonene decreased compared to control plants. Teixeira da silva et al. (2012) found that the content of linalool and geraniol were increased by 54.2 and38.8% respectively after application of $Ni_2SO_4{\cdot}7H_2O$ compared to control in geranium oil and also, cis-and trans-rose oxide increased, while geraniol decreased.

Table 9. Effect of phenylalanine and nickel on oil components of genoveser basil.

S/N	Compound	N0Ph0	N0Ph1	N0Ph2	N1Ph0	N1Ph1	N1Ph2	N2Ph0	N2Ph1	N2Ph2
1	α-Pinene	0.57	Traces	1.04	0.82	0.35	1.7	1.3	0.38	0.8
2	β-Pinene	1.22	0.42	1.83	1.4	0.66	2.93	2.34	0.82	1.63
3	Sabinene	0.46	Traces	0.77	0.59	Traces	0.94	0.9	0.34	0.5
4	Myrcene	0.67	0.33	1.12	0.8	0.39	0.85	1.17	0.61	0.68
5	Limonene	0.45	0.27	0.64	0.54	Traces	0.78	0.71	0.3	0.56
6	1,8 Cineole	17.67	14.53	16.82	16.66	12.52	20.35	18.89	12.8	17.33
7	Linalool oxide	0.42	0.43	0.47	0.47	0.33	0.4	0.45	Traces	traces
8	cis-Sabinene hydrate	0.36	0.30	Traces	0.39	0.43	0.36	0.39	0.33	0.38
9	Octenyl acetate	1.27	0.95	1.06	0.95	1.00	1.07	0.93	0.89	1.1
10	β -Bourbonene	0.47	0.29	0.56	0.55	0.52	0.46	0.41	0.52	0.54
11	Camphor	1.44	0.7	0.65	0.67	0.69	0.73	0.79	0.42	0.69
12	Linalool	36.27	50.64	34.47	37.61	38.65	31.76	33.91	39.22	32.13
13	α- Bergamotene	14.69	12.69	14.38	13.58	16.51	14.48	14.37	15.09	16.59
14	β - Elemene	1.09	0.33	0.83	0.72	0.93	0.97	0.77	0.9	1.07
15	α -Caryophyllene	1.2	0.89	1.48	1.33	1.45	1.23	1.28	1.61	1.29
16	β-Farnesene	0.65	0.33	0.83	1.18	0.68	0.62	0.65	0.68	0.69
17	α - Terpineol	0.38	0.44	0.38	0.37	0.35	Traces	0.36	0.29	0.3
18	Germacrene D	1.02	0.97	1.5	1.42	1.73	1.06	1.2	2.13	1.06
19	α - Bulnesene	0.54	0.25	0.66	0.49	0.6	0.39	0.44	0.78	0.46
20	Fenchyl ahcohol	1.92	2.57	1.92	1.98	1.97	1.61	1.83	1.56	1.68
21	γ – cadinol	3.25	1.91	3.93	3.4	3.98	3.55	3.48	4.02	4.22
22	Germacrene A	Traces	0.48	0.53	0.47	0.58	Traces	Traces	0.83	0.4
23	Vediflorol	1.01	1.23	1.37	1.51	1.51	1.64	1.24	1.43	1.48
24	Bergamotol	0.38	Traces	Traces	Traces	Traces	0.38	Traces	traces	0.41
25	Methyl Eugenol	0.53	0.56	0.66	0.57	0.65	0.44	0.48	0.54	0.62
26	Cubenol	1.1	0.73	1.1	1.11	1.26	1.14	1.08	1.27	1.35
27	Spathulenol	0.94	0.52	0.68	0.74	0.86	0.77	0.76	0.76	1.05
28	Ţ-Cadinol	6.78	3.96	6.72	6.66	7.79	6.77	6.51	7.9	8.31
29	Eugenol	2.39	1.97	2.42	2.17	1.98	1.39	2.22	2.24	1.68
30	*α* – Cadinol	0.53	0.25	0.49	0.51	0.63	0.51	0.48	0.58	0.65
-	Uindentified compounds	0.90	1.06	0.69	0.34	1.0	0.72	0.66	0.76	0.35

Conflict of Interests

The authors have not declared any conflict of interests.

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Full Length Research Paper

Development evaluation of Lesotho agricultural input subsidy policy based on rural households' food security and access to inputs: Evidence from Mohale's Hoek District

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The prevalence of poverty in Lesotho is a pressing issues raising concern in terms of rural households' food security and welfare. In that regard, this study attempts to establish or identify the determinants of farmers' access to inputs via the government. The second part incorporates the use of subsidized inputs and measure the impact of the government input subsidy program on food security. The motive behind this study is to fill a gap in the economics literature in this area, which often does not assess the impacts of agricultural input subsidy programs (despite their widespread prevalence) and its impact on food security. The Combination of econometric approaches was applied to a selected sample of rural households actively engaged in maize production, and the findings revealed the determinants of farmers' access to inputs as being cropland allocation, type of fertilizer and ecological zones. The vast majority of rural households doesn't receive or get subsidized inputs and out of that small portion of the recipients, half of them don't use their inputs (chemical fertilizers). This phenomenon is due to the fact that, rural households may not be in a position to use their inputs because of late delivery, or to use optimally because they do not perceive the benefits.

Key words: Agricultural input-subsidy policy, food security, Lesotho, Mohale's Hoek District.

INTRODUCTION

Smallholder farmers and resource-constrained households (HHs) in Lesotho have been consistently obtaining low yields from their staple crops, and that adversely affected food production as well as considerably reducing incomes. In an attempt to mitigate the situation by improving the welfare of rural households and spurring crop production, the government of Lesotho (GoL) endorsed universal input subsidy policy (UISP) on

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agricultural inputs from 2001/02 after food-security emergency was declared due to poor agricultural production. Based on the literature, agricultural input subsidy policy (AISP) is not yet an ultimate solution; prevailing government policies, which involve the subsidized provision of tractor services, seed, and fertilizer, seem to increase unit costs for smallholder farmers due to low market price for grains (Schwab and Porter, 2009).

In addition, Mohlatsane et al. (2009) also, discovered that, even though the government provides subsidies, subsistence farmers still do not afford the input costs as commercial banks find it risky to give them credit. There are also views that, targeting input subsidies to the poor and smallholder farmers is potentially more efficient than universal as targeted subsidies are directed to different needs of farmers instead of universal subsidies which might not be a response to or address needs of farmers (Mohlatsane et al., 2009; Houssou and Manfred, 2011).

Dorward (2009) also states that whether targeted or universal; subsidies are only effective where there are limited secondary markets in which recipients sell subsidized inputs to non-recipients. Dorward and Chirwa (2013) further reiterate that, targeted farm input subsidy irrespective of considerable improvements, there are still ongoing challenges regarding implementation, improving targeted outcomes and impacts. Huang et al. (2011) findings revealed that, about two-thirds of households who were subsidy recipients by the year 2008 believed that there is no link to the amount of their produce or cultivated land. While in Iran, food subsidy programs emerged as major developmental issues since consumers benefit from lower food prices (Karami et al., 2012). AISP contributes to farms efficiency and profitability; hence, there is a need for broader evaluations of the role of public support for various components of farm's performance (Bojnec and Latruffe, 2012).

There are different ways to evaluate input subsidy policy; taking access to input subsidies as the evaluation point, the findings reveal vulnerable and resource-constrained farmers being marginalized compared to well-off farmers in possession of bigger land size and have market accessibility or more income (Chirwa et al., 2011; Jayne et al., 2011). Only findings from Nigeria appear completely different from other studies in Africa due to the fact that Nigeria has successfully linked rural farmers with input suppliers (Liverpool, 2012). Political elites benefit more than less politically-connected households (Banful, 2011; Mason and Ricker, 2012) and the extension agents are biased toward better-producing households (Pan and Christiaensen, 2012).

GOL has been and continues to offer subsidized inputs to farmers but, this initiative and efforts by the government fail to achieve significant increases in national food output. Since 2012, 18 500 vulnerable farmers in Lesotho have received agricultural inputs through the Ministry of Agriculture and Food Security / Food and Agricultural Organization (MAFS/FAO) Emergency and Resilience Programmed. These inputs included a 5-kg bag of maize seeds and a 5-kg bag of bean seeds, Crop estimates were indicating that the domestic production will contribute less than 10% of the annual national cereal requirements for 2012/13 and that the Lesotho rural populations are in dire need of food (Lesotho flash Appeal, 2012; Lesotho Food Insecurity Situation Report, 2012). Prior to that, Lesotho Demographic and Health Survey (2009) showed chronic malnutrition (stunting) amounting to 39, 2% of the total population. Later on in two years' time, the percentage of the population living on less than $1.25 per day was 47.59% (Lesotho flash Appeal, 2012).

Owing to the prevailing situation in Lesotho afore-mentioned, the study attempts to establish the determinants of farmers' access to inputs via the government and other sources. A number of studies about an evaluation of agricultural input subsidy policy have been conducted in various countries across Africa; Ghana, Malawi, Nigeria, Tanzania and Zambia. However, Chirwa et al. (2011) and Jayne et al. (2011) were using access to input subsidies as the evaluation point. Therefore, in order to fill a gap in the economics literature in this area, which often does not assess the impacts of agricultural input subsidy programs (despite their widespread prevalence) and its impact on food security, the study seeks to measure or analyze the impact of the government input subsidy program as compared with other input subsidy programs on food security. That is, who actually benefit from input subsidy? And how subsidies can benefit rural households without benefiting farm inputs retailers?

CONCEPTUAL FRAMEWORK

Input subsidies from government stores either go directly to farmers or through seed retailers. Rural households (RHH) could be divided or separated into two groups; needy and less-needy based on their income, food security, welfare and whether they hire labor in or out, crop purchases or sales. Besides government input subsidy program, there are other input subsidy programs offered by non-governmental organizations like WFP, UNICEF and World Vision. RHH receiving social grants are regarded as needy or vulnerable and in most cases perceived to be eligible for being recipients of subsidized inputs. However, it may depend on different scenarios and perspectives as Dorward et al., (2010) regard vulnerable households as those that are female-headed, elderly headed and child-headed households. Input subsidy beneficiaries may use subsidies accordingly and increase their production while others might resale them or use them alternatively, which is, displacement use as depicted in Figure 1.

Targeting, implementation and geographic distribution

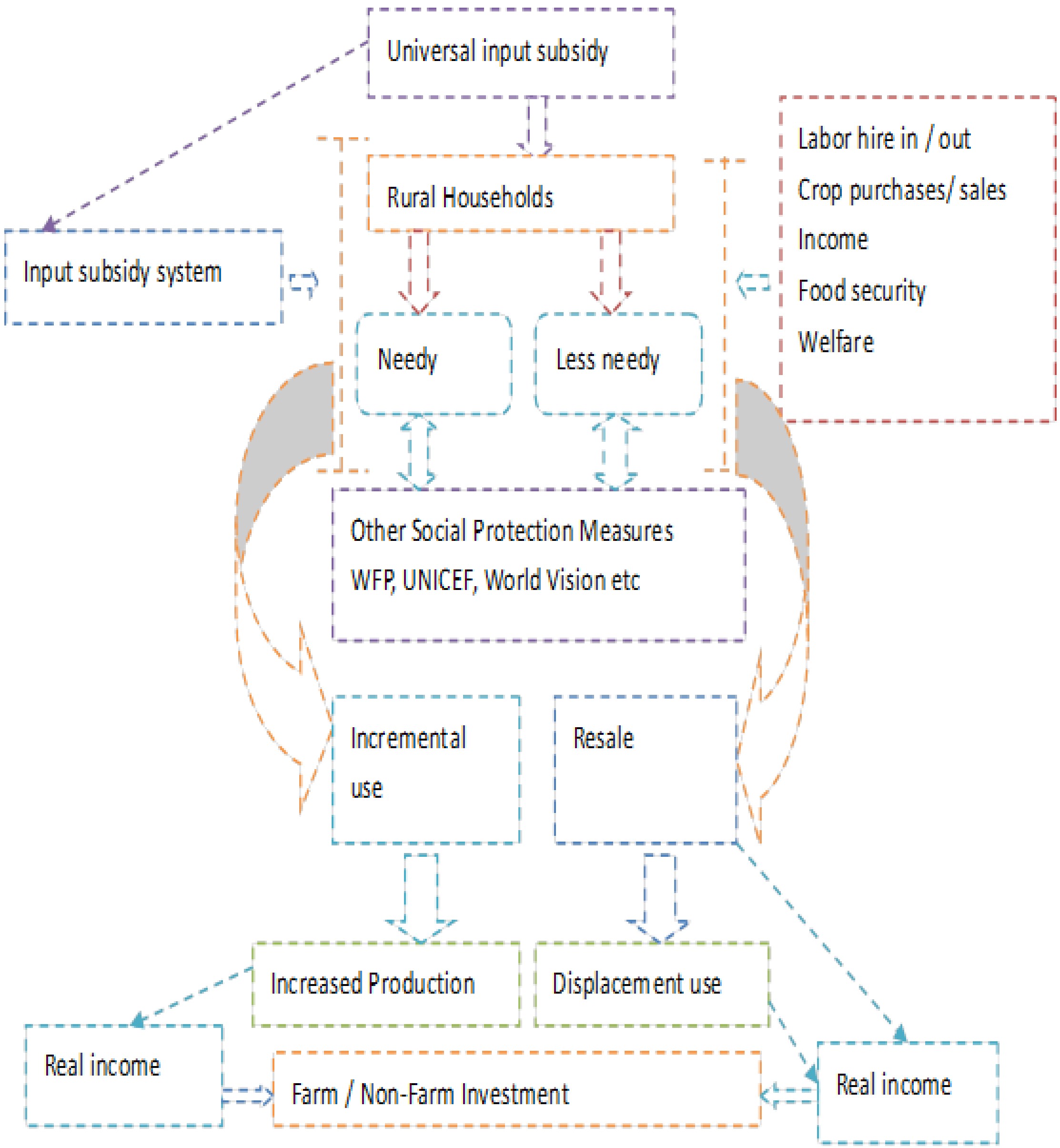

Figure 1. Conceptual framework for investigating rural households' food security, welfare and their access to input subsidies. (Source: Author)

of inputs subsidy are somehow challenging. Government subsidies are not targeted to different needs of different farmers, they are universal subsidies. This is owing to the government policy that there should be no discrimination among farmers, if subsidies are used to increase crop production, every farmer should be able to receive the subsidy. In some cases, subsidies are donor funded and they can come in different forms. The administration of donor funded subsidies depends on donor's requirements. For the year 2006/2007, the inputs were donor-funded by the Japanese government and input traders obtained such inputs at stores at wholesale price and sold at a price determined by the MAFS. For 2007/2008 season, input traders were to source inputs from their regular suppliers and sell at less 70% of the selling price and claim the 30% difference from MAFS.

Regarding geographic distribution, local authorities are entrusted with disseminating information about subsidies by holding public gatherings. Local authorities are to verify with Extension Officers the size of fields to be committed by farmers. They have to arrange and supervise the fill up of appropriate documents for farmers. Extension Officers together with local authorities are to supervise the delivery of mechanical operations and inputs. They also have to authenticate appropriate documentation that verifies delivery of supplies.

Figure 2. Cereal production and consumption pattern over a period of four years (Source: Statistical Report No: 26 of 2011 / 2012 & No.31 of 2013 / 2014 NOTE: The deficit/surplus is only for farming households not for the whole population).

Amounts of inputs provided depend on certain factors, for instance, in 2006/2007 the government subsidized chemical fertilizer, these fertilizers were supplied directly to farmers who bought a minimum of 200 x 50 kg bags as an incentive to encourage efficiency in terms of economies of scale. Those who bought less than 200 x 50kg were not offered transport, while others bought indirectly through traders who sold them at a price determined by MAFS. Alternatively, for better implementation of input subsidy, during the same period 2006/2007 growing season, block farming scheme which is a system that encourages planting one crop on a large scale in one locality was launched. This was done as a response to the Government policy of commercialization of agriculture, to assist block farmers in accessing credit from one of the local banks facilitated by the Agricultural Development Fund (government-guaranteed loans) aimed at providing capital to farmers for increasing the country's food security. The year 2007/2008 farmers were to obtain the input supplies and farming operations at 70% of the selling price and 40% on irrigation equipment. Recently, the government of Lesotho (GoL) has engaged in sharecropping program where the government provided all farming inputs and adopted a mechanized approach that necessitated the consolidation of blocks of farmers' fields and yields are divided between government and farmers, where GoL takes 70% of the yield and farmers take 30%.

MATERIALS AND METHODS

Study site

The study was undertaken in Mohale's Hoek, which is one of the 10th districts of Lesotho with the land size of 3,530 km^2 and total population 174,924 (Bureau of Statistics, 2012) located in the southern part. The district encompasses four agro-ecological zones of Lesotho namely, lowlands, foothills, mountains and the Senqu River valley. In terms of the level of food insecurity at the height of the lean season October to December, Mohale's Hoek compared to other districts came first with 62% share of population in dire need of food assistance, indicating Southern Lowlands and the Senqu River Valley as the most food insecure areas (FAO/WFP : 2007).

Taking the analysis of cereal production, consumption and surplus / deficit over a period of four years as portrayed in Figure 2, it's clearly notable that Mohale's Hoek is heading towards severe food shortage once experienced in 2011 / 2012. Considering the state of food security in Lesotho as a whole, statistics reveal the increasing number of food insecure population (Figure 3).

Data collection

Data collection was conducted in Mohale's Hoek district from July up to October 2014 randomly picking one constituency from each Agro-ecological Zones. The survey design adopted stratified sampling procedure structured implicitly into recipients / non-recipients dichotomy and four constituencies representing four Agro-ecological Zones. The focus was based on maize production as the staple food of Basotho people, hence regarded more important in terms of rural households' food security and welfare. Farm visits and open-ended questionnaires employed were specifically targeted to individual input subsidy beneficiaries as well as key informants. Owing to the terrain of Lesotho and time constraint, it was not possible to include all constituencies during the survey; therefore, in this case, the researcher opted to pick one constituency from each zone in order to have a representative of all agro-ecological zones in the data set. Finally, four constituencies namely; Mpharane, Mekaling, Mohale's Hoek and Taung respectively were covered during the survey.

METHODOLOGY

Rural households' welfare is analyzed based on their production

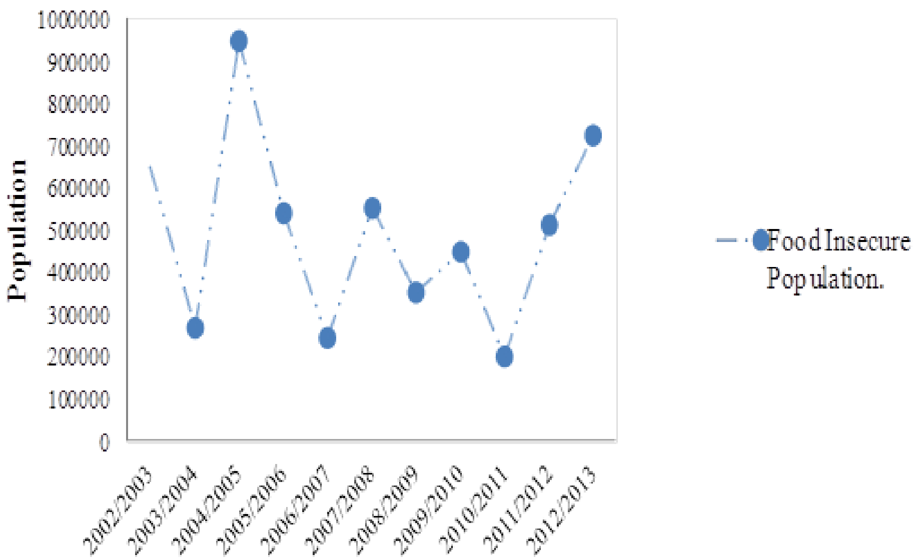

Figure 3. Trend in food insecure population in Letsotho (Source: SADC Regional Vulnerability Assessment and Analysis (RVAA) Synthesis Report 2012).

performance, but in this case emphasis is on maize production as the staple food for Basotho people. Therefore, welfare was determined by changes in farmers' maize production also regarded as farmer' income, which can be written as $[\partial \boldsymbol{W} = \partial \boldsymbol{P}(\boldsymbol{Q}^{\boldsymbol{p}} - \boldsymbol{Q}^{c})]$ and real income $\left[\frac{\partial W}{\sum PQ^c} = \frac{\partial P(PQ^p - PQ^c)}{P \sum PQ^c}\right]$. Maize output (**Y**) is a function of a number of fertilizers, hybrid seed planted, machinery and other factors, ***x.*** While a number of fertilizers applied, hybrid seeds planted and machinery utilized is a function of the subsidy and other factors, ***z.*** In Lesotho, farmers are extremely land – scarce hence it's vital to shift from low – input systems characterized by relatively low land productivity. High-input systems would restore fertility via fertilizer application (Matlon, 1987; Wong et al., 1991). Given the low levels of fertilizer use in Lesotho and the demonstrated contribution of fertilizers to increasing crop yields and land productivity, the increased use of fertilizers has great potential for boosting food production (Wilfred: 1996), and overcome a problem of food insecurity prevalent in rural households of Lesotho. The effectiveness of ISP is measured by the impact of the fertilizers, hybrid seeds and machinery subsidy (D) on rural households (RHH) maize produce based on the quantity of hybrid seeds planted and fertilizers applied per hectare (Q); compared to the RHH produce, and total income. All these can be summarized as:

$$Y = Y\,[Q\,(D, z), x \qquad (1)$$

Lesotho mostly use universal input subsidies but assuming trade-off by some of the recipients, commercial farmers would turn to benefit more and they are expected to increase their production (food supply) which ultimately could result in a drop of imports from South Africa, and consequently a decline in local market price giving rise to poverty alleviation and of course an improvement in food security and self sufficiency. Continuous dependency on imports from South Africa means failure of Lesotho farmers to alleviate poverty irrespective of input subsidies and this phenomenon could imply number of things like poor distribution channels leading to leakage of subsidized inputs to South African farms, or political manipulations meant to tarnish government reputation or put government into disrepute in order to score political points or gain political mileage (Figure 4).

Econometric model

The model encompasses two ways of accessing subsidized inputs in the quest for answers to the questions raised; that is, the household is a beneficiary of input subsidies whether received vouchers from FAO or inputs from licensed seed retailers. Zhong et al. (2013) estimated a similar model, Chirwa et al. (2011) also focused on access to fertilizer coupons irrespective of whether recipients utilized them or not to purchase subsidized fertilizers, while SOAS (2008) model focuses on those households that have utilized their coupon to purchase fertilizers. The second part incorporates the use of subsidized inputs and access in terms of location of resource centers. Access to input subsidy is measured based on the Chirwa et al. (2011) index:

$$ASI_i = \alpha + \omega HS + \varphi FP + \gamma PV + \tau X + \varepsilon_i \qquad (2)$$

Where; for household *i*, *ASI* is access to subsidized inputs, *HS* is a vector of household situation including living conditions and durable assets, *FP* is a vector of farm properties like land size, cultivated land, and type of farmer, while *PV* is a vector of poverty and vulnerability variables, *X* is a vector of other control variables including participation in the labor market (employment), business enterprises, remittances and ε_i includes the effect of unobserved factors on the access of individual *i* as well as the impact of measurement errors (error term). Access to subsidized inputs is a dichotomous variable being the beneficiary of input subsidies; equation (3) was estimated using the Logit model (linear probability model).

$$\mathbf{F}(\mathbf{x}'\boldsymbol{\beta}) = \boldsymbol{\Lambda}(\mathbf{x}'\boldsymbol{\beta}) = \frac{e^{X'\beta}}{1+e^{X'\beta}} = \frac{\exp(x'\beta)}{1+\exp(x'\beta)} \qquad (3)$$

RESULTS AND DISCUSSION

Descriptive statistics

In an overall sampling of rural households actively

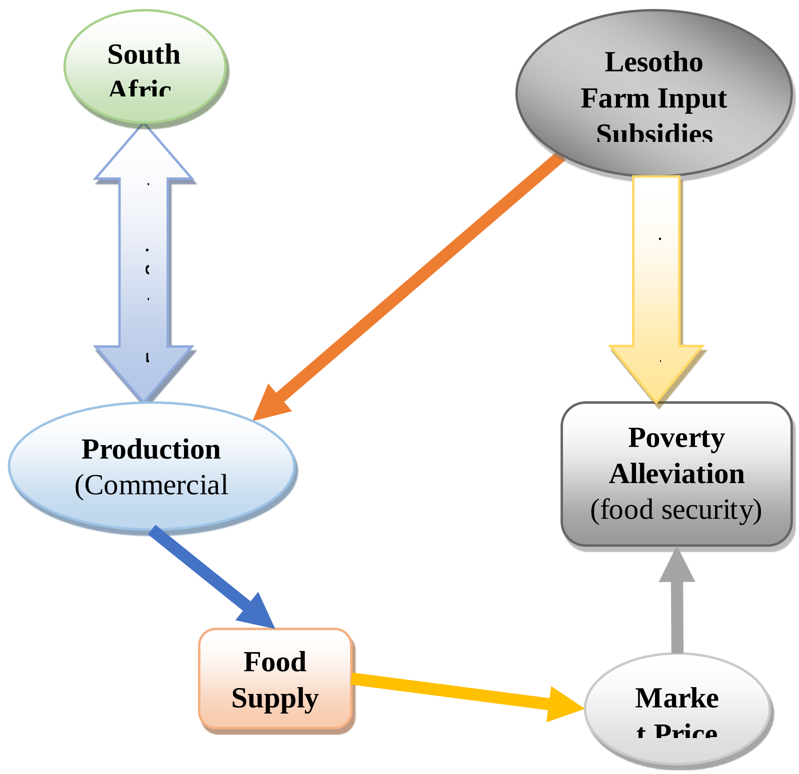

Figure 4. Research model illustrating Lesotho agricultural input subsidies distribution (Source: Author)

Table 1. Households' age group and gender.

Variable		Frequency	Percentage (%)	Valid Percent
Gender	Male	54	40.9	40.9
	Female	78	59.1	59.1
	Total	132	100	100
Age group	25-30	5	3.8	3.8
	31-35	6	4.5	4.5
	36-40	13	9.8	9.8
	41-45	4	3	3
	46-50	11	8.3	8.3
	51-55	93	70.5	70.5
	Total	132	100	100

Source: Farm visits.

engaged in crop production, results reveal that most farmers are old ranging between 51 to 55 years and constituting 70.5% of the population covered in the study. It's also noted there were more female farmers (59.1%) than males as shown in Table 1. The percentages of rural households receiving subsidized inputs are summarized in (Table 2). Based on the findings, 62.1% of households do not receive subsidized inputs; showing that decentralizing targeting to local authorities does not improve targeting efficiency. Compliance with program guidelines is not assured and local elites capture most of the benefits, reducing targeting performance both for poverty alleviation and improved production objectives. Only a small privileged group of individuals amounting to 37.9% receive subsidized inputs, but surprisingly half of the subsidy beneficiaries still use organic fertilizers instead of chemical fertilizers. This phenomenon is due to the fact that, households may not be in a position to use

Table 2. Percent distribution of households using chemical fertilizers by subsidy recipient

Type of fertilizer	Input subsidy		
	Non-recipient (%)	Recipient (%)	All households (%)
Organic	62 (71.3)	25 (28.7)	87 (100)
Chemical	20 (44.4)	25 (55.6)	45 (100)
All households	82 (62.1)	50 (37.9)	132 (100)

Note: These data include all rural households for whom input subsidies information was collected (132 observations). Pearson chi-squared test affirms that subsidy distributions differ by fertilizer use at less than 1% statistical significance (Source: Author)

Table 3. Comparing means of outcome variables, recipients & non-recipients of subsidy.

Variable	Maize production (metric tons)			
	Subsidy	No subsidy	Overall	T-test subsidy vs no subsidy
Culti land 2014 (ha)	5.82	3.65	79.4	***
Culti land 2013 (ha)	6.17	3.59	69.9	***
Surplus/ deficit (tons)	3393	1457	55.9	***
Self- sufficiency (years)	5.3	3	66.1	***

(***) = statistically significant difference at 5% level (Source: Author. Significant differences with two – tailed difference of means tests (***) = 5%).

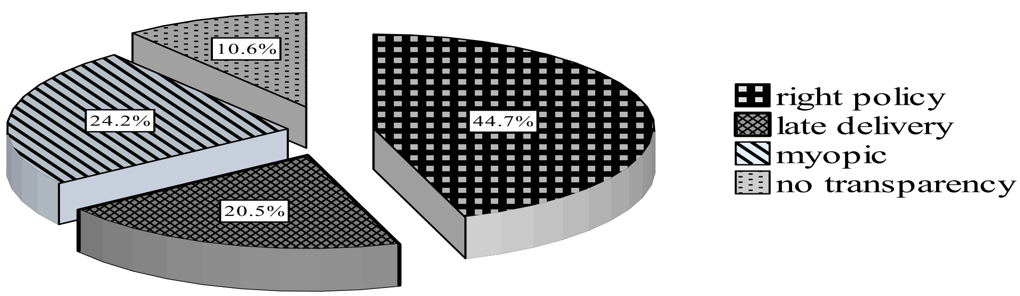

Figure 5. Farmers' opinion regarding ISP (Source: Field survey).

fertilizer because of late delivery, or to use optimally, because they do not perceive the benefits (Druilhe and Barreiro-Hurlé, 2012).

The mean amounts of maize production and mean values of outcome variables are presented in Table 3 by subsidy recipient and maize production. Input subsidy beneficiaries seem to have high maize production on average than non-beneficiaries, for instance, subsidy recipients cultivated more land compared to non-recipients with the difference of 2.17 hectares in the year 2014 and 2.57 hectares in 2013. Similarly in terms of surplus or deficit and self-sufficiency, non-recipients produced an average of 1,457 metric ton of maize with a shortfall of 1,935.6 metric tons compared to the recipients and also on the side of self-sufficiency results revealed that non-recipients production can only sustain them for a period of 3 years, which is 2.2 years less compared to the recipients.

Lesotho government effort to nurture farmers' production through input subsidy program is heavily criticized and viewed as myopic since farmers were not initially engaged in probing their needs and challenges which they are faced with. Late delivery of subsidized inputs and lack of transparency in allocation of subsidized inputs contribute a lot towards food insecurity, reducing performance both for poverty alleviation and improved production objectives. In some other constituencies, there were clear instances of fraud and political manipulations hence in general, only 44.7% of farmers recognized ISP as a right policy while the rest criticize it for lack of transparency viewing it as myopic and also expressed concern over late delivery of input subsidies. Figure 5 shows more clarification concerning farmers' views and perceptions about input subsidy policy (ISP).

Based on the results (Figure 5), rural households may not be in a position to use their inputs due to late delivery,

Table 4. Variables used in regression analysis.

Variable	Mean	Std. Deviation
Access to input subsidy	0.38	0.487
Market participation	0.42	0.496
Household head	0.70	0.458
Educational background	1.12	0.350
Seed variety	1.40	0.492
Tenant occupation	1.50	0.531
Gender	1.59	0.494
Type of fertilizer	1.66	0.476
Agroecological zones	2.4848	1.05197
Economic status	2.81	1.099
Cultivated land	4.7163	3.74411
Household size	5.1061	1.27368
Age group	5.19	1.457
Size of the land (hectares)	7.73	4.453
Farm assets	8.6515	4.75665
Valid N (listwise)	-	-

Table 5. Binary logistic model coefficients and odds ratios.

Access to inputs	Coef.	Odds ratio	z	P>z
Cropland alloc~n	0.1939034	1.213979	2.76	0.006
Gender	-0.0962961	0.908195	-0.22	0.822
Economic status	0.0327232	1.033264	0.15	0.881
Type of farmer	-0.1789429	0.8361536	-0.73	0.467
Type of fertilizer	1.098441	2.999487	2.13	0.033
Seed variety	-0.1079464	0.8976757	-0.24	0.811
Market partici~n	-0.8363874	0.4332729	-1.7	0.089
Tenant occupat~n	0.7223864	2.059342	1.72	0.085
Household head	-0.534448	0.5859927	-1.09	0.274
Ecological Zones	-0.6675538	0.5129619	-3.2	0.001
Household size	0.0822273	1.085703	0.44	0.656
_Cons	-1.461011	0.2320016	-0.74	0.459
Number of Obs	132	132	-	-
Pseudo R^2	0.1851	0.1851	-	-
LR $chi^2(11)$	32.42	32.42	-	-
Prob > chi^2	0.0007	0.0007	-	-

or to use optimally because they do not perceive the benefits. Input subsidy programs are rendered ineffective by the government universal approach which gives rise to unfair treatment as some regions get more advantage over other regions in terms of infrastructure and market structure.

ECONOMETRIC MODEL RESULTS

Results for ISP participation

Table 4 presents descriptive statistics for variables used in the regression models. Based on the research findings presented on Table 5, cropland allocation, type of fertilizer and ecological zones are the determinants of farmers' access to inputs. Meaning that, vulnerable rural households are marginalized though they were regarded as more eligible for being input subsidy beneficiaries. For instance, households which afford cultivation costs (cultivate more land) and utilize chemical fertilizers are more likely to access input subsidies than the dis-advantaged households. This is coherent with Chibwana et al. (2012) regarding cropland allocation effects in Malawi, Ricker-Gilbert et al. (2011) and Xu et al. (2009) concerning input subsidies in Malawi and Zambia.

In addition, differences in geographical region play a major part. Farmers in the mountain areas and foothills are less likely to access input subsidies than those in the lowlands and Senqu river valley due to differences in geographical zones of Lesotho and poor infrastructure. This phenomenon is one of the contributing factors to poor maize production because plowing season varies across the regions, maize plantation in Mountainous Region is from September to October, and Foothills is from September to November, Lowlands and Senqu River Valley is October to November.

Moreover, Senqu River Valley experiences early frost. The results (Table 5) can also be interpreted in terms of odds ratios, where farmers allocating more land for maize production are 1.2 times more likely to access input subsidies. This coincides with the fact that, most of the fields (land) belonging to the poor rural households are left fallowing for a long period of time since they don't afford inputs cost even at a subsidized price unless they can be in share cropping. It is noticed that farmers using chemical fertilizers are 3 times more likely to access input subsidies, which is not always the case in rural areas where most households don't even know the state of their soil fertility or the appropriate chemical fertilizers for their fields because no soil analysis test have ever been conducted. In the nutshell, resource-constrained house-holds are marginalized as also noted by Chirwa and Dorward (2013) and Mvula et al. (2011) that, the vast majority of vulnerable and poor rural households are neglected. Farmers in remote areas are discriminated (extension agents are not willing to stay in those areas) mainly due to poor roads infrastructures (distance travelled and difficulties in transportation), therefore collecting subsidized inputs cost rural households relatively same amounts of money they would spend if buying inputs from private seed retailers located in their vicinity (Chirwa et al., 2011 and Jayne et al., 2011).

Regression results for factors influencing rural households maize production

In order to get rid of outliers from the data set, outlier labeling rule was utilized with 2.2 multiplier effect instead of 1.5 suggested by Turkey (1977) as Hoanglin et al.

Table 6. Multiple regression results.

Variable	Coeff.	t	Lower bound	Upper bound
(Constant)	0.0*** (0.861)	4.502	2.172	5.583
Type of farmer	-0.314*** (0.271)	-3.370	-1.450	-.377
Land size(hectares)	0.175*** (0.034)	2.100	0.004	0.137
Source of come	0.323*** (0.301)	2.822	0.253	1.447
Social safety nets	-0.320***(0.458)	-2.476	-2.041	-0.227
Households head	-0.138 (0.360)	-1.450	-1.235	0.191
Agro – eco Zones	-0.168 (0.139)	-1.931	-0.543	-0.007
Economic status	-0.167*** (0.137)	-2.026	-0.547	-0.006
Cultivated land~ha	-0.159 (0.035)	-1.936	-0.136	0.002

Standard errors are in parentheses. One hundred and thirty – two observations in all regress ***$p < 0.05$.

(1986) discovered that 1.5 often identifies outliers that are not actually outliers and, therefore, proposed or advised people to use the value of 2.2 provided sample sizes were not huge and distribution was normal.

Based on multiple regression results in Table 6, land size and source of income show a strong statistical significance. On an average, a unit increase in the size of land leads to an increase in maize production by 0.18 metric tons. These findings suggest that the size of the landholding affects maize yield as a function of the scale of maize area (economies of scale). The source of income as a means of capital for farmers appears to have a greater impact with the magnitude of 0.32 which is far beyond the magnitude of landholding, this affirms Johnston (1996) findings viewing landlessness as not a perfect proxy for poverty, but rather, access to non-agricultural income being an important indicator of the economic situation of the household because such an income crucially influences a household's ability to make use of the agricultural assets that it holds.

Off-farm income improves households' welfare according to the following three outcomes; source of income, increase maize production and hence household's total income also increases. The inverse relationship between household's economic status and their production performance reveals relative deprivation of farmers compared to their counterparts or reference group, a unit change in farmers' economic status result in 0.17 metric tons decline in their produce confirming that less wealthy households depending on farm produce as their income were most disadvantaged. The negative magnitude for a type of farmer showed that subsistence farmers were losing 0.31metric tons on average compared to commercial farmers and that increased severity of poverty and relative deprivation among subsistence farmers.

CONCLUSION

The government of Lesotho (GoL) has regularly resorted to input subsidies as a way of increasing food production, notably through the block farming program and its predecessors, however, only a few minority access such inputs while displacement use is also more prevalent (Pearson chi – square results presented in Table 2). Proper use of inputs significantly increase farmers' production (t – test results), therefore, GoL has to put in place the follow-up strategies in ensuring use of inputs accordingly. Additionally, access to non-agricultural income is an important indicator of the economic situation of the household as such an income crucially influences a household's ability to make use of the agricultural assets that it holds (depicted from multi-linear regression results), therefore, GoL should put more focus on job creation. The determinants of farmers' access to inputs include cropland allocation, type of fertilizer and ecological zones. The vast majority of rural households doesn't receive or get subsidized inputs and out of that small portion of the recipients, half of them don't use their inputs (chemical fertilizers). This phenomenon is due to the fact that, rural households may not be in a position to use their inputs because of late delivery, or to use optimally because they do not perceive the benefits. GoL universal approach gives rise to unfair treatment as some regions get more advantaged over other regions in terms of agro – ecological economic conditions and rural livelihoods conditions, infrastructure and market structure. Lesotho is not exceptional from other South African countries like Ghana, Malawi, Tanzania and Zambia where similar studies have been conducted. Vulnerable and resource-constrained households are still being marginalized compared to well-off households in possession of bigger land size and have market accessibility or more income.

RECOMMENDATION

GoL has to make use of all geographical regions, improve infrastructure and open market for farmers' produce.

Farmers should be involved in the probe regarding their needs and challenges which they are faced with; top down approach doesn't address farmers' problems. Lesotho ISP has potential to change and improve rural households' food security and welfare, but there are a number of issues which need to be addressed; decentralizing targeting to local authorities does not improve targeting efficiency, as compliance with program guidelines is not assured and local elites capture most of the benefits, reducing targeting performance both for poverty alleviation and improved production objectives. Therefore, information transfer between rural households and extension agents should be revised, and lastly but not least, political disparities should be downplayed in order to bring unity among local people.

Conflict of interests

The author has not declared any conflict of interests.

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Full Length Research Paper

Farmer participatory varietal selection in pearl millet: Experience across some states of Northern Nigeria

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Farmers participation in the process of on-farm research does not only enrich the speed up of information gathering, but also result in large scale adoption of the product of research. A small farmer deals with a variable environment and has multiple production objectives that will affect his or her choice of crops and selection of genotypes. In areas where farmers are unfamiliar with available improved varieties, there is need of conducting effective variety evaluations with farmers. The usefulness of the participatory approach for identifying cultivars for harsh environments, which are difficult to replicate in research stations, has been recognized by the crop breeders. Participatory plant breeding/selection has shown success in identifying more number of preferred varieties by farmers in shorter time (than the conventional system), in accelerating their dissemination and increasing cultivar diversity. This paper describes how plant breeders and farmers worked together to test and selected farmers preferred pearl millet varieties; PE05684 and PE05532 from a diverse pearl millet accessions in a participatory varietal selection program conducted across some states of Northern Nigeria.

Key words: Diversity, pearl millet, participatory plant breeding, varietal selection, ranking.

INTRODUCTION

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] provides diet for over 40 million people who live especially in the arid and semi arid regions of Northern Nigeria. With an average annual production of 3.8 million tons, Nigeria ranks second after India in global millet production (FAO, 2012). In Nigeria, the crop can be used for a variety of purposes. The flour is processed into thick porridge called 'tuwo' served with traditional vegetable soup and fried snack called 'Masa' and non-alcoholic beverages called 'fura'.

Addressing poverty in rural Semi-Arid West-Africa and especially Nigeria requires interventions in the dry-land cereal production systems that continue to provide the basis of life in the region. Farmers' prospects are more at risk in this zone due to both the vagaries of weather as well as their disadvantaged access to markets, especially opportunities for marketing grain surpluses which hinder adoption of improved varieties. In areas where farmers are unfamiliar with available improved varieties, there is need of conducting effective variety evaluations with

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farmers. This ideology was based on reconnaissance survey which indicated that, the uptake and sustained use of improved varieties is constrained by lack of awareness of the improved varieties, traditional values, seed unavailability, early maturity, bird damage, and fertilizer unavailability.

In a world of limited resources, research must be cost-effective. The usefulness of the participatory approach for identifying cultivars for harsh environments, which are difficult to replicate in research stations, has been recognized by the crop breeders (Gowda et al., 2000). Interestingly, farmers are increasingly participating in agricultural research as scientists and development workers become more aware of the philosophy of 'farmer first' and its effectiveness. Participatory plant breeding/selection has shown success in identifying more number of preferred varieties by farmers in shorter time (than the conventional system), in accelerating their dissemination and increasing cultivar diversity (Weltzien et al., 2003). According to several authors (Kornegay et al., 1996; Van Oosterom et al., 1996), it is well suited for niche breeding, or development of varieties that perform well in specialized environments.

Farmer participation in the breeding of crop varieties for low-resource farmers is regarded by some as necessary to help ensure acceptance and eventual adoption (Franzel et al., 1995; Gyawali et al., 2007; Maurya et al., 1988; Mekbib, 2006; Prain et al., 1992).

Thus farmers' requirements have to be identified first so that they can be given more appropriate genetic materials to test based on the following potentials inherit in participatory selection.

(1) Farmers participation in the process of on-farm research does not only enrich in the speed up of information gathering but also result in large scale adoption of the product of research.
(2) It gives the breeder a great deal of confidence when presenting the varieties to the release committee.
(3) It provides impetus for release if popularity among farmers is documented.
(4) It helps in overcoming the initial inertia in bulking and distribution of newly released varieties.

By making selection criteria more relevant to end user needs, it can reach poor households that have not yet benefited from multiple varieties, increases the benefits and is more effective at reaching women and the poor (Michael and Mauricio, 2004). This provides a rationale for on-farm farmers' participatory variety evaluation and selection.

This paper describes how plant breeders and farmers worked together to test and selected farmers preferred pearl millet varieties from a range of pearl millet accessions in a participatory varietal selection program.

The specific objective of this project was to select from diverse and productive pearl millet lines received from ICRISAT Niamey during the BMZ and IFAD projects, that are adapted to local conditions and accepted by farmers and consumers' at large using farmers' indigenous knowledge and breeders' scientific approach.

METHODOLOGY

Participatory rural appraisal

The Lake Chad Research Institute/Community Based Agricultural and Rural Development Project (LCRI/CBARDP) team carried out community consultation across trial implementation sites before each of the 2006 to 2008 cropping seasons.
The goals were to:

(1) Discuss participatory selection/breeding results and suggest which variety to replace modalities on how to share seeds harvested from trial among participating farmers, agronomic conditions for the trial-evaluate target condition, uniformity of dates of sowing, population density, replications (3 to 4) to enable yield evaluation (possibility of trying 2 replications per farmer were sought), cases of intercrop, which seeds should be uniform for all farmers.
(2) Mobilize rural entrepreneurship through the use of processing technologies that are affordable and sustainable for rural community for millet products.
(3) Discuss opportunities for grain and product commercialization from farm-gate to urban centres.
(4) Select farmer groups for activities in Breeding and seed systems, production system with respect to striga management and documentation of available food products from millet/sorghum and commercial opportunities.

At each location, the discussions were first preceded by paying a courtesy call on the local village head, introduction of the visitors, and drawing of the village map with the community participation and CBARDP staff. This is to ascertain the spread of the sites were the trials will be conducted. The village maps were first demonstrated by placing small stones representing settlements and later transferred unto papers as a map with well written names of the villages. The major spoken language at Ngetera-Gubio (Borno) is Kanuri, at Tikau (Yobe) is Karekare, while at Sabon-Gari (Jigawa), Garin-Garu (Katisna), Gusau (Zanfara), and Alero (Kebbi) is Hausa, and presentations were translated accordingly. Attendances for each location were recorded.

Test sites selections were based on the following criteria: (a) easily accessible from a paved road (less than 20 km from the main road in rainy season; (b) the community is responsive to the innovations; (c) place of intensive sorghum production in the western states; (d) place of intensive millet production in the eastern states.

Despite the mentioned criteria, the following was also considered critical for the site selection. Land must be suitable for the activities, accessible, acceptable to all members of the community, non-conflict area and is recognized by the community.

These sites were situated within the target zones of IFAD investment projects (CBARDP) in six states of Northern Nigeria and were used to both implement a Farmer Field School where proven technologies were proposed to farmers and participatory trials to check their local adaptation and interest and to realize participatory activities on variety improvement, that is, tests of varieties from the whole region, selection within the breeding populations in process and organisation of a community level seed production.

While presenting the proposals, willing farmers were selected based on the following criteria: active and willing to participate, volunteering, should be resident in the community, have group spirit, willing to share experiences, ready to follow rules and posses good human relations.

Project officers (POs) and development officers (DOs) along with their field assistants assisted in identifying farmers who participated in the focus groups discussions with representation of both men and women.

Priority ranking

Participatory rural appraisals were conducted on the major characteristics of pearl millet and sorghum landraces. Priority ranking for setting breeding objectives using matrix approach was used to determine what traits the farmers prefer most in a variety of interest. A set of traits were identified by farmers at various locations which were tabled against each other in a matrix. In the process farmers were asked to score the traits in a pair-wise comparison by raising their hands and counted. The trait with the highest score was ranked as the first, followed by the second highest and so on.

Participatory variety selection

Participatory variety selection was carried out to select from diversified pearl millet lines that possess farmer's preferred plant and grain traits (earliness to maturity, high grain yield, downy mildew resistance, etc). The pearl millet accessions were provided by ICRISAT_NIAMEY through BMZ and IFAD TAG817 project. During 2007, 27 entries selected from the 360 Germplasm materials were evaluated on two row plot of 5 m length with 2 replications across seven IFAD-CBARDP participating states (Kebbi, Katsina, Zamfara, Jigawa, Yobe, and Borno) where farmers were exposed to the diversity and expressed their opinion. During 2008 cropping, 17 entries selected from the 2007 cropping season were repeated across the seven participating states to confirm farmers' choice. These were established in 12 villages each with an average of 200 farm families.

Rather than being provided with a package of improved technologies, as usually happens under conventional on-farm testing, each group of farmers was advised to conduct the trial in community plots using existing management practices. The objective was to enable the farmers to select those genotypes with better performance *per se* rather than genotypes which perform better in a higher-input management environment that they may be unable to sustain once external support is withdrawn. Farmers carried out all cultural operations including planting, thinning, weeding, fertilizer applications, harvesting, and grain processing. The selection was based on plant growth, stem thickness, resistance to lodging, drought resistance, insect resistance, time to maturity, grain size, and grain color. For each evaluation, 30 farmers in the village assembled and visited all the plots together. Informal interviews were used immediately after the field review to elicit farmers' preliminary evaluation of the varieties tested.

Ballot paper approach

Ballot papers of different colours were used to rate their choices:

(a) White/Green ballot paper, good and acceptable for men/women, respectively.
(b) Blue/Yellow ballot paper -accepted as alternative for men/women respectively.
(c) Red/Pink ballot paper, rejected for men/women, respectively.
Ballot papers were dropped in black polyethylene bags by farmers and these are counted per plot and expressed in % as follows:

(1) % white for men/green for women;
(2) % blue for men/yellow for women;
(3) % red for men/pink for women.

Selected entries scores of at least 70 to 100% white/green votes of the total farmers per site were considered selected. Alternatives scores were between 51 and 69% blue/yellow votes, while rejected entries scores were between 50 and 100% red/pink votes.

Data analysis using Genstat Discovery Edition was carried out for individual locations, while combined analyses were carried out on only those that were consistent for parameters across the locations and years.

RESULTS AND DISCUSSION

Priority ranking

Result from priority ranking from some selected sampled locations (Tikau, Gubio and Gwoza) showed that earliness and yield ranked 1st and 2nd, respectively across all the sites (Table 1) due to the following reasons:

(1) For pearl millet, it is the first crop to be planted at the onset of rains and later intercropped with either cowpea or groundnut.
(2) Early maturing cultivars escape bird's damage at migration and striga infestation.
(3) Drought escapes, since most people living in these areas where pearl millet or sorghum is being produced have short rain periods ranging from 75 to 100 days.

Field data

Data for 2008 cropping season for some selected locations is presented. Data analysis of the 2008 participatory selection, showed that farmers across sites gave the highest scores to the 2 most common entries; PE05684 and PE05532 of 76 and 80% acceptance, respectively (Table 2), characterized by earliness, bold grain, stout stalk, compact panicle, less downy mildew, and no insect pest attack. Accordingly, most farmers expressed that, these varieties met their earlier criteria from priority ranking (Table 1), that is, earliness and yield ranking 1st and 2nd, respectively. PEO5984 though early scoring 45% acceptance was considered as alternative choice due to its short panicle which may not be suitable for bundling.

To confirm the farmers choice of lines selected, data analysis for the locations combined is presented on Table 3. Grain yield ranged from 1829 to 4366 kg/ha with PE05631×PE05393 having the highest grain yield of 4366 kg/ha. Days to 50% flowering ranged from 52 to 88 days with PEO5984 being the earliest (52 days to 52% flowering). PE05684 and PE05532 recorded grain yield of 3502 and 4046 kg/ha, respectively with both having a yield advantage of 30% over the local check confirming

Table 1. Priority ranking for setting breeding objectives for pearl millet and sorghum selection criteria.

Traits	Millet			Sorghum		
	Tikau	Gubio	Benesheikh	Gwoza	Dikwa	Daniski
Maturity (earliness)	1	1	1	1	1	1
Yield (high)	2	2	2	2	2	3
Plant height (medium)	11	11	11	5	6	5
Panicle length (medium)	9	9	8	11	11	11
Panicle size (medium)	12	12	13	12	12	12
Grain size (bold)	4	4	4	6	5	9
Grain colour (white)	6	7	6	3	3	2
Thresh ability	13	13	12	7	7	13
Grain hardness (hard)	5	5	5	8	8	6
Taste	8	8	9	9	9	8
Storability	10	10	10	10	10	10
Panicle compactness (compact)	3	3	3	4	4	7
Dm/Striga resistance	7	6	7	13	13	4

Table 2. Participatory pearl millet varietal selection score for locations combined in Northern Nigeria 2008 cropping season.

S/N	Pedigree	Percent acceptance (%√)	Percent alternative (%ф)	Percent rejection (% ×)	Remark
1	PE01490	30	29	35	-
2	PE00404	9	4	74	Rejected
3	PE05419	3	22	71	,,
4	PE05607	9	32	47	,,
5	PE05611	11	20	68	,,
6	PE05684	76	17	7	Selected
7	PE00382	21	18	61	Rejected
8	PE05449	14	17	61	,,
9	PE05463	20	17	50	,,
10	PE05631	16	37	46	
11	PE05532	80	7	11	Selected
12	PE05593	37	35	28	Alternative
13	PE05631XPE05393	39	40	21	,,
14	B-9 Tabi	21	49	30	,,
15	PE05984	45	26	28	,,
16	LCICMV-1 (SOSAT-C88)	76	11	12	Selected
17	LOCAL CHECK	58	1	32	-

%√ = percent score for selection. %ф = percent score for use as alternative. % × = percent score for rejection.

the farmers earlier choice of these lines.

PE05631×PE05393 with the highest grain yield of 4366 kg/ha was not selected due to variability within plot as a result of segregation for days to 50% flowering. Plant height ranged from 175 to 310 cm with mean of 272 cm. PE05684 and PE05532 selected by farmers were of medium height of 228 and 303 cm, respectively, thus good stalk height for fencing and roofing purposes.

Downy mildew infestations were generally ≤1% indicating the genotypes are moderately resistant across the sites tested.

Conclusion

Result from both participatory and field evaluation suggest that participatory variety evaluation offers the possibility of bringing modern and traditional plant breeding traditions together to increase the usefulness of new crop varieties to farmers, especially small-scale farmers working in stress environments with limited external inputs.

It is however, suggested that the medium maturing PE05684 and PE05532 which recorded grain yield of

Table 3. Performance of pearl millet lines for some agronomic characters across some selected states (Zanfara, Jigawa and Yobe) combined during 2008 season.

Entry	Pedigreee	Downy mildew score (%)	Days to 50% flowering	Plant height (cm)	Grain yield (kg/ha)
1	PE01490	0	69	272	3235
2	PE00404	0	77	271	2837
3	PE05419	0	88	283	1951
4	PE05607	0	76	321	1829
5	PE05611	0	77	239	2039
6	PE05684	0	61	228	3502
7	PE00382	0	75	309	2716
8	PE05449	0	79	306	2494
9	PE05463	0	86	310	2550
10	PE05631	1	73	272	2693
11	PE05532	1	62	303	4046
12	PE05393	1	66	296	3906
13	PE05631XPE05393	0	69	299	4366
14	B-9 Tabi	0	66	213	3556
15	PEO5984	1	52	175	3680
16	LCICMV-1 (SOSAT-C88)	0	61	267	4212
17	LOCAL CHECK	1	62	265	2870
mean		0	71	272	3087
se±		0	2.9	15.4	389.6
cv%		-	5.8	13.9	30.9

3502 and 4046 kg/ha, respectively can further be subjected to on-farm adaptive trials.

Conflict of Interests

The authors have not declared any conflict of interests.

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How to control *Helicoverpa armigera* on soybean in Brazil? What we have learned since its detection

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The present study was motivated by a lack of information on how to control *Helicoverpa armigera* in soybean fields in Brazil. Nine chemical and four biological treatments were tested. Control efficiency was evaluated at 3, 7, 10, and 14 days after spraying. Moreover, the cost benefit ratio by the yield and cost of insecticide application and the economic injury level (EIL) were used to calculate the chemical and biological treatments. Chemical insecticides chlorantraniliprole, flubendiamide, chlorfenapyr, spinosad and acephate with 90.9, 90.9, 90.9, 72.7 and 90.9% of control efficiency, respectively, were efficient to control *H. armigera* along the evaluations. Bt Control® was efficient controlling small and large larvae, with 100 and 66.7% of control efficiency, respectively. Gemstar® and HzNPV CCAB® were efficient against small larvae. The treatments acephate (1:10), chlorantraniliprole (1:6.6), flubendiamide (1:5.3), Bt Control® (1:6.6), Gemstar® (1:5) and HzNPV CCAB® (1:5.7) had higher cost benefit ratio (ratios are indicated in parentheses after the treatments names). The EIL is flexible and vary according to the control efficiency, cost of treatment application and market value of soybean. The lowest value of EIL was Dipel® (0.2) and the highest value was chlorfenapyr (2.3). These findings support a decision of when, which treatment, and dose to spray to control *H. armigera* on soybean with a high cost benefit ratio.

Key words: Old world bollworm, control pest, chemical insecticide, biological insecticide.

INTRODUCTION

The confirmation of the presence and invasion of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) in Brazil (Czepak et al., 2013) and in South and Central America (Murúa et al., 2014; Smith, 2014; Arnemann et al., 2016) brought serious implications in terms of the management of this pest for the main agricultural crops cultivated in these areas. Furthermore, Kriticos et al. (2015) alerted about the extraordinary spread potential of this pest to North America and in July 2014, USDA/APHIS and Florida Department of Agriculture and Consumer Services (FDACS) confirmed the first detection of *H. armigera* in USA.

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Table 1. Chemical and biological treatments and rate per hectare.

Chemical treatment	Trademark	Rate (g ha^{-1})[1]	Biological treatment	Trademark	Rate (g ha^{-1})
1. Chlorantraniliprole	Premio® 200 SC	10.0	*B. thuringiensis*	Dipel® SC	4.5×10^{11}*
2. Flubendiamide	Belt® 480 SC	33.6	*B. thuringiensis*	Bt Control® SC	2.5×10^{13}*
3. Indoxacarb	Avatar® 150 CE	60.0	*H. zea* nucleopolyhedrovirus	Gemstar® SC	4.0×10^{11}**
4. Chlorfenapyr	Pirate® 240 SC	240.0	*H. zea* nucleopolyhedrovirus	HzNPV CCAB® SC	1.5×10^{12}**
5. Spinosad	Tracer® 480 SC	33.6	Control treatment	-	-
6. Chlorfluazuron + Methomyl	Atabron® 50 CE + Lannate® 215 SL	25.0 + 215.0	-	-	-
7. Methoxyfenozide	Intrepid® 240 SC	96.0	-	-	-
8. Lambda-cyhalothrin + Chlorantraniliprole	Ampligo® 50 + 100 SC	3.7 + 7.5	-	-	-
9. Acephate	Orthene® 750 PS	750.0	-	-	-
10. Control treatment	-	-	-	-	-

[1]Rate of active ingredient per hectare. *Rate of spore/crystal. **Rate of polyhedral inclusion bodies.

The management of *H. armigera* populations poses great challenges for the Brazilian soybean farmers, because there is little information available on the chemical and biological control of this pest in Brazil. These difficulties led the Brazilian Ministry of Agriculture and Food Supply to take immediate measures, such as the emergency registration of insecticides for the control of *H. armigera*. It makes the control recommendations susceptible to doubt and errors. The lack of regional control results still leaves the technical assistants, industry, farmers, and researchers without information to establish the management of this pest during recent crop production cycles. Therefore, to evaluate the role of chemical and biological insecticides used to control larvae of *H. armigera* under soybean field conditions, two experiments were accomplished at two locations under different environmental conditions.

MATERIALS AND METHODS

Two experiments were performed during the 2013/2014 growing season in Restinga Seca and Santa Maria, State of Rio Grande do Sul (RS), Brazil. In Restinga Seca, treatments were sprayed on the 3rd of February 2014 at the full pod (R4) growth stage and densities of *H. armigera* were 1.2 and 3.7 small (< 1.5 cm) and large (> 1.5 cm) larvae m^{-2}, respectively. In Santa Maria, treatments were sprayed on the 10th of February 2014 at the beginning seed (R5.1) soybean growth stage, with densities of 2.5 and 1.0 small and large larvae m^{-2}, respectively. The soybean variety on both areas was BMX Potencia RR. The species of *Helicoverpa* occurring on these experiments were identified at the Laboratory of Integrated Pest Management (LabMIP) of the Federal University of Santa Maria using the identification key of Hardwick (1965) from adults and larvae collected during the experiments' evaluations. The voucher specimens were deposited at LabMIP.

The experiment was carried out in a randomized complete block design with four replications and plot sizes of 4 × 6 m (24 m^2), distributed randomly with 0.5 m between each other on the field. Nine chemical and four biological insecticides were sprayed (Table 1; all insecticides were obtained from commercialized market insecticides). In both experiments, treatment applications were performed after 6:00 PM with a CO_2 pressurized backpack sprayer and a flow rate of 150 L ha^{-1}. The evaluations were conducted with a vertical beat sheet (Guedes et al., 2006) in order to count the number of small and large larvae collected on a 1.0 m^2 area per plot at 3, 7, 10, and 14 days after spraying (DAS). Control efficiency (E) of treatments was calculated according to the equation (Abbott, 1925):

$$E = \left(\frac{\text{Control treatment - insecticide treatment}}{\text{Control treatment}} \right) * 100$$

In the Restinga Seca experiment, grain yield was obtained by harvesting 2 km^2 of each plot on the 5th of April 2014. The cost benefit ratio (C:B - how many dollars returned per dollar invested) of each treatment were calculated with additional yield over control treatment, the cost of insecticide application and net income. The Economic Injury Level (EIL) were calculated considering the yield loss (kg/ha) of one *H. armigera* larvae/m^2 of 58 kg/ha (Rogers and Brier, 2010). The number of larvae (x) was transformed to the square root of x + 0.5 and submitted to joint analysis. The means were grouped using the Scott-Knott test (P>0.05).

RESULTS AND DISCUSSION

Chemical control of *H. armigera* in soybean

Most chemical treatments significantly reduced density of *H. armigera* larvae compared to the control treatment. At 3 DAS, control efficiency was the highest for chlorantraniliprole (83.3%), chlorfenapyr (90%), and acephate (83.3%; percent of control efficiency are indicated in parentheses after the treatments names; Table 2). At 7 DAS, control efficiency of larvae was above 90% for flubendiamide (93.1%), indoxacarb (96.6%), chlorfenapyr (100%), spinosad and acephate (93.1%). Chlorantraniliprole reduced the population density of *H. armigera* by 82.8%. At 10 DAS, chlorantraniliprole, flubendiamide, chlorfenapyr, spinosad, lambda-cyhalothrin + chlorantraniliprole, and acephate controlled the larvae >80%. Chlorantraniliprole, flubendiamide, chlorfenapyr, and acephate maintained >90% mortality of larvae at 14 DAS.

Chlorfenapyr (240 g a.i. ha^{-1}) always had the highest control efficiency (at all evaluations). This insecticide uncouples oxidative phosphorylation in mitochondria, thereby interrupting ATP production (Raghavendra et al., 2011). Thereby, this insecticide can be used as an alternative mode of action during the same crop season, delaying or mitigating development of insecticide resistance on this pest.

Chlorantraniliprole and flubendiamide at tested doses of 10 and 33.6 g a.i. ha^{-1}, respectively, had similar efficiencies against *H. armigera* consistent with their chemical group (anthranilic diamides). In cotton, flubendiamide 60 g a.i. ha^{-1} reduced the *H. armigera* larval population by decreasing crop damage by 96% (Thilagam et al., 2010). Furthermore, doses of chlorantraniliprole (31.5 to 52.5 g a.i. ha^{-1}) effectively controlled *H. armigera* in cotton in Australia (Leven et al., 2011). Therefore, in the present study, doses of chlorantraniliprole and flubendiamide lower than those recommended elsewhere effectively controlled *H. armigera*. It demonstrates the importance of local evaluation of insecticides. It was found out that spinosad (33.6 g a.i. ha^{-1}) was effectively >80% at 7 and 10 DAS. Similarly, it has high control efficiency (>90%) in cotton, albeit, at greater doses than those used in the present study (range: 72 to 96 a.i. ha^{-1}) (Leven et al., 2011). The use of higher doses of spinosad was suspected to be related to larval resistance, as reported in Pakistan (Ahmad et al., 2003), India (Kranthi et al., 2000), and Australia (Gunning and Balf, 2002). Improved metabolism by cytochrome P450 oxidase may be predisposed to rapid development of resistance to spinosad (Wang et al., 2006). Indoxacarb had limited residual effects in our results. Vinaykumar et al. (2013) reported reductions within seven DAS on soybean. However, this insecticide had a low residual effect due to its high photodegradation (DT_{50} = 4.5 days at pH 5 and 25°C; FAO). Therefore, indoxacarb requires applications at 7 to 10 days intervals, due to low persistence, despite high initial efficacy.

Biological control of *H. armigera* in soybean

The mortality varied according to size of larvae and DAS. Therefore, results of biological treatments are separately shown. At 3 DAS, all treatments had efficiencies <70%, attributed to delayed pathology of Baculovirus or *Bacillus thuringiensis* (Table 3). Dipel® and Bt Control® had the highest control of small larvae (63.3%). Gemstar® controlled 47.4% of large larvae. At 7 DAS, Bt Control® and HzNPV CCAB® controlled 85.7 and 100%, respectively, of small larvae, whereas Dipel® and Bt Control® had a higher control of large larvae (86.8 and 73.3%, respectively). At 10 DAS, Bt Control® (100%), HzNPV CCAB® (100%), and Gemstar® (87.5%) had the highest control of small larvae. However, for large larvae, Bt Control® and HzNPV CCAB® had control efficiency of 84.2 and 78.9%, respectively. At 14 DAS, Bt Control®, HzNPV CCAB®, and Gemstar® had control efficiency of 100%.

Biological insecticides only had a significantly larvae mortality after 7 DAS, due to its contamination and action mechanism, in which the insecticide needs to be ingested by the larvae to become pathogenic to the insect. Bt Control® had a higher mortality, mainly of small larvae of *H. armigera* compared to Dipel®. Dipel® and Bt Control® had faster mortality to large larvae than Gemstar® and HzNPV CCAB®, which can be attributed to the median lethal time (LT_{50}). Dipel® has a LT_{50} of 6.3 h for first instar larvae of *H. zea* (Junior et al., 2009), whereas for baculovirus it exceeds 3 days (Castro et al., 1999). Even though Dipel® and Bt Control® have the same active ingredient, the commercial products tested had distinct efficiencies due to their amount of *B. thuringiensis* spores/ml. Thereby, the dose of Dipel® to control *H. armigera* has to be increased.

Mortality also depends of larval stage and dose sprayed. The control efficiency of Bt Control®, Gemstar®, and HzNPV CCAB®, was higher to small larvae. Likewise, for the quantity of spores/ml, the amount of OBs on HzNPV CCAB® is higher than Gemstar®. Because of this, the control efficiency of HzNPV CCAB® reached 100% early for small larvae. These present findings were consistent with previous findings on larval stage and dose sprayed. Increase in the dose of OBs applied per larvae results in faster mortality and shorter survival time (Georgievska et al., 2010).

Soybean yield and benefit cost ratio from chemical and biological treatments

The active ingredients acephate (2,643 kg ha^{-1}), spinosad (2,594 kg ha^{-1}), chlorfenapyr (2,576 kg ha^{-1}), chlorantraniliprole (2,447 kg ha^{-1}), and flubendiamide (2,497 kg ha^{-1}) had the highest soybean yield (Table 4), attributed to larvae control efficiency. In this way, the benefit cost ratio was higher for acephate (1:10.0), chlorantraniliprole (1:6.6), and flubendiamide (1:5.3), because of low cost of insecticide application and high soybean yield. Although, acephate had higher benefit cost ratio, should lead to the highest yield,

Table 2. Number of *H. armigera* larvae (±SD) and efficiency (E) of the chemical treatments.

Treatment	[1]Rate (g ha^{-1})	Number of larvae m^{-2}											
		3 DAS[2]	t[3]	E (%)	7 DAS	t	E (%)	10 DAS	t	E (%)	14 DAS*	t	E (%)
1. Chlorantraniliprole	10.0	0.6 (±0.9)	a	83.3	0.6 (±0.5)	a	82.8	0.4 (±0.5)	a	88.9	0.3 (±0.5)	a	90.9
2. Flubendiamide	33.6	1.0 (±1.1)	a	73.3	0.3 (±0.5)	a	93.1	0.3 (±0.5)	a	92.6	0.3 (±0.5)	a	90.9
3. Indoxacarb	60.0	0.9 (±1.0)	a	76.7	0.1 (±0.4)	a	96.6	1.0 (±0.8)	a	70.4	1.5 (±0.6)	b	45.5
4. Chlorfenapyr	240.0	0.4 (±0.7)	a	90.0	0.0 (±0.0)	a	100.0	0.1 (±0.4)	a	96.3	0.3 (±0.5)	a	90.9
5. Spinosad	33.6	0.9 (±1.4)	a	76.7	0.3 (±0.5)	a	93.1	0.4 (±0.5)	a	88.9	0.8 (±1.0)	a	72.7
6. Chlorfluazuron + Methomyl	25.0 + 215.0	1.8 (±1.3)	b	53.3	0.8 (±0.7)	a	79.3	0.8 (±0.7)	a	77.8	1.5 (±0.6)	b	45.5
7. Methoxyfenozide	96.0	2.8 (±2.1)	b	26.7	1.4 (±1.5)	a	62.1	1.0 (±1.1)	a	70.4	1.0 (±0.8)	a	63.6
8. Lambda-cyhalothrin + Chlorantraniliprole	3.7 + 7.5	1.6 (±0.7)	b	56.7	0.9 (±0.6)	a	75.9	0.3 (±0.5)	a	92.6	0.8 (±1.0)	a	72.7
9. Acephate	750.0	0.6 (±0.5)	a	83.3	0.3 (±0.5)	a	93.1	0.5 (±0.5)	a	85.2	0.3 (±0.5)	a	90.9
10. Control treatment	-	3.8 (±1.3)	b	-	3.6 (±1.2)	b	-	3.4 (±1.3)	b	-	2.8 (±1.0)	b	-
CV (%)[4]	-	34.1	-	-	30.9	-	-	42.1	-	-	24.4	-	-

[1]Rate of active ingredient for hectare. [2]Days after spray of treatment. [3]Means separated by the Scott-Knott test (t). Values followed by the same letter do not differ significantly at the 5% probability level. [4]Coefficient of Variation. *Evaluation means of Santa Maria.

because it had a similar control efficiency of chlorantraniliprole and flubendiamide. The insecticide acephate has to be retested. Conversely, even with excellent control efficiency and high productivity, the benefit cost ratio of chlorfenapyr and spinosad insecticides was only 1:3.7 and 1:4.3, respectively, because of their high spray cost.

The yield of the biological treatments, Bt Control® (286 kg ha^{-1}), Gemstar® (297 kg ha^{-1}), and HzNPV CCAB® (301 kg ha^{-1}), differed from control treatment and Dipel® (Table 3). The benefit cost ratio was similar between Gemstar® and HzNPV CCAB® (baculovirus treatments), 1:5.0 and 1:5.7, respectively. Bt Control® had the highest benefit cost ratio (1:6.6). These biological insecticides had a similar benefit cost ratio to the chemical treatments acephate, chlorantraniliprole, and flubendiamide.

This result supports that an application of a biological insecticide affect the selectivity to natural enemies which naturally control the pests.

H. armigera economic injury level (EIL)

Once the density and population distribution of *H. armigera* have been determined, the next step is to decide whether a control program is required by EIL. The EIL is the population density of an insect that causes economic loss equal to the control cost (Pedigo and Rice, 2006). The EIL depends on cost of insecticide application, value of soybean kilogram, the damage (in kg), and the efficiency of the control method/treatment used.

The insecticide Dipel® had a mean efficiency of 60%, with a spray cost of US$13.20. Considering the soybean bag value of US$15.00, the EIL for Dipel® is much lower (0.5 larvae m^{-2}), mainly because of its low control efficiency (Table 5), moreover, to its low cost of insecticide application ha^{-1} (C). In general, the biological insecticides (Dipel®, Bt Control®, Gemstar®, and HzNPV CCAB®) had lower EILs compared to chemical insecticides. Therefore, biological insecticides should be applied in the beginning of an infestation by *H. armigera*. Conversely, the insecticide chlorfenapyr had the highest control efficiency among the evaluated insecticides. It means control efficiency of 94%, with the high cost of insecticide application ha^{-1} (US$35.90), soybean value of US$15.00 increased the EIL to 2.3 *H. armigera* larvae m^{-2}. It means that an efficient treatment can support higher pest density and each soybean field has to be sampled to know the density of pest and to decide the correct time to start the control.

These findings support how to manage *H. armigera* on soybean in Brazil, looking at the control data from chemical and biological insecticides, the cost benefit ratio and the EIL.

Monitoring of *H. armigera* during all the soybean growth stages are essential to make decisions from these results on when to control, which insecticide, and the dose that will result in a higher

Table 3. Number of small and large *H. armigera* larvae (±SD) and efficiency (E) of the biological treatments.

Treatment	Rate (g ha^{-1})	Number of small larvae m^{-2}											
		3 DAS[1]	t[2]	E (%)	7 DAS	t	E (%)	10 DAS	t	E (%)	14 DAS[*]	t	E (%)
1. Dipel®[4]	4.5 × 10^{11}	0.5 (±0.8)	a	63.6	0.6 (±0.7)	a	64.3	0.5 (±0.8)	a	50.0	0.3 (±0.5)	a	50.0
2. Bt Control®[4]	2.5 × 10^{13}	0.5 (±0.8)	a	63.6	0.3 (±0.7)	a	85.7	0.0 (±0.0)	a	100.0	0.0 (±0.0)	a	100.0
3. Gemstar®[5]	4.0 × 10^{11}	0.6 (±0.5)	a	54.5	0.8 (±1.2)	a	57.1	0.1 (±0.4)	a	87.5	0.0 (±0.0)	a	100.0
4. HzNPV CCAB®[5]	1.5 × 10^{12}	1.0 (±0.8)	a	27.3	0.0 (±0.0)	a	100.0	0.0 (±0.0)	a	100.0	0.0 (±0.0)	a	100.0
5. Control treatment	-	1.4 (±0.9)	a	-	1.8 (±1.7)	a	-	1.0 (±0.5)	a	-	0.5 (±0.6)	a	-
CV (%)[3]	-	19.8	-	-	38.3	-	-	31.9	-	-	24.0	-	-
		Number of large larvae m^{-2}											
1. Dipel®[4]	4.5 × 10^{11}	2.3 (±1.8)	a	5.3	0.3 (±0.5)	a	86.7	0.8 (±0.9)	a	68.4	1.0 (±0.0)	a	55.6
2. Bt Control®[4]	2.5 × 10^{13}	1.6 (±1.1)	a	31.6	0.5 (±0.5)	a	73.3	0.4 (±0.5)	a	84.2	0.8 (±1.0)	a	66.7
3. Gemstar®[5]	4.0 × 10^{11}	1.3 (±0.7)	a	47.4	1. 4 (±0.9)	a	26.7	1.4 (±1.8)	a	42.1	0.5 (±0.6)	a	77.8
4. HzNPV CCAB®[5]	1.5 × 10^{12}	2.0 (±1.4)	a	15.8	1.0 (±1.8)	a	46.7	0.5 (±0.5)	a	78.9	0.8 (±0.5)	a	66.7
5. Control treatment	-	2.4 (±1.4)	a	-	1.9 (±0.6)	a	-	2.4 (±1.2)	a	-	2.3 (±1.3)	a	-
CV (%)	-	42.8	-	-	40.8	-	-	44.4	-	-	24.8	-	-

[1]Days after spray treatment. [2]Values followed by the same letter do not differ significantly at the 5% probability level. [3]Coefficient of Variation and the data transformed to square root of x + 0.5. [4]Rate of commercial product = 500 mL ha^{-1}. [5]Rate of commercial product = 200 ml ha^{-1}. *Evaluation means for Santa Maria only.

Table 4. Soybean yield and benefit cost ratio of chemical and biological treatments.

Treatment	Rate (g ha^{-1})	Yield (kg ha^{-1})	Additional yield over control (kg ha^{-1})	Additional income over control (US$ ha^{-1})*	Cost of insecticide application (US$ ha^{-1})**	Net income (US$ ha^{-1})	Cost benefit ratio
1. Chlorantraniliprole	10.0	2447^{b}	349	122.64	16.11	106.53	1:6.6
2. Flubendiamide	33.6	2497^{b}	399	140.20	22.28	117.92	1:5.3
3. Indoxacarb	60.0	2370^{c}	272	95.52	19.81	75.70	1:3.8
4. Chlorfenapyr	240.0	2576^{a}	478	167.95	35.86	132.08	1:3.7
5. Spinosad	33.6	2594^{a}	496	174.18	33.00	141.18	1:4.3
6. Chlorfluazuron + Methomyl	25.0 + 215.0	2326^{c}	229	80.24	41.70	38.54	1:0.9
7. Methoxyfenozide	96.0	2200^{d}	103	36.08	20.31	15.77	1:0.8
8. Lambda-cyhalothrin + Chlorantraniliprole	3.7 + 7.5	2342^{c}	244	85.68	17.50	68.18	1:3.9
9. Acephate	750.0	2643^{a}	545	191.47	17.35	174.13	1:10.0
10. Control treatment	-	2098^{b}	0	0.00	0.00	0.00	-
CV (%)		3.3					
1. Dipel®[1]	4.5 × 10^{11}	2197^{b}	99	34.77	13.23	21.54	1:1.63

Table 4. Cont'd.

2. Bt Control®[1]	2.5 × 10^{13}	2384[a]	286	100.35	13.23	87.12	1:6.58
3. Gemstar®[2]	4.0 × 10^{11}	2395[a]	297	104.38	17.35	87.04	1:5.02
4. HzNPV CCAB®[2]	1.5 × 10^{12}	2399[a]	301	105.79	15.70	90.09	1:5.74
5. Control treatment	-	2098[b]	0	0.00	0.00	0.00	-
CV (%)	-	3.4	-	-	-	-	-

*Price per kilogram of soybeans (US$ 0.351). **Insecticide's cost plus operational application cost of US$5.00. [1]Dose of commercial product = 500 ml ha^{-1}. [2]Dose of commercial product = 200 ml ha^{-1}.

Table 5. Economic injury level (EIL) estimated for chemical and biological treatments.

Treatments	**E* (%)**	**Cost of insecticide application (US$ ha^{-1})**	**Value of a 60 kg soybean bag (US$)**					
			15.00	**20.00**	**25.00**	**30.00**	**35.00**	**40.00**
			Larval population of *H. armigera* m^{-2}**					
chlorantraniliprole	85	16.1	0.9	0.7	0.6	0.5	0.4	0.4
flubendiamide	86	22.3	1.3	1.0	0.8	0.7	0.6	0.5
indoxacarb	76	19.8	1.0	0.8	0.6	0.5	0.4	0.4
chlorfenapyr	94	35.9	2.3	1.7	1.4	1.2	1.0	0.9
spinosad	85	33.0	1.9	1.5	1.2	1.0	0.8	0.7
chlorfluazuron + methomyl	64	24.3	1.1	0.8	0.6	0.5	0.5	0.4
methoxyfenozide	57	20.3	0.8	0.6	0.5	0.4	0.3	0.3
lambda-cyhalothrin + chlorantraniliprole	75	17.5	0.9	0.7	0.5	0.5	0.4	0.3
acephate	86	17.3	1.0	0.8	0.6	0.5	0.4	0.4
Dipel®	60	13.2	0.5	0.4	0.3	0.3	0.2	0.2
Bt Control®	76	13.2	0.7	0.5	0.4	0.3	0.3	0.3
Gemstar®	63	17.3	0.8	0.6	0.5	0.4	0.3	0.3
HzNPV CCAB®	65	15.7	0.7	0.5	0.4	0.4	0.3	0.3

*Mean control efficiency of two experiments (percentage). **Consumption by one *H. armigera* m-2 is 58 kg ha-1 (ROGERS & BRIER, 2010). ***EIL = [(C / VD) * E] (adapted from PEDIGO & RICE 2006); "C": control cost (sum of the values of insecticide and application); "V": soybean value per kilogram; "D": damage (kg) caused by the pest; "E": efficiency of the method/treatment used for control.

benefit cost ratio.

Conclusions

The objectives of this study were supported with efficient alternatives of chemicals and biological insecticides to control *H. armigera* on soybean. Five chemical treatments are efficient to control *H. armigera*, from 3 to 14 DAS chlorantraniliprole, flubendiamide, chlorfenapyr, spinosad, and acephate. The biological treatment Bt Control® is efficient to control small and large larvae. Gemstar® and HzNPV CCAB® are efficient to control small larvae. The treatments, chlorantraniliprole, flubendiamide and acephate provided the highest yield and cost benefit ratio, which are similar to Bt Control®, Gemstar®, and HzNPV CCAB®. The EIL is flexible and range from 2.3 larvae m^{-2} to chlorfenapyr up to 0.2 larvae m^{-2} to Dipel®.

Conflict of Interests

The authors have not declared any conflict of interest.

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Full Length Research Paper

Agribusiness concerns in large scale processing and marketing of melon in Southeastern Nigeria

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The study aimed at determining strategies that could be utilized to reduce the concerns of consumers on the processed agricultural products through technology in order to make technological innovation effective and economically rewarding. Two research questions were developed and answered by the study using cross sectional survey research design. The sample for the study was 317 consisting of 116 registered women melon processors, 102 marketers and 98 extension agents. A 24-item well structured questionnaire was developed and used for data collection. The data collected were analyzed using principal component analysis with varimax rotation and factor loading of 0.40. The results showed that the flavour of melon seeds processed mechanically could be enhanced in Southeastern Nigeria through mechanical, maintenance and hygienic factors while that of neatness of melon seeds processed mechanically could be enhanced through hygiene, biological and handling/distributive factors. It was therefore recommended that Agricultural Extension Agents should utilized the identified skills with their corresponding factor loading in melon processing to make women melon processors improve in their processing methods among others.

Key words: Agribusiness concerns, large scale processing, marketing, melon, Southeastern Nigeria.

INTRODUCTION

Agribusiness is an industry that is engaged in the production operation of a farm, the manufacture and distribution of farm equipments, processing, storage and distribution of farm commodities (Merriam, 2015). Food and Agricultural Organization (2015) described agribusiness as the collective business activities that are performed from farm to fork, which covers all the supply of agricultural inputs, the production and transformation of agricultural produce and their distribution to final consumers. Encyclopedia Britannica (2014), reported that in highly industrialized countries, many activities essential to agriculture are carried on separately from the farm. These include the development and production of equipment, fertilizers and seeds. In some countries the processing, storage, preservation and marketing of products have also been separated from basic farming. Farmers who are into crop production are engaged in the production of crops such as maize, cassava, cereals, melon among others. Some other farmers could process, stored and market these crops such as cassava, melon

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among others into another form before marketing.

Egusi melon (*Colocinthis citrullus)* is one of the leguminous crops planted mainly in southeastern part of Nigeria. Ojiel et al. (2007) explained that egusi melon originated from West Africa and is a member of the Curcubitaceae family. There are two major varieties of melon favored in West Africa. The round brown seeded melon and the oval white seeded melon. Melon is a creepy annual herb with hairy stems, forked tendrils and three lobed hairy leaves. Brande et al. (2012) stated that melon is a good source of amino acids such as arginine, niacin, tryptophan, and metheonine; vitamins such as vitamins B1 and B2; and minerals such as zinc, iron, potassium, phosphorus, sulphur, manganese, calcium, lead chloride and magnesium. The seed of melon also contains 50 and 30% oil and protein respectively (Brande et al., 2012). Melon fruits are collected when ripe and processed to obtain the seeds for sale or use.

Processing of melon is the manual removal of seeds from melon fruit. Enugu State Agricultural Development Programme (ENADPE) indicated that five hundred and eighty women melon farmers still carry out manual processing of melon. Egunjobi and Adebisi (2004) and Jackson et al. (2013) stated that processing of melon seeds involved fermentation and washing to remove the fermented pod husks (depodding). Depodding and fermentation are carried out simultaneously as the pods are left on the field to rot for three to four days, after which the washing stage starts. This is followed by the drying of the seeds using the open air drying system at the ambient temperature of between 30 and 32°C (mean 31°C) and the relative humidity of 65 to 68% (mean 67%).

Based on the expansion on the growing of melon and the constraints from manual processing, mechanical processing, therefore, becomes necessary to sustain the tempo of melon production and guarantee some conservation of energy for the women processors.

The mechanical processing (shelling) of melon is fast and can produce very large amount of melon seeds (cotyledons) for the market. The processing machines are very expensive to buy, operate and maintain. For example it required a trained operator who will be paid high wages and also technician to repair and service the machine regularly and high cost of electric bills and security of the machine. Despite the high cost of mechanical processing, experience reviled that the market demand of mechanically processed melon by consumers was generally low because the consumers prefer manually processed melon to the mechanically processed melon.

A pilot study conducted by the researchers in a local market in the study area on the issue of rejection of the mechanical processed melon by the consumers reviled that: the flavor of the processed melon has a mixture of other elements other than that of the natural flavor of manually processed melon, the surface of the mechanical processed melon seed are usually coarse, rather than being smooth or nylon in appearance like the manually processed melon, some of the seeds are broken, indicating to the consumers that the nutritive values have been degraded, the natural colour of manual processed seeds have been stored for a long time and become filthy and finally the mechanical processed melon emits some odour of the presence of chemicals which consumers will not like to consume, hence consumers go in search for manually processed melon at a higher cost. Shittu and Ndrika (2012) stated that most of the machines developed for shelling melon are efficient but give high rate of seed damage. Based on these observations, women farmers are withdrawing gradually from the production of melon on commercial basis because of the low income received and the high resource input in terms of human and mechanical efforts.

There is always market for manually shelled (processed) Egusi, even if you bring 30 bags to the market, it will be bought. Enough Egusi is seen in the market from June to July and very cheap while from October to December Egusi is scarce and costly. Van der Vossen et al. (2004) equally stated that about 5,000 to 7,000 metric tonnes (MT) Egusi (melon) seed were exchange between Nigeria and countries in the Economic Community of West African States (ECOWAS) and North Africa.

The purpose of the study therefore, was to determine strategies for improving the processing of melon in order to make it demand-driven to consumers with reference to flavor, brightness, reduction of breakage and improvement in the odour from the machine. If these are achieved, processing of melon mechanically by women farmers will become more cost effective with high rate of returns.

MATERIALS AND METHODS

The study adopted cross-sectional survey design. The study was carried out in Southeastern Nigeria, made up of Abia, Anambra Ebony, Enugu and Imo State. South East, Nigeria is naturally endowed with good soil, adequate rainfall, optimal temperature and sunshine for melon production and women in rural areas of this zone are involved in melon production. Therefore, the area is considered very suitable for carrying out the study.

The population for the study was 4850 made up of 580 registered women melon processors, 510 marketers and 490 extension agents. The sample population was 317 consisting of 116 registered women melon processors, 102 marketers and 98 extension agents. Proportionate 20% stratified random sampling technique was used to select the sampling population for the study. Multi-stage sampling technique was used to select two out of five states that make up southeastern Nigeria. Simple random sampling technique was adopted in selecting one agricultural zone in each of the states, thus Enugu and Awka agricultural zones were selected. In each of the zones, simple random sampling technique was employed in selecting 58 registered women melon processors, 51 women marketers and 49 extension agents, respectively.

The instrument used for data collection was twenty-four item structured questionnaire containing skill items generated from

Table 1. Bartlett's test of sphericity and Kaiser-Meyer-Olkin (KMO) test for sampling adequacy of the factor analysis data.

KMO and Bartlett's test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.832
Bartlett's Test of Sphericity	Approx. Chi-Square	128.650
	Df	315
	Sig.	0.000

review of literature and focus group discussion. The questionnaire was divided into two sections based on strategies for improving the flavor and neatness of melon seed processed mechanically. The response scale for the items was based on the four-point rating scale of strongly agree, agree, disagree and strongly disagree with their corresponding values of 4,3,2,1 respectively. The instrument was face-validated by three experts; two from the Department of Food Science and Technology, University of Nigeria, Nsukka and one from women melon processors in Enugu State. The experts were requested to restructure and correct items that were wrongly written and eliminate all those that were irrelevant. Cronbach Alpha method was used to determine the internal consistency of the instrument. The Cronbach Alpha reliability co-efficient (r) of 0.72 was obtained. The instrument was administered by the researcher with the help of three research assistants.

The data collected were analyzed using exploratory factor analysis to identify strategies for improving the processing and marketing of melon in Southeastern Nigeria. To group the identified strategies, principal component analysis with varimax rotation was adopted with factor loading of 0.40. Therefore, factor loading of less than 0.40 or variables that load in more than one factor were discarded. Only variables with factor loadings of 0.40 and above at 10% overlapping variance (Ashley et al., 2006) were used in naming the factor strategies in this study. The naming of each factor is based on the set of variables or characteristics in the component (Kessler, 2006). The principal component factor analysis model for achieving the objective was given as:

$$Y_1 = a_{11}X_1 + a_{12}X_2 + * \ * * + a_{1n}X_n$$
$$Y_2 = a_{21}X_1 + a_{22}X_2 + * \ * * + a_{2n}X_n$$
$$Y_3 = a_{31}X_1 + a_{32}X_2 + * * * + a_{3n}X_n$$
$$* = \qquad *$$
$$* = \qquad *$$
$$Y_n = a_{n1}X_1 + a_{n2}X_2 + * \ * + a_{nn}X_n$$

Where: $Y_1, Y_2 \ldots Y_n$ = observed variables/strategies for improving the processing and marketing of melon.

$a_1 – a_n$ = factor loadings or correlation coefficients.

$X_1, X_2, \ldots X_n$ = unobserved underlying factors strategies for enhancing the processing and marketing of melon.

RESULTS

The results of the study were obtained from the research questions answered and are presented in Tables 1 and 2. The result presented in Table 1 shows the Kaiser-Meyer-Olkin (KMO) and Bartlett's tests for adequacy of the factor analysis data used for the study. From the result, the value of Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.832. This indicated that, the sampling used for the factor analysis was meritoriously adequate. In affirmation Kaiser (1974) reported that KMO values in the 0.90s as marvelous, in the 0.80's as meritorious while in the 0.70's as middling. On the other hand, the Bartlett's test of sphericity tests the hypothesis that the correlation matrix is an identify matrix. Since, the sig. value (0.000) for this analysis was less than 0.05, there were significant relationships between the specified variables and factor analysis is appropriate.

Research question 1

What are the strategies for improving the flavour of melon seed processed mechanically?

Table 2 presents the varimax-rotated principal component factor analysis of strategic factors for enhancing the flavour of melon seed processed mechanically in Southeastern Nigeria. From the result presented in Table 2, each factor was extracted based on the responses of the respondents. Under factor 1 (Mechanical factor), the specific strategy variables that could be employed for enhancing the flavour of melon seed processed mechanically in southeastern Nigeria included: using correct engine oil that would not allow smoke contamination to the melon (0.441), using the engine for one major job only (-0.451) and regulating the speed of the machine when processing to prevent oil or gas leakage (0.676).

Under factor 2 (Maintenance factor), the identified strategies included: washing and drying the machine before use (0.468), servicing the engine regularly to prevent bad odour from the melon (0.575) and marketing processed melon in a clean environment (0.684) while the specific strategy variables for enhancing the flavor of melon seeds processed mechanically under factor 3 (hygienic factor) included: using clean material for collecting the seed shell (0.435), winnowing under normal atmospheric condition and packaging in air-tight containers (0.766), containers for packaging should be free of any unfavorable flavor (0.541) and storing processed melon in a normal room temperature (0.589).

Research question 2

What are the strategies for improving the neatness of the

Table 2. Varimax Rotated Factors/Strategies for Enhancing the Flavour of Melon Seed Processed Mechanically in the South East, Nigeria.

S/N	Observed strategies / Variables	Factor 1: Mechanical factor	Factor 2: Maintenance factor	Factor 3: Hygienic factor
1	Wash and dry the machine before use	0.385	**0.468**	0.228
2	Leave the machine to dry after washing or clean the machine thoroughly	0.227	0.120	0.107
3	Use correct engine oil that will not allow smoke contamination to the melon	**0.441**	0.355	0.283
4	Service the engine regularly to prevent bad odour from the melon	0.283	**0.575**	0.253
5	Use the engine for one major job only	**-0.451**	0.269	0.230
6	Sun-dry the melon seed properly to avoid the growth of mold	0.365	0.215	0.050
7	Use clean material for collecting the shell seed	-0.368	0.225	**0.435**
8	Regulate the speed of the machine when processing to prevent oil or gas leakage	**0.676**	0.215	0.250
9	Winnow under normal atmosphere condition and package in air-tight containers	0.257	-0.051	**0.766**
10	Containers for packaging should be free of any unfavorable flavor	0.224	0.206	**0.541**
11	Package in an air tight containers correctly label	0.053	0.252	0.104
12	Store processed melon in a normal room temperature	0.175	0.266	**0.589**
13	Market processed melon in a clean environment	0.183	**0.684**	0.399

Factor loading of **0.40** was used at 10% overlapping variance. Variables with factor loadings of less than **0.40** were not used.

What are the strategies for improving the neatness of the melon seed processed (shelled) mechanically?

The data presented in Table 3 shows that the strategies for improving the neatness of melon seeds processed mechanically in Southeastern Nigeria. They were grouped into three factors: Factor 1 (Hygienic factor); Factor 2 (Biological factor) and Factor 3 (Handling/distributive factor).

Under factor 1 (Hygienic factor), the specific strategy variables that could be employed for enhancing the neatness of melon seeds processed mechanically in southeastern Nigeria included: processing only ripe pod of melon (0.750), washing melon seeds thoroughly with clean water (0.522), keeping the grinding machine clean to avoid impurities in the processed melon (-0.472) and observing personal hygiene such as wearing apron, covering head and washing hands before processing (0.522).

The identified strategies under factor 2 (Biological factor) included: keeping to the normal fermentation period to prevent over fermentation to avoid germination (0.530), testing for moisture content before processing (0.429) and shelling melon appropriately with the correct machine (0.497) while the specific strategy variables for enhancing the neatness of melon seed processed mechanically under factor 3 (Handling/distributive factor) included: keeping to the washing period to avoid melon seeds soaking water (0.567), winnowing immediately and packaging in an air-tight container for sale (0.423) and market-processed melon in a clean environment (0.660).

DISCUSSION

The findings of this study on the strategic factors for enhancing the flavor of melon seeds processed mechanically agreed with the findings of Weimer (2007) on improving the flavour of cheese where the author found that mechanical, physical and chemical factors significantly influenced the processing of cheese flavour. In addition, the study also found that milk, salt and other ingredients had positive effects on flavour of processed cheese.

The findings of this study also corroborated with that of FAO (2009) on meat and meat products in human nutrition in developing countries. The findings of the study showed that mechanical refrigeration and hygiene practices were important in processing and improving the flavor of processed meat products. Chilled" meat is hygienic and usually stored at temperatures around 1 to +4°C when it keeps well. Oscar and Parker (2007) claimed that meat could keep for 10 weeks if slaughtered/cut under strict hygienic conditions, packaged using modern packaging techniques and stored in cool (1 to 0°C) environment under carbon dioxide or nitrogen or in a vacuum. The findings of this study on the factors for enhancing the neatness of processed melon supported that of Mahmud (2004) on socioeconomic factors influencing meat value chain in Kano State where the author found that hygiene, neatness and distributive approach were determinants of acceptability of meat products.

Table 3. Varimax Rotated Factors/Strategies for Improving the Neatness of Melon Seed Processed Mechanically in Southeastern Nigeria.

S/N	Observed strategies / Variables	Factor 1: Hygiene factor	Factor 2: Biological factor	Factor 3: Handling/distributive factor
1	Processed only ripe pod of melon	**0.750**	0.290	0.206
2	Keep to the normal fermentation period to prevent over fermentation to avoid germination.	0.398	**0.530**	0.291
3	Keep to the washing period to avoid melon seed soaking water	0.367	0.192	**0.567**
4	Wash melon seeds thoroughly with clean water	**0.522**	0.334	0.302
5	Sun-dry melon under normal atmospheric condition	0.370	0.373	-0.283
6	Test for moisture content before processing	0.225	**0.429**	0.186
7	Remove stones and dirty before sending for shelling	0.228	-0.361	0.103
8	Shell melon appropriately with the correct machine	0.140	**0.497**	0.253
9	Keep the grinding machine clean to avoid impurities in the processed melon	**-0.472**	0.369	-0.219
10	Winnow immediately and package in an air tight container for sale	0.118	0.232	**0.423**
11	Wash and sun-dry processing equipment and tools before and after processing melon	0.204	0.081	0.230
12	Observe personal hygiene such as wearing apron, covering head and washing hands before processing	**0.522**	0.237	0.176
13	Market processed melon in a clean environment	0.335	0.111	**0.660**

Factor loading of **0.40** was used at 10% overlapping variance. Variables with factor loadings of less than **0.40** were not used.

Conclusion

In Southeastern Nigeria, the concerns about the use of technology were real. Processed (shelled) melon seeds had poor flavour and the neatness was not guaranteed. Seed moisture content was found to be the main predictor of shelling efficiency while speed uniquely predicts percentage seed damage. Based on the findings of this study, the following recommendations were therefore made:

1). Agricultural extension agents should utilized the identified skills with their corresponding factor loading in melon processing to make women melon processors improve in their processing of melon.
2). The Government through Agricultural Development Programme (ADP) should utilize the findings of this study to organize awareness training programme to all the farmers to enable them improve their processing and marketing strategies of melon seeds.
3). Appropriate machine should be redesigned for the women for more efficiency of processing.

SUGGESTION FOR FURTHER RESEARCH

1). Further research could be replicated in other geopolitical zones in Nigeria.
2). Proficiency improvement needs of Women farmers for effective mechanical processing of melon South Eastern Nigeria.
3). Finding out the training skills required by trainers for helping women farmers to manage their resources in melon production effectively.

Conflict of interests

The authors have not declared any conflict of interests.

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Effect of seasonality on abundance of African weaver ant Oecophyllalonginoda (Hymenoptera: Formicidae) in cashew agro-ecosystems in Tanzania

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The effect of seasonality on abundance of the African weaver ant (AWA) was determined in the cashew fields at Bagamoyo and Kibaha districts, Coast Region of Tanzania. Twenty cashew trees colonized by AWA were randomly selected per site and its abundance was monitored during cashew on-seasons and off-seasons in 2011 and 2012. Results showed that abundance of AWA, which was expressed as mean numbers of leaf nests per tree and colonization of trails on main branches, varied significantly between cashew on-seasons and off-seasons. The mean numbers of leaf nests per tree during cashew on-season and off-season varied between 8.3 and 5.0 and between 7.5 and 4.8 at Bagamoyo and Kibaha, respectively, in 2011. Similarly, in 2012 it varied between 9.5 and 5.6 and between 8.6 and 5.3 at Bagamoyo and Kibaha, respectively. The mean percentage AWA colonization of trails during cashew on-seasons and off-seasons varied between 72.5 and 54.2% and between 73.3 and 50.9% in 2011and 2012; it also varied between 74.3 and 57.0% and between 72.6 and 54.9% at Bagamoyo and Kibaha, respectively. The abundance of AWA in the two parameters studied varies significantly between the two seasons. This suggests the use of conservation strategies during the off-seasons to supplement diets of AWA.

Key words: Colonization, *Oecophyllalonginoda*, off-season, on-season, trail.

INTRODUCTION

Ants are more abundant and ubiquitous nearly in all types of terrestrial habitats, especially in the tropics (Kaspari, 2000; Fisher, 2010). They are considered as useful tools for biodiversity evaluation, monitoring purposes, quick response to environmental changes and relative ease of sampling (Kaspari and Majer, 2000; Bestelmeyer et al., 2000; Underwood and Fisher, 2006). Ants also play key roles in ecological processes namely nutrient cycling, energy turnover, pollination, seed dispersal and regulating populations of other insects (Hölldobler and Wilson, 1990; Andersen and Majer, 1991; Gomezi and Zamora, 1992). Ants are used as indicators of exposure to environmental stressors (Whitford, 1999; Wang et al., 2000), whereby their distributions are determined by rainfall patterns and seasonal temperatures (Lindsey and Skinner, 2001; El Keroumi et al. 2012). For example, higher abundance and richness values of ants were recorded during the dry season in the Moroccan Argan

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Forest (El Keroumi et al., 2012). On the other hand, in the semi-arid Karoo of South Africa, ant abundance and diversity were higher during summer than in winter (Lindsey and Skinner, 2001). The effect of seasons was also reported at species level, the common pugnacious ant (CPA), *Anoplolepis custodiens* Smith (Hymenoptera: Formicidae) was the most abundant species during summer, while *Monomorium albopilosum* Emery (Hymenoptera: Formicidae) was the most abundant species during winter (Lindsey and Skinner, 2001). Apparently, increase of primary productivity is the most important factor, which determines the abundance of ant species at a given area, followed by the temperature and seasonality (Kaspari et al., 2000).

Arboreal ants are partially herbivorous and they consume nectaries and hemipteran honeydew (Davidson et al., 2003; Blüthgen et al., 2004). More importantly, arboreal ant species of the genus *Oecophylla* are efficient in controlling insect pests (Hölldobler and Wilson, 1990). Members are commonly known also as the weaver ants, which consist of two species, the African weaver ant (AWA), *O. Longinoda* and the green tree ant, *O. smaragdina*. The distribution of these species depends on the vegetation, physical factors such as temperature and rainfall (directly or indirectly) and the abundance of competitor ant species namely *Pheidole megacephala* Fabricius and *Anoplolepis custodiens* Smith (Hymenoptera: Formicidae) (Lokkers, 1986). The AWA is widely distributed in Sub-Saharan Africa (SSA), particularly in the equatorial tropical forests (Hölldobler and Wilson, 1990; Van Mele and Cuc, 2007). In East Africa, the AWA is most abundant in the coastal forests of Kenya and Tanzania. More than 80 species of shrubs, cultivated and wild trees are used by AWA as host plants (Varela, 1992). The AWA plays an essential role in regulating populations of sap-sucking pests in East Africa (Seguni, 1997; Olotu et al., 2012) and West Africa (Van Mele et al., 2007; Dwomoh et al., 2009). In Tanzania, AWA colonies are widely distributed in coconut orchards (Varela, 1992; Seguni, 1997) and cashew orchards in Tanzania (Stathers unpublished; Olotu et al., 2012). It forms large polydomous colonies consisting of many leaf nests in the crowns of a wide range of host plant species (Varela, 1992). These host plants supply nectaries that supplement their diets (Way and Khoo, 1991; Blüthgen and Fiedler, 2002). Preliminary information showed that the abundance of AWA in cashew agro-ecosystem rely on availability of food resources mainly honeydew and the sap-sucking pests, which reaches their peak at the onset of cashew flowering periods (Stathers unpublished; Olotu et al., 2012).

Despite the importance of AWA in the control of sap-sucking insects, there is little information on the effect of seasonality on abundance of AWA in cashew agro-ecosystem in Tanzania. The present study therefore investigated the abundance of AWA with respect to cashew seasons (cashew on-seasons and off-seasons) in order to design conservation strategies for this useful natural enemy.

MATERIALS AND METHODS

Experimental sites

Experiments were conducted in cashew fields from January to December in 2011 and 2012 at Bagamoyo (S 06° 49.3', E 38° 54.8', 53.43 m.a.s.l) and Kibaha (S 06° 33.4', E 38° 54.7', 150.57 m.a.s.l), Coast region of Tanzania. The mean temperature recorded at Bagamoyo and Kibaha during cashew off-seasons and on-seasons ranged between 30.1-31.2 and 31.4-32.2˚C and that of rainfall ranged between 600-800 and 100-600 mm in 2011 and 2012. The cashew seasons are categorized as the cashew off-season and on-season. The former was considered as the inactive reproductive phase or period of non-flowering, nut set and fruiting, which usually occurs between January and June. The later was considered as the active cashew reproductive phase which is marked by new flushes of shoots and mass flowering followed by fruit and nut development, this reproductive phase usually occurs between July and December.

Quantification of AWA abundance

Abundance of arboreal ants is usually estimated indirectly by counting leaf nests per treeand ant trails on main branches (Peng and Christian, 2006) or counts of ants on selected plant parts (Blüthgen et al., 2004). Direct methods to count the ants are always disruptive to nest inhabitants, for example the partial opening of nests for enumerative purposes (Peng et al., 1998). AWA abundance can be considered as the total number of AWA leaf nests per trees and mean percentage of AWA trails on the main branches (AWA colonization). Twenty cashew trees were selected randomly per site. AWA abundance on each tree was quantified as follows: (i) all the leaf nests were carefully counted with the aid of binoculars, and (ii) the total number of main branches with AWA trails was recorded. More than ten AWA walking along a main branch was recorded as one AWA trail. Between one and ten AWA along the main branch was recorded as 0.5 AWA trail (Peng and Christian, 2006). The individual percentage of AWA trails on main branches was calculated as (i), the mean percentage of AWA trails on occupied trees in the field was calculated as (ii) and the average number of nests per AWA occupied tree was calculated as (iii).

(i) Number of main branches with a weaver ant trail in a tree)/(Number of main branches in the tree) x 100
(ii) Mean AWA trail colonization based on trails per tree was calculated asthe average of AWA colonization per field
(iii) Mean number of nests on AWA occupied trees per field was calculated as the sum of all nests counted/20 trees

AWA on a tree was treated as 'abundant' when more than 50% of the main branches had AWA trails, or as 'fewer' when less than 50% of the main branches had AWA trails. Twenty cashew trees with abundant AWA were randomly selected per site. Quantification of AWA abundance (that is, leaf nests and trails) was done monthly for two consecutive years.

Data analysis

Count and proportion data were transformed to Log (n+1) before being subjected to statistical analysis. Total number of AWA leaf nests during cashew on- and off seasons was analysed by means

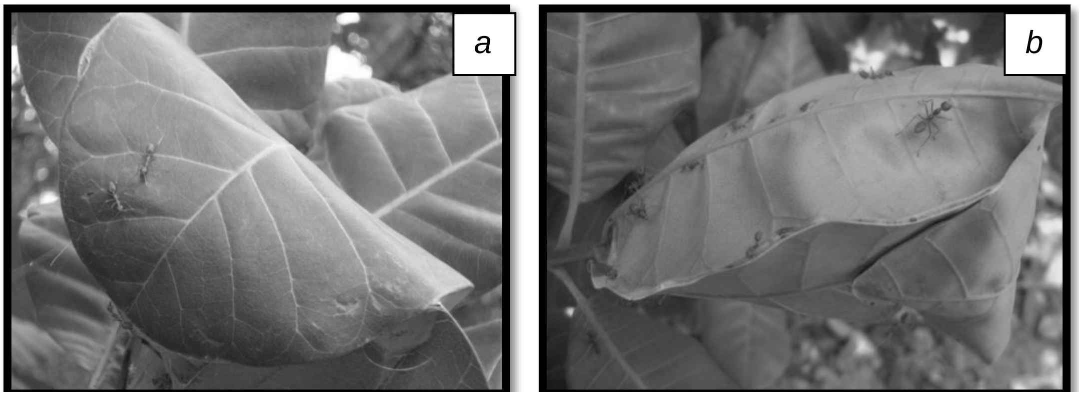

Figure 1. Leaf nests of AWA: (a) a nest consisting of a single cashew leaf and (b) a nest consisting of multiple cashew leaves.

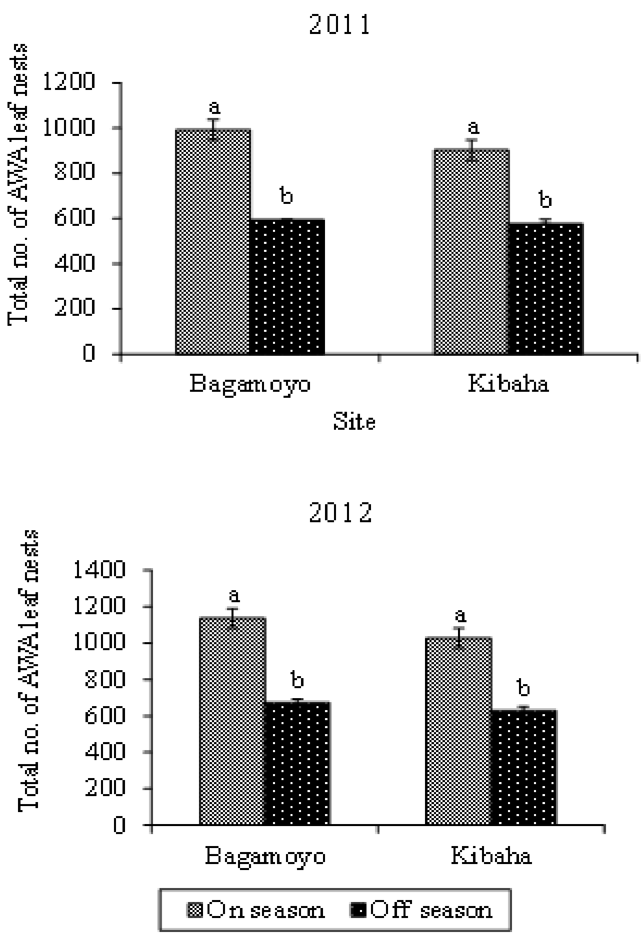

Figure 2. Total numbers of AWA leaf nests in cashew fields at Bagamoyo and Kibaha during the 2011 and 2012 seasons. Paired means indicated by different letters differed significantly at P < 0.05. Bars indicate SE.

of the Behrens-Fisher t-test. Analysis of variance (ANOVA) was used to compare the mean difference between treatments, day and time and their interactions using STATISTICA version 11 (Stasoft, Inc., Tulsa, Oklahoma, USA). Bonferroni correction was used to adjust for multi means comparisons. The Bonferroni correction has been frequently considered as the most common way to control the family-wise error rate (McDonald, 2009).

RESULTS

AWA leaf nests

The nest of AWA is illustrated in Figure 1; it is constructed by gluing a single cashew leaf or multiple leaves with larval silk. Numbers of AWA leaf nests per tree in the cashew fields at Bagamoyo and Kibaha varied significantly at P < 0.05 between cashew on-seasons and off-seasons. At both sites more AWA leaf nests were recorded during cashew on-season than during off-season in both 2011 and 2012 (Figure 2). For example in 2011, 933 and 903 leaf nests were recorded during cashew on-seasons as compared to 593 and 577 leaf nests during off-seasons at Bagamoyo and Kibaha, respectively (Figure 2). The mean numbers of AWA leaf nests per tree varied according to month of the year at both sites: Bagamoyo ($F_{(11,228)}$ = 12.74; P < 0.001) and ($F_{(11,228)}$ = 26.25; P < 0.001) during 2011 and 2012, respectively; Kibaha ($F_{(11,228)}$= 23.66; P < 0.001) and ($F_{(11,228)}$ = 35.71;P < 0.001) in 2011 and 2012, respectively (Figures 3 and 4).

AWA trails colonization

Similar to AWA leaf nests, AWA trails colonization was higher during cashew on-seasons than during off-seasons in the two cashew fields at Bagamoyo and Kibaha during 2011 and 2012 monitoring periods (Figures 5 and 6). For example in 2011, 72.5 and 73.3% trail colonization levels were recorded during cashew on-seasons as compared to 54.2 and 50.9% during off-

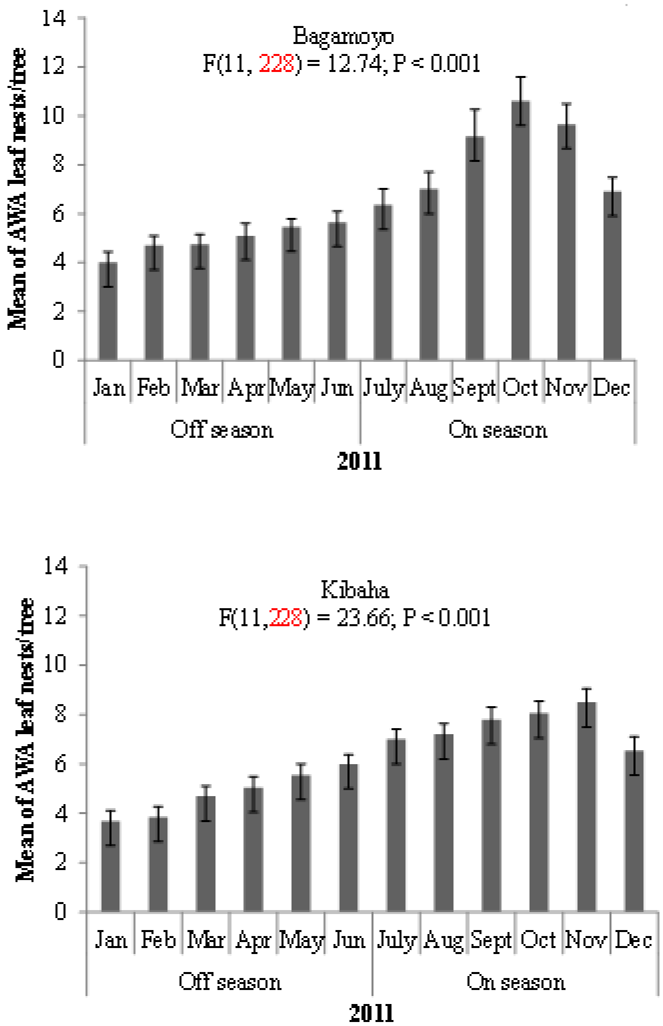

Figure 3. Mean numbers of AWA leaf nests in cashew fields at Bagamoyo and Kibaha during the 2011season. Bars indicate SE.

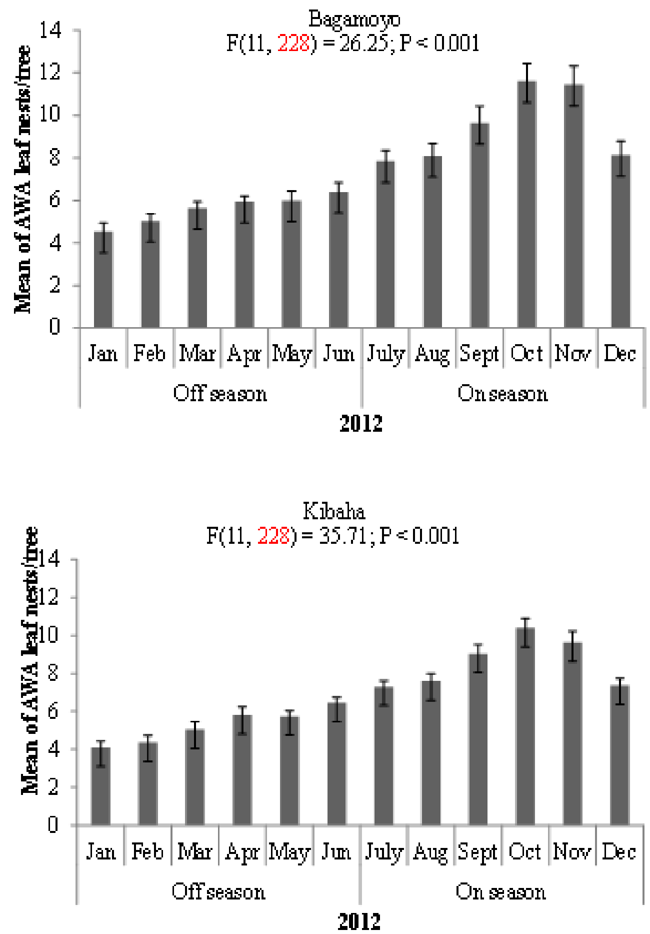

Figure 4. Mean numbers of AWA leaf nests in cashew fields at Bagamoyo and Kibaha during the 2012 season. Bars indicate SE.

seasons at Bagamoyo and Kibaha, respectively (Figure 5). The AWA trails colonization also varied according to season, with higher mean percentage during cashew on-seasons in both sites: Bagamoyo ($F_{(11,228)} = 11.76$; $P < 0.001$ and $F_{(11,228)} = 18.90$; $P < 0.001$) during 2011 and 2012 respectively; Kibaha ($F_{(11,228)} = 24.02$; $P < 0.001$ and $F_{(11,228)} = 20.45$; $P < 0.001$) in 2011 and 2012, respectively (Figures 5 and 6).

DISCUSSION

The abundance of AWA, expressed total number of AWA leaf nests per tree and their trails on the main branches, was high during cashew on-seasons than during off-seasons in the two sites and both years (2011 and 2012). This was probably due to cashew flowering, which occurs during the dry season of the year (Wait and Jamieson, 1986). The cashew reproductive season in the studied sites was also reported to prevail between August and December (Olotu et al., 2012). This could be due to fluctuations in food resource availability between cashew on-seasons and off-seasons. For example, nectar which is considered as an important source of food to arboreal ants is only available during new shoot flushing and flowering periods (Gottlieb et al., 2005; Stone et al., 1999).

Besides this, during the mass flowering, cashew trees provide nectaries for other purposes such as pollination attraction. However, these nectaries have also been reported to attract other insect fauna such as homopteran insects, *Coccus hesperidum* Linnaeus (Homoptera: Coccidae) and *Hilda patruelis* Stål (Homoptera: Tettigometridae) (Stathers unpublished). As a result, AWA also tended the homopteran insects for honeydew in cashew crops (Dwomoh et al., 2009; Olotu et al., 2012).

High abundance of AWA during cashew on-seasons could also be attributed to the occurrence of sap-sucking pests, *Helopeltis anacardii* Miller, and *H. schoutedeni* Reuter (Hemiptera: Miridae), and *Pseudotheraptus wayi*

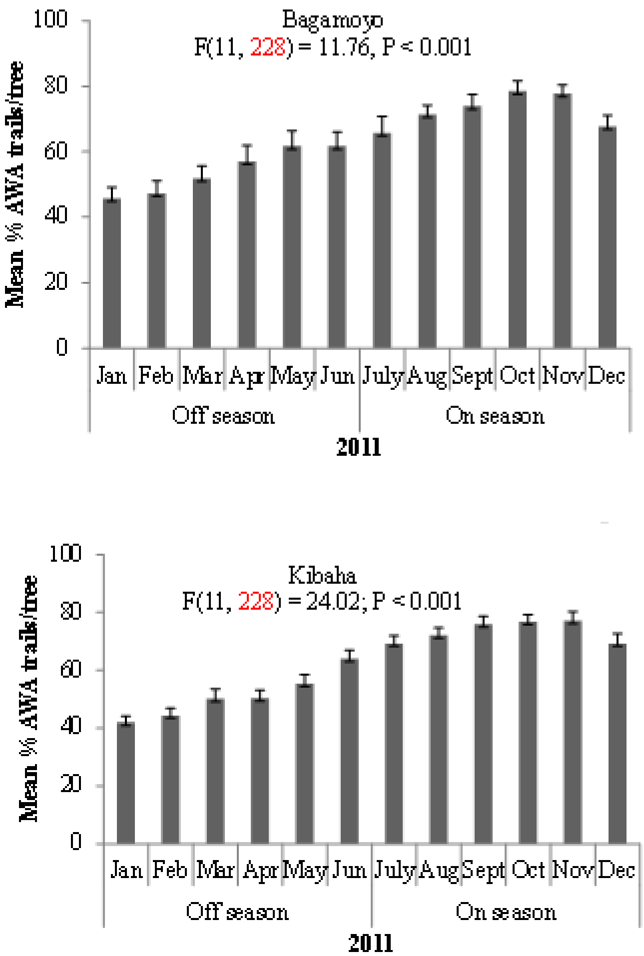

Figure 5. Percentage AWA trails colonization per 20 occupied trees in cashew fields at Bagamoyo and Kibaha during the 2011 season. Bars indicate SE.

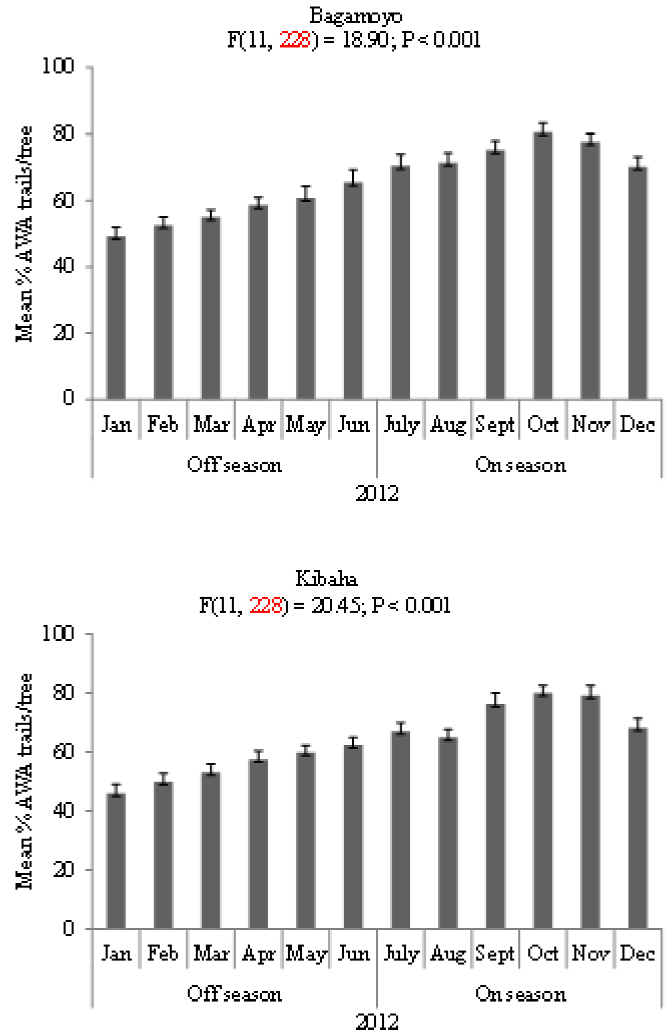

Figure 6. Percentage AWA trails colonization per 20 occupied trees in cashew fields at Bagamoyo and Kibaha during the 2012 season. Bars indicate SE.

Brown (Hemiptera: Coreidae) during on-seasons. A similar observation was reported in coconut orchards, where an increase in *Helopeltis* spp. and *P. wayi* populations coincides with the main growing period of the crop, which begins shortly after the end of the rainy season in July or August, resulting in high abundances of AWA (Seguni, 1997). AWA abundance could also be associated with more nest building activities for establishment of colonies. Apart from nest building, the major workers are also responsible for foraging and defending the colony (Varela, 1992). This could be associated to their higher abundance during the cashew on-seasons to meet the demand for expansion of the colonies.

In conclusion, the abundance of AWA varies significantly between cashew on-seasons and off-seasons at the different sites of the Coast region of Tanzania. High numbers of AWA leaf nests per tree and high AWA trail colonization were recorded during cashew on-seasons compared to off-seasons. Therefore, conservation of AWA during cashew off-seasons is needed for high AWA abundance throughout the year. Provision of diet supplement especially by the use of fish-based bait and suppression of inimical and competitor ant species such as *P. megacephala* by sprinkling the granules of hydramethylon bait around the bases of the cashew trees are recommended for strengthening AWA colonies during cashew off-seasons. The use of fish based bait has been reported to be effective in supplementing their diets during seasons when food is scarce (Van Mele and Cuc, 2007). The suppression of the inimical ant using Hydramethylon ant bait (Amdro®) has been successfully used to control *P. megacephala* in coconut (Zerhusen and Rashid, 1992; Seguni, 1997).

Conflict of Interests

The authors have not declared any conflict of interests.

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Productivity of transplanted rice as influenced by weed control methods

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Rigorous research efforts are being made by scientists around the world to evolve different strategies for improving rice yield. Most of the improved crop management practices in rice cultivation failed due to poor and improper practices for containing weeds. At present, no single approach, that is, uses of herbicides or manual or mechanical weeding is effective in containing the weed menace. Hence, the present investigation was aimed to study the influence of integrated weed control (chemical + hand weeding) on the productivity of transplanted rice. Ten weed control treatments like application of herbicides alone and their integration with one-hand weeding, two-hand weeding and unweeded check were tested in randomised block design with three replications. The highest weed control efficiency (90 and 93%) and maximum grain yield (5831 and 8783 kg ha^{-1}) were recorded under two-hand weeding during both years respectively which was at par with post emergence application of bispyribac sodium 25 g ai ha^{-1} supplemented with hand weeding at 45 DAT. Uncontrolled weed growth reduced grain yield to the tune of 47.02 and 53.79% during 2011 to 2012 and 2012 to 2013, respectively.

Key words: Transplanted rice, integrated weed control, herbicides, hand weeding, weed control efficiency, yield.

INTRODUCTION

Rice (*Oryza sativa* L.) is a staple food for more than 60% of the world population. It is the most important cereal crop and is extensively grown in tropical and subtropical regions of the world. Rigorous efforts are being made under several research programmes by scientists around the world to evolve different strategies for improving rice yield. Most of the improved crop management practices in rice cultivation failed due to poor and improper practices for containing weeds.

In India, rice is cultivated in an area of 44.07 million hectares annually with a production of 103.4 million tonnes, with an average productivity of 2.3 t ha^{-1} (FAO, 2012). There are several reasons for low productivity and the one due to weeds is the most important. Weeds compete with rice for moisture, nutrients, light, temperature and space. Uncontrolled weeds have caused yield reduction of 28 to 45% in transplanted rice (Singh et al., 2007; Manhas et al., 2012). Furthermore, any delay in weeding will lead to increased weed biomass which has a negative correlation with yield.

Butachlor, anilofos, oxadiargyl and pretilachlor are herbicides presently used for weed control in transplanted rice. These herbicides provide effective control of annual grasses, but not annual sedges and broad leaved weeds.

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For example, it has been reported that whenever there is effective control of grasses due to these herbicides, annual sedges and broad leaved weeds emerge in high density competing with crop and resulting into heavy yield losses (Singh et al., 2004). At present, no single approach of either use of herbicides or manual/mechanical weeding is effective in containing weed menace. Therefore, there is a necessity that these herbicides are supplemented with hand weeding to widen weed control spectrum. Hence, the present investigation was to study the influence of integrated weed management package on weed control efficiency and productivity of transplanted rice.

MATERIALS AND METHODS

Field experiment was conducted at Tamil Nadu Rice Research Institute, Aduthurai (11° N latitude, 79° E longitude and at an altitude of 19.5 m above mean sea level) in Cauvery Delta Zone of Tamil Nadu during wet seasons of 2011 to 2012 and 2012 to 2013 to study the effect of integrated weed management packages on weed control, growth and yield of transplanted rice. The soil of the experimental field was clay with slightly alkaline pH (8.2), medium in organic carbon (0.52%), low total nitrogen (161 kg ha^{-1}), high available phosphorus (54.5 kg ha^{-1}) and medium available potassium (206 kg ha^{-1}). The experiment was laid out in randomised block design with three replications. Treatments consisted of application of pre mergence (PE) herbicides viz., clomazone 500 g ai ha^{-1}, clomazone + 2, 4-DEE (ready mix) 500 g ai ha^{-1} alone and their integration with one-hand weeding (HW) at 45 DAT; butachlor 1250 g ai ha^{-1} + HW at 45 DAT; pretilachlor 750 g ai ha^{-1} + HW on 45 DAT; post emergence (POE) herbicide bispribac sodium 25 g ai ha^{-1} + HW at 45 DAT and pre plant incorporation of glyphosate at 15 days before transplanting followed by PE application of bensulfuron methyl plus pretilachlor 660 g ai ha^{-1} tested with two–HW at 25 and 45 DAT and unweeded control for weed control efficiency and productivity of transplanted rice. Hand weedings were carried out as per the treatment schedule.

Long duration (155 days) high yielding paddy variety CR 1009 was transplanted two seedlings per hill 7 and 17 September, 2011 and 2012, respectively with a spacing at 20 × 15 cm. The crop was fertilized with recommended dose of 150: 50: 50 kg N,P_2O_5,K_2O ha^{-1}. The entire dose of phosphorus was applied as basal in addition to zinc sulphate 25 kg ha^{-1} and gypsum 500 kg ha^{-1} while nitrogen and potassium were applied in four equal splits at basal, active tillering (4 Weeks After Transplanting-WAT), panicle initiation (8 WAT) and heading stages (12 WAT). Pre emergence herbicides were mixed with sand at 50 kg/ha and applied uniformly to the field on 3 DAT. The post emergence herbicide was sprayed at 2 to 3 leaf stage of weeds (15 DAT) by using knapsack sprayer fitted with flat fan nozzle. A thin film of water was maintained at the time of herbicide application. All other agronomic and plant protection measures were adopted as per the standard recommendations.

Weed species present in the experimental plot were identified at flowering stage of crop from weedy check plot and grouped as grasses, sedges and broad leaved weeds. The data on weed density and weed dry weight (60 DAT) were recorded with the help of a quadrate (0.25 m^2) at four places randomly chosen and then expressed in number per square metre and kilogram per hectare. The weed control efficiency was worked out on the basis of weed dry matter recorded in each treatment at 30, 60 DAS/DAT and at harvest by using the formula suggested by Mani et al. (1973).

$$\text{WCE (\%)} = \frac{\text{Total weed dry weight in unweeded control (kg ha}^{-1}) - \text{Total weed dry weight in treated plot (kg ha}^{-1})}{\text{Total weed dry weight in unweeded control (kg ha}^{-1})} \times 100$$

Values were subjected to square root transformation (√x+0.5) prior to statistical analysis to normalize their distribution. Observations on yield attributes like panicles per meter square (m^2), grains per panicle, 1000 grain weight and grain yield of paddy were recorded at harvest.

The data recorded were analysed statistically in Randomized Block Design (RBD) as per the method suggested by Gomez and Gomez (1984). Wherever the treatment means were significant, critical differences were calculated at 5% probability level for comparisons of mean values. Non significant differences among treatment means were denoted as NS.

RESULTS AND DISCUSSION

Weed growth

The dominant weed flora of experimental fields consisted of *Echinochloa crusgalli*, *Echinochloa colonum* and *Leptochloa chinensis* among grasses, *Cyperus difformis*, *Cyperus iria* and Fimbristylis miliacea among sedges and *Marselia quadrifolia*, *Eclipta alba*, *Ammania baccifera*, *Bergia capensis* and *Ludwigia parviflora* among broad leaved weeds.

Effect on weeds

All the weed control treatments significantly reduced total density and dry weight of weeds during both years (Table 1). The lowest density (5.67 and 4.33 No./m^2) and dry weight (2.04 and 1.47 g/m^2) of weeds were recorded under two-hand weeding on 25 and 45 DAT followed by post emergence application of bispyribac sodium 25 g ai ha^{-1} supplemented with HW at 45 DAT during both years. The reduced density and dry weight of weeds might be attributed to broad spectrum and season long weed control by the application of post-emergence herbicides followed by HW as observed in the plots in which two-hand weeding were given. These results are in line with findings of Singh et al. (2012) who reported that density and dry weight of weeds were greatly reduced under two-hand weeding in transplanted rice. The highest weed density and dry matter was recorded with unweeded check during both years. It means that if weeds were not controlled properly within critical period of crop weed competition, their density continuously remained increasing and crop growth badly affected. The highest weed control efficiency (90 and 93%) was observed under two-hand weeding in both years (Table 1) which was at par with post emergence application of bispyribac sodium 25 g ai/ha supplemented with HW at 45 DAT (87 and 92%) during both years. Yadav et al. (2009) and Upendra Rao et al. (2009) also reported that results of post emergence herbicide bispyribac sodium were found comparable with two-hand weeding. No significant differences were observed on weed control efficiency among pre emergence application of pretilachlor, butachlor and clomazone + 2,4-DEE ready mix followed by one-hand weeding at 45 DAT and pre plant post emergence application of glyphosate 2.5 L/ha at 15 days before

Table 1. Influence of weed management practices on weed density, weed dry weight, and weed control efficiency (WCE) (60 DAT) in transplanted rice.

Treatment	2011 to 2012			2012 to 2013		
	Weed density (No./m²)	Weed dry weight (g/m²)	WCE (%)	Weed density (No./m²)	Weed dry weight (g/m²)	WCE (%)
Clomazone 500 g ai/ha	7.65(58.00)	3.28(10.29)	51.68	7.56(56.67)	3.24(9.99)	53.03
Clomazone + 2, 4 DEE 500 g ai/ha	6.89(47.00)	3.16(9.50)	55.39	6.62(43.33)	3.04(8.74)	58.91
Clomazone 500 g ai/ha + HW 45 DAT	3.54(12.00)	2.53(5.92)	72.22	3.34(10.67)	2.29(4.73)	77.74
Clomazone + 2, 4 DEE 500 g ai/ha + HW 45 DAT	3.39(11.00)	2.39(5.20)	75.58	2.80(7.33)	2.22(4.47)	78.99
Butachlor 250 g ai/ha + HW 45 DAT	2.92(8.00)	2.27(4.67)	78.09	2.74(7.00)	2.18(4.37)	79.46
Pretilachlor 500 g ai/ha + HW 45 DAT	2.80(7.33)	2.29(4.77)	77.62	2.80(7.33)	2.22(4.50)	78.84
Bispyribac Sodium 25 g ai/ha + HW 45 DAT	2.55(6.00)	1.82(2.83)	86.70	2.27(4.67)	1.45(1.62)	92.40
PPI Glyphosate 2.5 L/ha. 15 DBT + Bensulfuron methyl + Pretilachlor 660 g ai/ha	2.92(8.00)	2.31(4.85)	77.21	2.86(7.67)	2.25(4.56)	78.57
Two HW at 25 and 45 DAT	2.48(5.67)	1.57(2.04)	90.41	2.20(4.33)	1.40(1.47)	93.10
Unweeded control	10.06(100.67)	4.67(21.30)	0.00	10.01(99.67)	4.65(21.26)	0.00
SEd	0.21	0.12	-	0.20	0.20	-
CD (P = 0.05)	0.44	0.26	NA	0.42	0.42	NA

Figures in parentheses are original values, which were subjected to square root transformation (√x + 0.5) before statistical analysis, NA - Not Analysed, DBT - Days Before Transplanting, DAT - Days After Transplanting and HW – hand Weeding.

transplanting followed by post plant pre emergence application of bensulfuron methyl + pretilachlor 660 g ai/ha at 3 DAT. These results are in conformity with the findings of Ramachandra et al. (2010).

Yield and yield attributes of rice

From the research findings, it was found clearly that yield attributes like panicles per square metre, grains per panicle and grain yield of transplanted rice were significantly influenced by weed control treatments in both years (Table 2). Maximum number of panicles (319 and 362 m^{-2}) was recorded in two-hand weeding at 25 and 45 DAT followed by post emergence application of bispyribac sodium 25 g ai ha^{-1} supplemented with HW at 45 DAT (315 and 355 m^{-2}) and unweeded check recorded minimum number of panicles (222 and 263 m^{-2}) during both years. Increase in panicles per meter square, grains per panicle might be due to better environment with increased uptake of both macro and micro nutrients and ultimate development of large sink created out of reduced crop weed competition.

The highest grain yield (5831 and 8783 kg ha^{-1}) were recorded in two-hand weeding over application of herbicides alone, herbicides followed by one-hand weeding and unweeded check during both years of study. Similar results have been reported by Deepthi Kiran and Subramanyam (2010). Superiority of two-hand weeding could be attributed to reduced competition by weeds due to frequent elimination of weeds from the field and hence better crop growth.

Weeds in weedy plot caused 47.02 and 53.79% reduction in grain yield of paddy as compared to two-hand weeding. This reduction in yield was mainly due to high density of weeds (100.67 and 99.67 m^{-2}) in both years. Grain yield (5613 and 8653 kg/ha) recorded under post emergence application of bispyribac sodium 25 g ai ha^{-1} followed by HW at 45 DAT was comparable with that of two-hand weeding. Higher grain yield under these treatments might be due to increased panicles/m^2 and grains/panicle. Similar findings were also obtained by Veeraputhiran and Balasubramanian (2010) and Nalini et al. (2012). Grain yield under pre plant application of glyphosate at 15 days before transplanting followed by post plant application of bensulfuron methyl + pretilachlor at 3 DAT were comparable with application of butachlor, pretilachlor, clomazone + 2,4-DEE followed by HW at 45 DAT. These results are in agreement with the findings of AICRIP (2011) and Kishor Jalindar et al. (2012). This might be attributed to better growth of

Table 2. Influence of weed management practices on yield and yield attributes of transplanted rice.

Treatment	2011 to 2012			2012 to 2013		
	Panicles/m^2	Grains/panicle	Grain yield (kg/ha)	Panicles/m^2	Grains/panicle	Grain yield (kg/ha)
Clomazone 500 g ai/ha	238	115	4141	286	117	6162
Clomazone + 2, 4 DEE 500 g ai/ha	249	118	4330	291	128	6643
Clomazone 500 g ai/ha + HW 45 DAT	272	126	4701	308	131	7826
Clomazone + 2, 4 DEE 500 g ai/ha + HW 45 DAT	293	132	4934	331	142	8013
Butachlor 250 g ai/ha + HW 45 DAT	309	135	5180	347	147	8277
Pretilachlor 500 g ai/ha + HW 45 DAT	300	133	5062	341	148	8067
Bispyribac Sodium 25 g ai/ha + HW 45 DAT	315	141	5613	355	155	8653
PPI Glyphosate 2.5 L/ha. + Bensulfuron methyl + Pretilachlor 660 g ai/ha	284	136	4928	326	150	7973
Two HW at 25 and 45 DAT	319	142	5831	362	163	8783
Unweeded control	222	112	3089	263	114	4059
SEd	14	8	230	13	8	297
CD (P = 0.05)	29	17	483	27	17	624

plants on account of reduced crop - weed competition resulting in increased availability of nutrients, water and light.

Conclusion

Application of post emergence herbicide bispyribac sodium 25 g ai/ha at 15 DAT followed by hand weeding at 45 DAT produced higher grain yield and this was at par with two-hand weeding due to lower crop-weed competition. Sequential application of herbicides *viz.*, glyphosate 2.5 L/ha at 15 DBT followed by bensulfuron methyl + pretilachlor 660 g ai/ha at 3 DAT was also found promising and it can also be recommended for weed control in transplanted rice during the peak period of labour scarcity. No doubt, the results of two-hand weeding are significantly better in terms of weed control and rice grain yield, but as it is time consuming, laborious and expensive, it can not be recommended for large scale rice production. From the research findings, it can be concluded that application of post emergence herbicide bispyribac sodium 25 g ai/ha followed by HW at 45 DAT can be recommended for effective weed control and higher productivity in transplanted rice.

Conflicts of Interests

The authors have not declared any conflict of interests.

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Full Length Research Paper

Effects of cover crops in the dynamics of organic matter and potassium in the soil and performance of common bean in the Brazilian Cerrado of Goiás State

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The effects of several cover crops on common bean cv. Pérola productivity cropped at Goiano – Ceres Campus (Brazil) and changes in soil organic matter and potassium were evaluated for one season. The experiment was based on a randomized complete blocks design encompassing four treatments (spontaneous vegetation, *Crotalaria spectabilis* L., *Mucuna aterrima* L. and *Pennisetum glaucum*) and four replications. Soil cover by cover crops was assessed 40 days after sowing (DAS). Manure was applied at 25 DAS at a rate of 250 kg ha^{-1} with a NPK formulation 20-00-20.Cover crops increased soil cover by approximately 170% when compared with the natural vegetation. Plant residues and manure also led to changes in the soil organic matter and potassium during the common bean growth cycle. Apparently, the *Mucuna aterrima* L. favored mostly the bean productivity and increased the organic matter and potassium in the soil.

Key words: Green manuring, manure, organic matter, *Phaseolus vulgaris,* potassium

INTRODUCTION

Cerrado soils present low organic matter (OM) rate due to fire, to the hot weather and, in some times of the year, to high humidity. Such conditions speed up OM decomposition. Besides, the adopted production strategies lead to significant physical, chemical and biological degradation increase in these soils and, consequently, to productivity reduction as well as to economic and environmental cost increase. Thus, Meschede et al. (2007) reported that it becomes mandatory to adopt conservationist handling systems, and that the main challenge lies on handling and on OM rate increase in the soil.

The use of cover crops becomes an excellent handling option in these soils. They may be incorporated to or used in coverage formation in tillage system (TS). Among the most used plants it is possible highlighting: millet, *Cajanus cajan*, *Canavalia ensiformes*, *Crotalaria* and *Mucuna*. Some of these plants produce more than 30 t

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ha^{-1} of fresh biomass.

The use of cover crops is associated with carbon (C) and nitrogen (N) mineralization, OM accumulation, nutrient cycling, invasive plant population's reduction, pest cycle rupture and with erosion reduction, therefore, improving the physical, chemical and biological properties of the soil.

Perin et al. (2004) reported that plant biomass production by *Crotalaria* was higher than that of spontaneous vegetation and millet. It also presented higher rates of accumulation of N and calcium (Ca), whereas millet and the invasive plants presented higher potassium (K) release.

According to Jesus et al. (2007), rice cultivation after leguminous crops resulted in larger foliar area, higher plant biomass and higher N concentration in the leaves. Silva et al. (2006) found that millet used as a cover crop increased native N absorption by corn, whereas *Crotalaria* led to higher grain production. Soratto et al. (2010) observed higher castor beans production in soil covered by straw from fallowing and millet combination. Duarte Júnior and Coelho (2008) got 37% increase in sugarcane production in TS using leguminous as cover crop when it was compared to the conventional system. The use of green manuring with leguminous also leads to changes in the succession dynamics of invasive plants (Favero et al., 2001).

Although the tillage system is widely adopted in the Brazilian Cerrado, this system prevails in soy, cotton and corn cultivation, whereas there is still lack of information on its use in rice and beans cultivation. Kluthcouski et al. (2000) reported that the bean plant culture presents better adaptability to the tillage system than corn and, mainly, than rice; and it may also reach high productivity rates. However, cultivation is compromised when soil presents physical impairments to radicular growth, low hybrid and nutrients availability in the soil (EMBRAPA, 2003).

With regards to bean, tillage system using adequate coverage leads to water saving when it is compared to other soil management. It also influences pods production and the number of grains per plant (Stone and Moreira, 2000). Arf et al. (1999) obtained higher bean plant productivity in treatments using black mucuma, lablab and corn plus black mucuma. According to Favero et al. (2001), black mucuma also has a great potential for soil covering and invasive plants' suppression.

The current study aims to evaluate the cover crop biomass production and straw effect before common bean plant cv. Pérola cultivation as well as changes in invasive plant population, and levels of OM and K levels in the soil.

MATERIALS AND METHODS

The study was conducted in the experimental area of IF Goiano – Ceres Campus (Brazil) during the 2010/2011 cropping season and was split in two stages: fresh and dry biomass production were assessed in the first stage, as well as the invasive plant suppression by cover crops *Crotalaria spectabilis* L., *Mucuna aterrima* L., *Pennisetum glaucum* L. and spontaneous vegetation; in the second stage, the straw effects of these species on bean plant cv. Pérola and on soil OM and K levels were assessed.

The experiment followed the randomized complete block design encompassing four treatments and four replications in 25 m² plots. The clayey soil in the experimental area is classified as red latosol (Oxisol) (EMBRAPA, 2006); the climate is humid tropical presenting a mean annual rainfall above 1.600 mm (SEPLAN, 2005, with rainy season from October to April and dry from May to September. Figure 1 shows the maximum and minimum mean temperatures and monthly rainfall during the experimental period.

The experimental design was in randomized blocks, with for treatments with four repetitions. The treatments were composed of tree cover crops (*C. spectabilis* L.; *M. aterrima* L. and *P. glaucum* L) and control, using the spontaneous vegetation.

Initially, the soil preparation consisted of one plowing operation and followed by two harrows. The result of the chemical analysis of the soil, there was the need of pH correction. Cover crop sowing was done at 0.4 m inter-row spacing to form stands holding 750,000, 205,000 and 175,000 of *C. spectabilis*, *P. glaucum* and *M. aterrima* plants per ha^{-1}, respectively.

Coverage of soil was determined at 40 DAS, according to method described by Alvarenga (1993). The harvest of cover crop aerial biomass was performed at flowering, at 72, 84, 94 and 97 DAS for *P. glaucum*, *C. spectabilis*, *M. aterrima* and spontaneous vegetation, respectively. The number of natural vegetation in the plots was determined and samples were collected to set fresh and dry biomass. The biomass accumulation in the cover crops was determined from four 0.25 m² samples for *M. aterrima* and spontaneous vegetation, and in plots containing *P. glaucum* and *C. spectabilis* four 0.5 m linear. The samples were kept for 72 h at 70°C in order to estimate the dry weight.

The aerial plant biomass was kept on the soil surface and at 106 DAS of cover crops the common bean (cv. Pérola) was sown in rows 0.5 m apart from each other, at a seeding rate of thirty seeds per meter. Manure was applied to 250 kg ha^{-1} of the 04-30-16 NPK formation. Thinning was performed to set a population of 250,000 plants per hectare at 16 DAS for beans. Besides thinning, the culture tracts consisted of manual invasive plant control at 16 DAS during the bean plant cycle, of three contact insecticide application and of the pyrethroid chemical group ingestion as well as of the active ingredient permethrin at 384 $g.L^{-1}$ concentration, in dosage 0.13 L ha^{-1}, in tail 200 L ha^{-1} at 15, 33 and 50 DAS in bean, and one coverage manure using 250 kg ha^{-1} of the 20-00-20 formation, at 25 DAS bean.

When the common bean was at the R5 stage, at 91 DAS, the bean plants height (cm) was assessed as well as the number of pods per plant, the amount of seeds per pod and productivity (kg ha^{-1}), depending on cover crop material. The pods were maintained at 60°C for 72 h, and, subsequently, the weight of 100 seeds and grains productivity was determined.

Soil samples were collected from 0 to 20 cm soil depth after the cover crop harvest, which was done in a monthly basis, within a 120 day period of time after harvest cover crop. The OM and K contents in the soil were determined (EMBRAPA, 1997). Elements' dynamics was set by the following equation:

Dynamics (%) = {(OM or K contents at harvest – OM or K contents at the first stage) / OM or K contents at the first collection)} x 100

Results are presented in graphics in order to show the OM and K levels in the soil after harvesting the cover crops. Data of cover crop biomass and beans' productivity were subjected to variance analysis and means comparison was done by Scott-Knott's test at 5% probability level using the SAEG software version 9.1 (UFV, 2007).

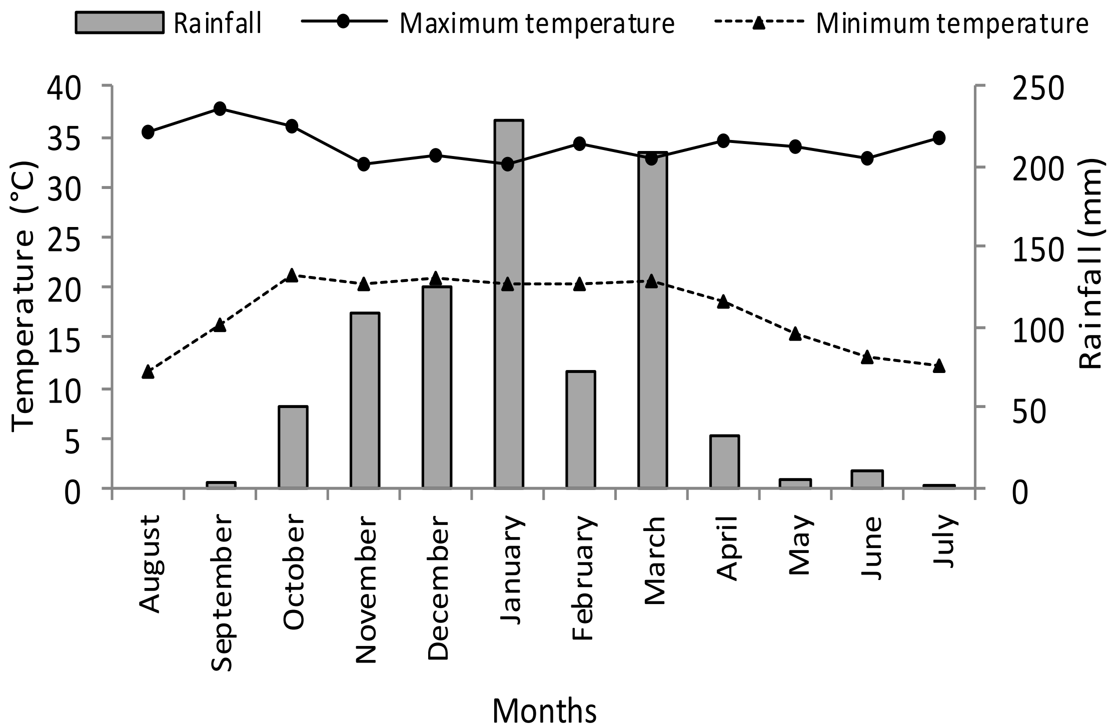

Figure 1. Maximum and minimum air temperature (ºC); and monthly rainfall (mm) during the experimental period. Ceres City, GO, Brazil, 2010/2011.

Table 1. Number of invasive plants, % soil cover and biomass production depending on cover crops under the weather and soil conditions in Ceres, GO.

Cover crops	Number of invasive plants m^{-2}	Soil cover (%)	Fresh weight (kg ha^{-1})	Dry weight (kg ha^{-1})
Crotalaria spectabilis	42.72[a]*	83.37[a]	39,023.75[a]	5,362.50[a]
Pennisetum glaucum	65.72[a]	65.15[a]	35,681.25[a]	5,781.25[a]
Mucuna aterrima	16.48[b]	74.70[a]	26,300.00[a]	5,010.00[a]
Spontaneous vegetation	73.72[a]	27.45[b]	32,322.50[a]	5,100.00[a]
Average	49.66	62.67	33,331.87	5,313.43
CV (%)	23.64	24.58	18.73	19.14

*Means followed by the same letter in the column do not differ from each other by the Scott-Knott'test at 5% probability level.

RESULTS AND DISCUSSION

Data on soil cover (%), number of invasive plants and cover crop biomass are presented in Table 1. There was no significant difference among treatments in dry and fresh biomass; however, there was a significant difference between the spontaneous vegetation and the other treatments in soil coverage. According to Duarte Júnior and Coelho (2008), such high speed coverage feature, in the initial period, gives *C. spectabilis* good erosion control and soil protection potential in a short period of time.

Mucuna was statistically different from the others when it came to invasive plant suppression; it presented 16.48 invasive plants per m² on average. However, it did not differ from the other straws (Table 1). Favero et al. (2001) found that black mucuna presented greater potential for invasive plant suppression. They also observed that the use of leguminous plants for green manuring leads to changes in the spontaneous species' suppression dynamics. Silva et al. (2010a) also found such effect in straw formed by mucuna plants.

The fresh and dry biomasses from the cover crops were not influenced by the studied species and they reached more than 26 and 5 t ha^{-1}, respectively (Table 1). The general dry biomass productivity mean was about 5.313 kg ha^{-1}. Darolt (1998) recommended 6 t ha^{-1} of dry mass in order to get obtain adequate soil coverage,

Table 2. Agronomic features of bean plants cultivated under the cover crop straw at Ceres, GO.

Treatments	Plant height	Number of pods $plant^{-1}$	Number of grains pod^{-1}	Weight of 100 grains (g)	Productivity (kg ha^{-1})
Crotalaria spectabilis	137.70[b]*	9.00[b]	4.55[a]	22.42[a]	2,299.75[b]
Pennisetum glaucum	136.75[b]	9.15[b]	4.75[a]	21.20[a]	2,465.25[b]
Mucuna aterrima	149.40[a]	11.40[a]	4.80[a]	21.80[a]	2,957.25[a]
Spontaneous vegetation	147.30[a]	9.40[b]	5.05[a]	21.21[a]	2,398.00[b]
Average	142.78	9.73	4.78	21.65	2,530.06
CV (%)	4.78	8.53	5.13	4.86	10.33

* Means followed by the same letter in the column do not differ from each other by Scott-Knott's test at 5% probability level.

whereas Kluthcouski (1998) suggested that something between 5.0 and 6.0 t ha^{-1}. Lopes et al. (1987) considered 4 t ha^{-1} of residue to be enough to achieve up to 95% hydric erosion reduction. Therefore, the obtained dry mass production values indicate that the studied cover crops may be used for soil coverage and they may work as additional tool in conservationist practices.

The dry weight produced by *M. aterrima* L. at Ceres (GO) was lower than that obtained by Duarte Júnior and Coelho (2008), who have achieved 10.05 t ha^{-1} in Campos dos Goytacazes (RJ), but did not differ from other cover crops, including the natural vegetation (Table 1). However, it was higher than the productivity achieved by Oliveira et al. (2002), who just obtained 1.09 t ha^{-1} at Lavras (MG). Such divergence in cover crop biomass production shows the need for studying and defining promising species for each region, including density, sowing season and crop interest.

Common beans height, number of pods per plant and productivity were influenced by the studied cover crops (Table 2). The obtained values were higher than those found by Oliveira et al. (2002) and by Siqueira (1989). Common bean plants cultivated under mucuna and spontaneous vegetation presented better height performance (Table 2). Such difference in plants height in response to soil coverage may be explained by a higher nutrients accumulation in soil.

There was no significant difference among treatments for the number of grains per pod and the mean weight of 100 grains; however, mucuna straw led to higher number of bean pods per plant and better productivity (Table 2). Bean plant productivity in mucuna straw was 23% higher compared with the natural vegetation. The productivity obtained in all treatments was more than the double of national average in 2012 cropping season (1.046 t ha^{-1}), according to CONAB (2012) data. Therefore, at Ceres environmental conditions, mucuna was the most promising cover crop before bean plant cultivation with greater plant productivity.

Cover crops also influenced the OM and K levels in the soil during the cropping season (Figures 2 and 3). The observed variations are associated with the rate and pattern of cover crops decomposition.

Bayer et al. (2003) found that the inclusion of leguminous species for soil covering increased organic carbon stocks and also led to greater cation exchange capacity. Camargo and Piza (2007) found significant differences in dry biomass production in forage species; however, they did not find any difference in the level of soil OM.

The OM content in the soil covered with *C. spectabilis* and *P. glaucum* was reduced during the 150 days after plants' harvest. In the first case, there was a reduction in the first 40 days and thereafter the OM stabilized in the soil (Figure 2). Mucuna was the cover crop that has led to an increase in OM in the soil right after the biomass cut. However, there was a decrease 40 days after the harvest, increasing again 75 days after the plant cut (Figure 2). The results the release of N, P and K of indicated that, in climatic conditions favor the decomposition of cultural residues of cover plants, it is necessary to optimize the synchrony between the release of nutrients and the demand for commercial crops (Salmi et al., 2006). These variations may be associated with the C/N ratio in the biomass, with the lignin rate in tissues and with decomposition speed.

The most intense change in the OM and K levels are associated with cover crop decomposition and with climatic conditions approximately 40 days after biomass cut. Figure 1 shows that there was rainfall and temperature increase in February and March which favored OM decomposition and nutrients release. Bean plants' flowering started approximately 35 days after emergence, therefore, at this point, the decomposition and nutrient release peak may have favored bean plant production. On the other hand, part of the K released during the residue decomposition may have been leached before flowering, due to the high rainfall rate (Figure 3).

Salmi et al. (2006) found that approximately 50% of K found in *C. cajan* biomass was released at the 30th decomposition day. Crusciol et al. (2008) showed that at the 50th day after oatmeal management as cover crop, almost all K in the straw was released. Teixeira et al. (2012) found that there was 99% mineralization of K found in the dry mass of millet, sorghum and spontaneous

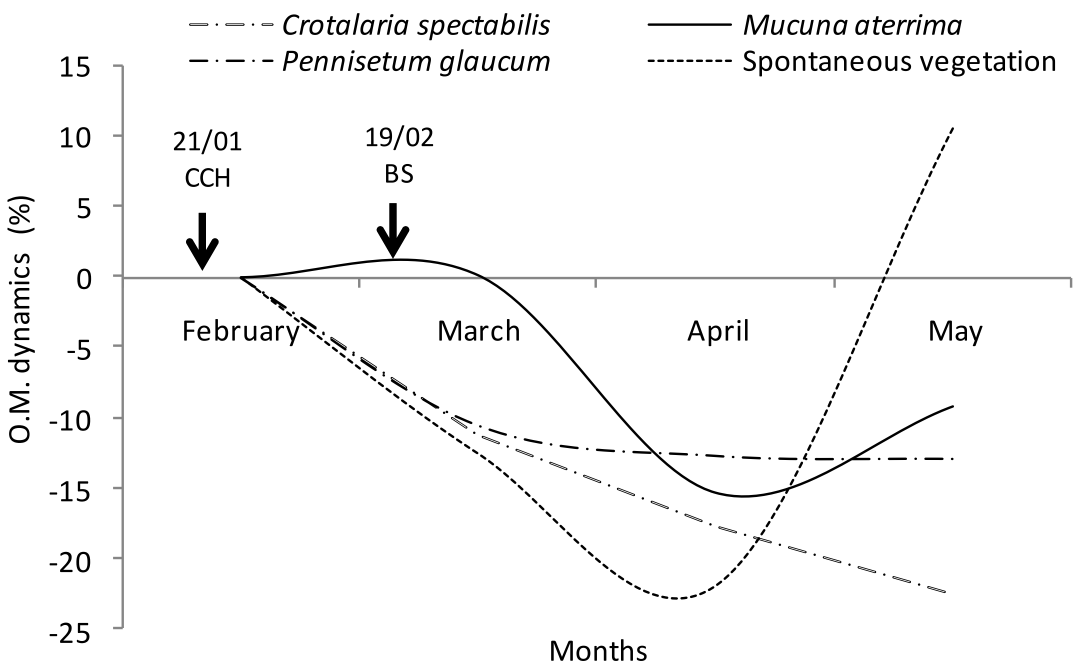

Figure 2. Organic matter (OM) dynamics in the soil during common bean plant cultivation under different cover crops. (CCH – cover crop harvest; BS – bean sowing).

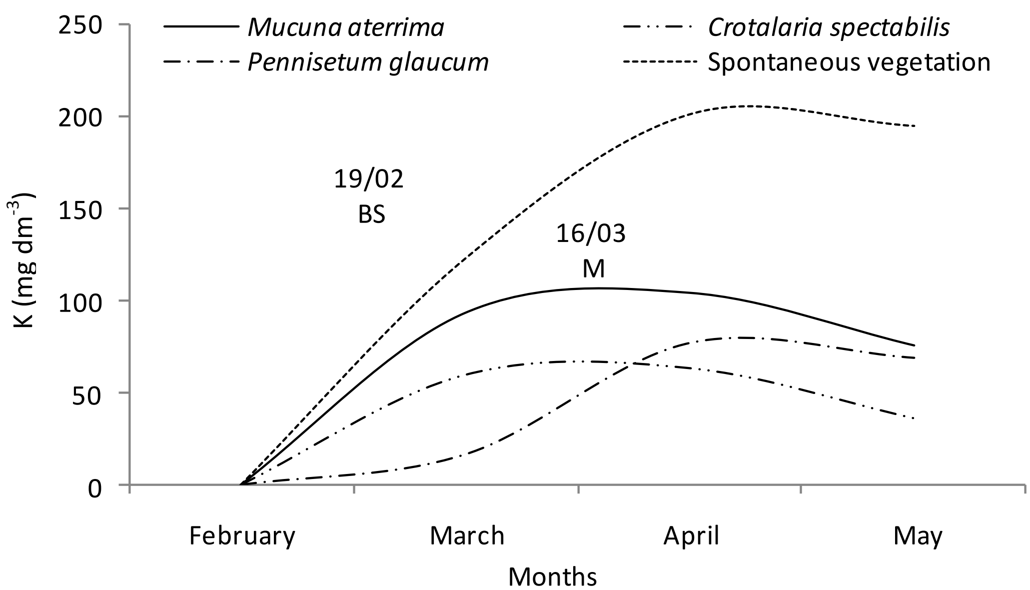

Figure 3. Potassium concentration in the soil during bean growth season under several cover crops (BS – bean sowing / M –manure).

vegetation 120 days after harvest. It shows that the release of nutrients in cover crops depend on plant species, as well as the climatic conditions of the region.

Cover crops influenced bean production as well as soil OM and K contents. Apparently, under the present climatic conditions, black mucuna was the best crover crop, either for common bean cv. Pérola productivity and to increase the OM and K contents in the soil. The increment in production beans can be associated with the availability of nutrients during the decomposition of the cover crops. Pittelkow et al. (2012) reported that K accumulation in *Crotalaria* and millet cover crops were

150.6 and 108.9 kg ha^{-1}, respectively, being released in soil and available plants during decomposition.

Conflict of Interests

The authors have not declared any conflict of interests.

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Full Length Research Paper

Assessment of genetic divergence in runner peanut genotypes grown in the Brazilian Northeast environments

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Runner cultivars are widely demanded by peanut farmers because of their high oil and grain productions. As those are late cycles, the management is limited in environments with water restriction. For improvement of runner genotypes to these environments is necessary to identify genotypes adapted and the knowledge of genetic divergence is quite relevant to assist the breeding procedures. In this work, ten morphological and agronomic traits were measured on 13 runner peanut genotypes grown in sandy loam textured soils during the rainy season in three environments on Brazilian Northeast region. These measurements included harvest index (%), main stem height (cm), 100 seed weight, 100 pod weight, pod length (mm), number of pod/plant, blooming (days after emergence, dae), number of seed/plant, physiological maturation of pods (dae) and oil content in seeds (%). The genetic divergence of genotypes was estimated by multivariate methods. Data set was analyzed by canonical variable (CV) in combination with UPGMA-clustering analyses. The statistical analysis was performed using the GENES program. We found that the first two CV were significant and accounted for 82.13% of the total variation. Three groups were clearly formed, separated by earliness and pod production. This arrangement was further attested by the dendrogram generated by UPGMA. The CV indicated that physiological maturation of pods, main stem height, number of pods/plant and 100 seed weight were the most differentiating traits among the genotypes. These two last allowed high magnitude associations and were contributive to selection procedures in improvement works. We provide indications of the best genotypes with potential to generate robust progenies, in a peanut breeding program.

Key words: *Arachis hypogea* L., canonical variables, traits associations, breeding.

INTRODUCTION

Peanut (*Arachis hypogea* L.) is an oilseed crop grown in many countries and is stands out commercially due to high value of grains, indicated to both food and oil markets. The species has two subspecies: The fastigiata,

Table 1. Geographical coordinates, soil and climate characteristics of environments.

Environment	Coordinates	Climate	Soil	T (°C)/RH (%)[1]	Rainfall (mm)[2]
Barbalha, CE	07º18'S; 39º18'W; 415 m	Semiarid	Vertisol	32/60	520
Campina Grande, PB	07º13'S; 35º53'W; 552 m	Tropical	Vertisol	28/68	730
Abreu e Lima, PE	07º54'S; 34º54'W; 19 m	Tropical	Entisol	29/66	820

[1]Means of temperature (T) and relative humidity (RH) fair during experimental period; [2]Total volume during experiment.

which includes Valencia and Spanish types, both upright and short cycle; and hypogea, that include Virginia and Runner types, both high yield and late cycles (Gibbons et al., 1977). The accessions from hypogaea usually have large seed and high oil yield, attracting to both food and oil market segments, but have limited adaptation to environments with water restriction (Isleib et al., 2004).

The Brazilian Company of Agricultural Research (EMBRAPA) coordinates a robust peanut breeding program targeted to oil and food markets, focusing on the development of Valencia and Runner cultivars adapted to environments with water restriction (Santos et al., 2013). Annually EMBRAPA has invested a large sum in generation of populations derived from interspecific genotypes in order to combine yield and early maturity, concentrating efforts in environments with semiarid climates (Luz et al., 2014; Vasconcelos et al., 2015; Pereira et al., 2015).

Analysis of genetic relationships is an important component of crop improvement programs because it provides information about genetic diversity, and is a platform for stratified sampling of breeding populations (Mohammadi and Prasanna, 2003). Such analysis can facilitate reliable classification of genotypes with possible utility for specific breeding purposes.

The univariate methods are widely adopted by breeders in several statistical models, in which each trait is analyzed separately allowing for substantial overlapping of results to occur (Yeater et al., 2004). Moreover, these methods do not explain how genotypes differ when all measured traits are considered jointly. In multivariate methods, all traits are considered simultaneously in the differentiation of populations, resulting in a more reliable comparison of germplasm. These methods are more suitable for assessing genetic divergence because it allow a more holistic interpretation of data, once consider the potential of the random trait sets, setting them at the same level of importance (Cruz and Regazzi, 2014). Among them, clustering and graphic dispersion techniques have been widely adopted by breeders (Pitta et al., 2010; Cruz and Regazzi, 2014).

The methods of graphic dispersion more often used are Principal Components (PC) and Canonical Variables (CV) analyses, that are linear combinations of the original quantitative measurements that contain the highest possible multiple correlation with each group and that best summarize among-class variation (Pitta et al., 2010; Cruz and Regazzi, 2014). To plant breeder, CV are more contributive because it allows the interpretation of the data with repetition, taking into account the residual covariance between the means of genotypes (Oliveira et al., 2003). As to clustering techniques, Hierarchical-UPGMA (Unweighted Pair Group Method with Arithmetic Mean) is widely adopted, which classifies similar individuals by clustering, based on similarity index (Bassab et al., 1990; Cruz and Regazzi, 2014). This method is based on genetic distances and has been considered an efficient estimator of phylogenetic linkages (Nei et al., 1983).

The combination of these techniques allow to clearly estimate the genetic interrelations in bred lines or core collections, providing valuable information to contribute to progress of allogamous or autogamous plant improvements. In this work we used UPGMA and CV analyses in order to assessing the genetic divergence in runner peanut genotypes grown in the Brazilian Northeast environments.

MATERIALS AND METHODS

The experiment were carried out in 2014 in three environments located in Brazilian Northeast region (Table 1), in sandy loam texture soils, previously limed and fertilized according to the needs of culture, revealed in soil analysis. The assays were performed in dry station of each places, at February, April and May in Barbalha (CE), Campina Grande (PB) and Abreu and Lima (PE), respectively.

Thirteen runner genotypes were evaluated, whose agronomic traits are shown in Table 2. The plot consisted of three 5 m-rows, spaced between other in 0.7 m. Plants (2/hole) were spaced in 0.3 m. Data were collected from central row. A randomized block design with three replications was adopted.

The crop management was performed according peanut crop recommendations described in Santos et al. (2010). The harvest took place between 115 to 130 days to earliness and late cycle earlier genotypes, respectively. These traits were collected: 100pod-weight (100P), 100 seeds-weight (100S), pod length (PL), height of main stem (HMS), number of pods/plant (PPl), number of

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Table 2. Origin, genealogy and some agronomical traits of runner genotypes.

Genotype	Origin	Genealogy	Seed			SP	PMP (dae)	Oil (%)	MSH (cm)
			Size	Color					
BRA 02179201	DF, Brazil	Accession	M	T	P	2	118-120	46	23
BRS Pérola Branca	PB, Brazil	Cultivar	L	W	P	3-4	110-115	50	25
Florunner	EUA	Cultivar	L	T	D	2-3	125-130	52	12
M407.F(B)	PB, Brazil	Top line	M	T	P	2	115-120	48	27
L50	Senegal	Top line	M	T	P	2	113-115	48	22
F.M424(B)	PB, Brazil	Top line	L	T	P	2-3	115-120	48	26
M424.F(B)	PB, Brazil	Top line	L	T	P	2	115-118	49	25
IAC Caiapó	SP, Brazil	Cultivar	L	T	D	2	125-130	51	13
Porto Alegre	PR, Brazil	Accession	M	T	P	2	118-120	48	24
Cavalo	RB, Brazil	Accession	EL	T	D	2	130-135	52	12
LGoPE-06	PE, Brazil	Top line	EL	T	D	2	125-130	52	13
BR1xAnonV	PE, Brazil	Top line	G	R	P	2-3	110-115	50	24
LViPE-06	PE, Brazil	Top line	EL	T	D	2-3	125-130	52	12

Seed size: M - mid, L - large, EL - extra large; Seed color: T - tan, W - white, R - red, C - Canopy: P - prominent main stem and side branches up to 1 m; D - decumbent, with no-prominent main stem and side branches up to 1 m; NSP - number of seeds/pod; PMP - physiological maturation of pods; MSH - Main stem height.

seeds/pod (S/P), harvest index (HI), Blooming (B), physiological maturation of pods (PMP), and oil content in the seeds (O). The height and production data were taken after harvest of genotypes. Blooming data was estimated as 50% of plants started the flowering, in central rows. The harvest index was estimated by dry weight of pod yield/ dry weight of total plant ratio (Duarte et al., 2013). The oil content was (H1 OXFORD MQA 7005) estimated by Nuclear Magnetic Resonance spectrometer H1 OXFORD MQA 7005, using from 20 g of seeds of each genotype (AOCS, 2004).

Data were submitted to variance analysis by F test ($p < 0.05$) and the means were submitted to the canonical variables (CV) analysis. The genetic distance between accessions was estimated by Mahalanobis distance (D^2), expressed by:

$$D^2_{i'i} = \delta\psi^{-1\delta}$$

Where: $D^2_{i'I}$ = Mahalanobis distance between I and I' genotypes; ψ: variances and covariance matrix residuals; δ'= (d1 d2 ... dv), where dj = Y; ij - Yi'j and Yij: mean of the i^{th} genotype in relation to j^{th} trait (Cruz and Regazzi, 2014).

The UPGMA method was adopted to clustering analysis. In order to eliminate the non-hierarchical effects, the cophenetic correlation coefficient was estimated (Sneath and Sokal, 1973), which indicates the distortion produced by clustering in the original genetic distances. This coefficient is a matrix correlation between original genetic distances and a new distance matrix (the cophenetic matrix), derived directly from the UPGMA dendrogram. Additionally, linear associations between traits were estimated adopting Pearson correlation method. Statistical analyzes were performed using the GENES software (Cruz, 2006).

RESULTS AND DISCUSSION

A summary of variance analysis for all eight traits is shown in Table 3. Statistical differences were found to genotypes (G). To environments (E) and G x E interaction, statistical differences were found for most traits, excepting 100P, PL, S/P, PMP and O, indicating that the environments did not influence their expressions.

In Table 4 are shown the eigenvalues, individual variation (%) and accumulated variation associated to CV, based on ten traits from runner genotypes. It was found that the first two CV explained approximately 83.11% of the total variance (CV1 = 68.91%; CV2 = 14.19%), indicating that the most of variability is summarized in these two component. Then, the classification of genotypes by plotting of values in the two-dimensional level is feasible.

The graphical dispersion of genotypes is found in Figure 1. Three groups were formed with heavy contribution of traits associated with earliness and pod production.

Group 1 - clustered earliness and mid-cycle genotypes, with physiological maturation of pods ranging from 110 to 120 days, and oil content ranging from 47 to 50%. They are F.M424B, L50, M424.F (B), F.M407 (B), BR 1xAnonV, BRS Pérola Branca and Porto Alegre. These materials have prominent main stem, side branches up to 1 m and main axis up to 20 cm (Table 2). The highlight of this group is BRS Pérola Branca, the most earliness genotype, with maturation cycle starting from 110 days and mild tolerance to indian summers (Pereira et al., 2012). BRS Pérola Branca was developed by EMBRAPA to semiarid environment and inherited robust earliness and yield traits from their parents: BR 1, an earliness Valencia type and LViPE-06, a Runner-high yield material (Pereira et al., 2012). The isolines F.M407 (B), M424.F (B) and F.M424 (B), all generated by crossings between Argentina (Manfredi) and North American (Florunner) cultivars also offer interesting contributions to runner

Table 3. Summary of variance analysis for runner peanut traits.

		Mean square									
SV	**FD**	**HI**	**MSH**	**100S**	**100P**	**PL**	**NSP**	**PPI**	**B**	**PMP**	**O**
B/E	6	7.68	0.92	6.62	382.01	0.25	0.06	6.81	1.10	7.53	9.16
B	2	17.72	1.19	1.43	888.49	0.03	0.19	6.72	2.67	6.33	10.80
B x E	4	2.67	0.78	9.22	128.78	0.36	0.01	6.85	0.31	8.14	8.34
G	12	226.19**	408.87**	859.63**	9422.26*	157.09*	1.20**	842.90*	58.97*	658.38*	41.99*
E	2	670.49**	12.88**	48.26*	35.35	3.30**	0.02	719.44**	6.72*	19.92	9.80
G x E	24	27.73**	8.32	16.78*	86.28	3.71**	0.01	29.93**	3.17**	5.03	8.13
Error	72	2.85	4.18	9.72	83.39	1.51	0.03	8.91	1.17	7.32	7.86
CV (%)	-	3.77	9.42	5.28	6.26	4.10	8.82	9.16	3.11	2.22	5.67
Mean	-	44.66	21.69	59.05	145.68	29.94	2.12	32.55	34.85	121.66	49.40

** and * - significant by F test F (p<0.01 and p<0.05, respectively); B - block; E - Environment; G - Genotype; CV - Coefficient of variation; SV - source of variation; FD - freedom degree; HI - harvest index (%); MSH - main stem height (cm); 100S - 100 seed weight (g); 100P - 100 pod weight (g); PL - pod length (mm); NSP - number of seed/plant; PPl - number of pod/plant; B - blooming (days after emergence, dae), PMP - physiological maturation of pods (dae), O - oil content in seeds (%).

Table 4. Estimate of variance (eigenvalues and accumulated variation) of the canonical variables for ten peanut traits.

Canonical variable	Eigenvalue	%	Acumulated variation (%)
VC1	65.35	68.91	68.91
VC2	13.46	14.19	83.11
VC3	6.56	6.92	90.04
VC4	4.31	4.54	94.59
VC5	2.43	2.56	97.15
VC6	1.34	1.41	98.57
VC7	0.96	1.01	99.59
VC8	0.28	0.29	99.89
VC9	0.07	0.08	99.97
VC10	0.02	0.02	100.00

peanut breeding due to their better productivity, in tropical climate (Santos et al., 2010).

Group 2: Clustered late materials, with maturation cycle from 120 days. They are: IAC Caiapó, Florunner, Cavalo, LviPE-06 and LgoPE-06, all with decumbent canopy and no-prominent main stem. Side branches reach up to 1.5 m and oil content are up to 50% (Table 2). These genotypes have high oil and grain yield, are sensitive to Indian summers and broad tolerant to leaf diseases (Isleib et al., 2004; Santos et al., 2010; Duarte et al., 2013). They are, therefore, excellent genetic resources for breeding works, aiming to broadening the genetic basis of Valencia or Spanish materials.

The Group 3 contained only one genotype (BRA02179201), newly incorporated in EMBRAPA *A. hypogaea* collection, and involved in pre-breeding procedures. This genotype is a mid-cycle material, and shows no-typical traits of Runner types, such as low harvest index and oil content below 46%. In field, the plants showed a flow of pods concentrated next to main stem. This ideotype can later be interesting to generate runner cultivars indicated to no-mechanized management.

Based on the group compositions formed by the CV analysis, we recommended adopting genotypes from Groups 1 and 2 in breeding program in order to obtain promising progenies for further use in selection procedures focusing on environment adaptation to Brazilian Northeast region.

The dendrogram generated by UPGMA is found in Figure 2. The comparison of the distance matrices and clustering were based on the estimative of cophenetic correlation (0.74). Two groups were formed and similar as found in Figure 1, excepting that BRA02179201 was clustered in the same group of earliness and mid cycle genotypes (Group 1).

The classification method of germplasm using UPGMA offers various advantages to the plant breeder, such as the sharp perception of similarity level among genotypes. Sometimes this proximity may not be noticeable on the

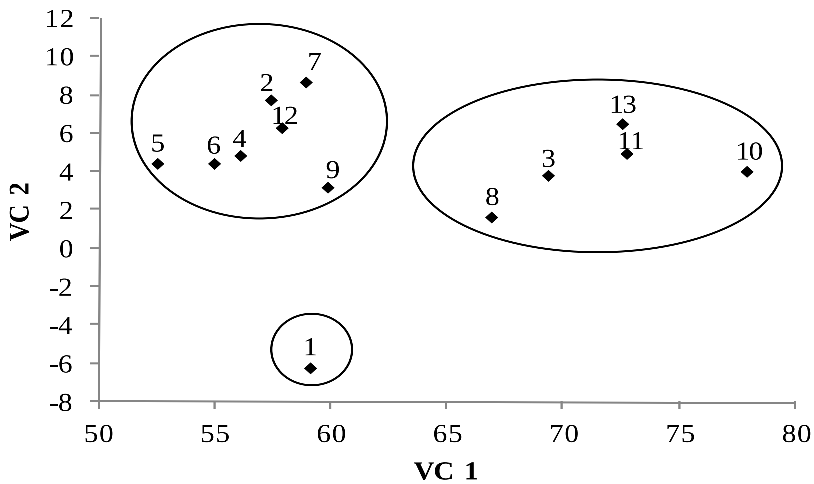

Figure 1. Graphical dispersion of scores in relation to first two canonical variables, based on ten agronomic traits obtained in the 13 runner peanut genotypes. 1 - BRA02179201, 2 - BRS Pérola Branca, 3 - Florunner, 4 - F.M424 (B), 5 - L50, 6 - M424.F (B), 7 - M407.F (B), 8 - IAC Caiapó, 9 - Porto Alegre; 10 - Cavalo, 11 - LGoPE-06, 12 - BR1xAnon, 13 - LViPE-06.

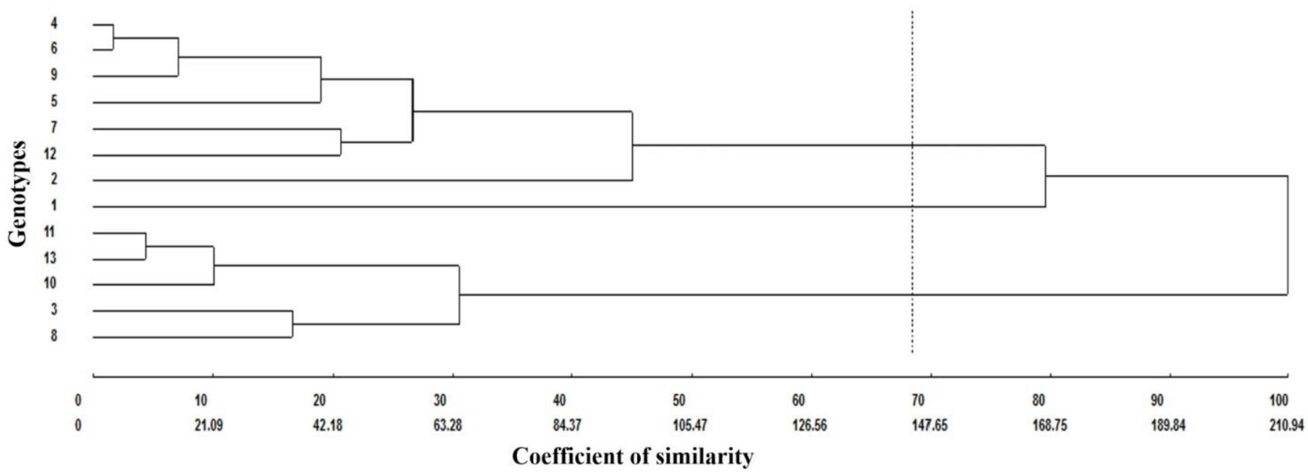

Figure 2. Dendrogram generated by NTSYS-pc software 2:10 using UPGMA clustering method, based on ten traits obtained from runner peanut genotypes. 1 - BRA02179201, 2 - BRS Pérola Branca, 3 - Florunner, 4 - F.M424 (B), 5 - L50, 6- M424.F (B), 7 - M407.F (B), 8 - IAC Caiapó, 9 - Porto Alegre; 10 - Cavalo, 11 - LGoPE-06, 12 - BR1xAnon, 13 - LViPE-06. Cophenetic correlation coefficient: 0.74.

graphic plan. In Figure 2 we confirmed the high relationship between M424.F (B) (4) and F.M424 (B) (6), and also between LViPE-06 (11) and LGoPE-06 (13), that have closely related to each other (Duarte et al., 2013). LViPE-06 and LgoPE-06 are late cycle genotypes widely used by EMBRAPA breeders due to high capacity to pod production and resistance do leaf diseases (Santos et al., 2013). Luz et al. (2014) estimated the genetic gain of progenies derived from these genotypes and cv. BR 1 (earliness, Valencia type) and found gains ranging from 6 to 15% to number of peg, 4 to 17% to number of pod/plant and 3 to 17% to 100 pod weight.

Vasconcelos et al. (2015) estimated the stability and adaptation of runner genotypes to semiarid environment during three years, including LViPE-06, LGoPE-06, BRS Pérola Branca, Florunner and IAC Caiapó. The authors found best results to BRS Pérola Branca and LViPE-06, while LGoPE-06 showed excellent results to pod production, but was highly dependent upon favorable environments.

The relative contribution of traits to genetic divergence among genotypes, based on D2, is found in Table 5. The following traits were more contributive: physiological maturation of pods, main stem height, number of

Table 5. Relative contribution of traits to genetic divergence of runner peanut genotypes.

Trait	PMP	MSH	PPl	100S	HI	100P	B	PL	NSP	O
%	16.18	15.97	14.69	14.09	12.59	11.95	5.76	4.75	3.82	0.15

PMP - physiological maturation of pods (dae); MSH - main stem height (cm); PPl - number of pod/plant; 100S - 100 seed weight (g); HI - harvest index (%); 100P - 100 pod weight (g); B - blooming (days after emergence. dae); PL - pod length (mm); NSP - number of seed/plant; O - oil content in seeds (%).

Table 6. Linear associations between traits collected in 13 runner peanut genotypes.

	HI	100P	PL	NSP	100S	MSH	PPl	B	PMP	O
HI	1	0.66*	0.60*	-0.45	0.85**	-0.62*	0.65*	0.91**	0.70**	0.64*
100P		1	0.89**	-0.00	0.87**	-0.35	0.73**	0.78**	0.69**	0.59*
PL			1	0.13	0.87**	-0.33	0.73**	0.74**	0.60*	0.75**
NSP				1	-0.07	0.11	0.08	-0.37	-0.21	0.20
100S					1	-0.56*	0.77**	0.85**	0.65*	0.77**
MSH						1	-0.33	-0.65*	-0.64*	-0.52
PPl							1	0.61*	0.42	0.72**
B								1	0.82**	0.67*
PMP									1	0.59*
O										1

HI - harvest index (%); 100P - 100 pod weight (g); PL - pod length (mm); NSP - number of seed/plant; 100S - 100 seed weight (g); MSH - main stem height (cm); PPl - number of pod/plant; B - blooming (days after emergence - dae); PMP - physiological maturation of pods (dae); O - oil content in seeds (%).

pods/plant and 100 seed weight. These results were also found by Santos et al. (2000) and Ajay et al. (2012) using principal component analysis, indicating that all of them are responsive to discrimination of runner genotypes. The linear associations generated from means of traits are shown in Table 6. Several significant associations were verified; some of them had high magnitude, indicating possible relation with linked genes or pleiotropic effects. They are B x 100S, 100P x PL, 100P x 100S, 100P x PPl, 100P x B, 100S x PL, PL x PPl, PL x B, 100S x PPl and 100S x B. These results are widely useful to seletion procedures in peanut breeding program. The length of the main stem, for example, negatively correlated with blooming (-0.65) and physiological maturation of pods (-0.64), are a clear demonstration of robustness of these traits to selection of runner genotypes, serving even as a reference for selection in progenies derived from cross between fastigiata x hypogeae. It is quite interesing to realizes that the decrease the main stem height does not contribute to the reduction of seed production and therefore, main stem height is a good demonstration of the practical use of correlation estimates in breeding programs because it is a trait that can be measured at the beginning of the cycle, anticipating the selection to productive genotypes.

Negative associations were found only to HI x MSH (r = -0.62), MSH x 100S (r = 0.57), MSH x PMP (-0.64) and MSH x B (r = -0.65), all of which involving plant height, indicating that lower plants tend to be late and more productive. These results are consistent with pattern of runner plants that often are decumbent, fostering a better exploitation of pegs to facilitate the formation of pods (Gomes and Lopes, 2005).

Conclusions

1. The runner genotypes showed variability based on traits selected, however, they showed G x E interactions to traits associated with earliness and production, such Blooming, 100 seed weight, harvest index, pod length and number of pod/plant.
2. The high magnitude-associations here identified were important for setting selection strategies in runner peanut breeding, focused on Northeast region.

Conflict of Interests

The authors have not declared any conflict of interests.

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Full Length Research Paper

Coping measures required by farmers in managing climate change stress for effective agricultural crop production: Case study of Abia State, Nigeria

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This study was carried out to identify coping measures required by farmers in managing climate change stress for effective agricultural production in Abia State, Nigeria. Design of the study was descriptive survey. The study was carried out in Abia State. Two research questions guided the study while two null hypotheses were formulated and tested. Population for the study was 1,009 made up of 768 farmers and 241 extension agents in Abia State. Sample for the study was 302 made up of 230 farmers and 72 extension agents obtained through proportionate (30%) stratified random sampling technique. A 30 item questionnaire was developed and used to collect data for the study. Data obtained were analyzed using mean and standard deviation to answer the research questions while t-test statistic was used to test the hypotheses at probability level of 0.05. It was found by the study that crop farmers require the 30 coping measures identified in managing climate change stress among which include; use of high yielding and tolerant crop varieties, harvesting of water for irrigation and advertising agricultural produce. It was therefore recommended that the identified coping measures be packaged into a training programme by relevant stakeholders for training or retraining of farmers through seminars or workshops to enable them manage climate change stress for effective agricultural crop production in Abia State, Nigeria.

Key words: Agriculture, climate change, extension service, marketing, production.

INTRODUCTION

Climate change has become a global issue being discussed and researched due to its impact on numerous economic activities in many countries. Climate change is a shift in the normal weather cycle over time as a result of human or earth's activities. Climate change is any prolonged alteration in average weather due to natural variability or as a result of human activities (IPCC, 2007). Climate change is the variation in the statistical distribution of average weather conditions over a prolonged period of time in any region of the world (Adetayo and Owolade, 2012; Ikehi, 2014; Ikehi et al., 2014a). According to the authors, results of climatic

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studies have shown that compared to the pre-industrial era, the world temperature has warmed by at least 1/2°C. The major causes of this worldwide warming have been linked to rising amount of Green House Gases (GHG) in the atmosphere. Adger et al. (2003) stated that negative impacts of extreme events such as floods and droughts are expected to be high in developing countries particularly in rural areas due to climate changes and the stress it poses. Adebayo et al. (2012) explained that climate change impacts on agriculture include adverse effects on crop yield, prices of agricultural goods as well as per capita income and malnutrition. Adetayo and Owolade (2012) stated that climate related risks are major causes of human suffering, poverty and reduced opportunity for people. According to the authors frequent incidents of extreme weather events such as flooding, droughts, desertification, hurricane and other forms of disaster have plagued different parts of the world. The authors further stated that farmers require coping measures to reduce effects and negative impacts of climate change on agriculture and the farmer.

Coping is expending conscious effort to solve personal and interpersonal problems, and seeking to master, minimize or tolerate stress or conflict (Weiten and Lloyd, 2008) are thoughts and actions that are used in dealing with stress. Dealing with stress depends on whether one has the coping resources to handle the challenges. In this study, coping is the process through which farmers can adjust, deal with or manage difficult situations posed by climate change stress by adopting some measures. Coping measures in relation to this study are actions, steps or procedures directed to helping farmers adjust, deal with and manage climate change stress for effective agricultural crop production.

The farmers work with agricultural extension agents who have been trained to provide them with information, advice, guidance and counseling towards solving problems they encounter in agricultural production. It was observed by the researchers that crop farmers in Abia State make low returns in yields and revenues from their farms due to the incidence of extreme weather conditions such as high and fluctuating rainfall patterns, flooding, droughts, high temperature and other unfavorable weather conditions. These weather conditions cause the loss of soil nutrients, planted crops, farm lands and damage of stored farm produce. The crop farmer is vulnerable to the menace of any or a combination of these in which he becomes helpless and discouraged due to stress associated with the weather conditions. It is therefore necessary to expose the farmers to coping measures which would help them in the management of climate change stress for effective agricultural crop production and marketing for profit.

Stress in the view of Warheit in Belkin (1988) is the altered state of an organism produced by agents in the psychological, social, cultural and physical environment. This altered state, the author continued, negatively affects the well being of individuals; also, it has noticeable physiological indices which together constitute what is often called stress reaction in which an individual's characteristic psychological way of responding to stress is manifested. According to the author, stress should not be viewed simply as a problem; it prepares one to deal with a situation from which one might otherwise retreat and shapes one into a physical condition to do so. Allen (1999) explained that stress is a force or system of forces which tend to produce deformation in a body on which it acts. Bayne and Horton (2003) viewed stress as the experience of unpleasant over or under stimulation that can actually or potentially lead to ill-health. According to the author, it is accompanied by feeling of threat and strain to the extent of being overwhelmed and includes too much or too little stimulation or being bored out of ones mind. In the context of this study, stress is the experience of unpleasant weather conditions caused by climate change in which farmers are exposed to menace of flood, droughts, excessive heat and other extreme weather conditions that do not favour agricultural production and marketing which leads to physical and mental trauma as well as ill-health to the farmers. The extent which an individual can accommodate or withstand stress depends on the coping measures or strategies adopted by the individual against the stressful condition. Agricultural production as explained by Olaitan et al. (2010) is a process of utilizing farm inputs such as land, finance and labour in producing a product following approved logical steps. In this study, agricultural production is the process of utilizing farm inputs such as land, labour and finance as well as adopting coping measures in managing climate change stress for effective production and marketing of plant materials (crops) by crop farmers. Like other produced commodity, agricultural products are distributed to the final consumers to buying and selling.

Agricultural marketing as explained by Abbott and Makeham (1990) are the series of activities that take place between production and consumption of farm produce. According to the authors, it begins at the farm when the farmer plans his production to meet specific demands and market prospects. It involves activities like harvesting, processing, storage, transportation, sorting, grading, packaging and fixing of prices on agricultural produce. Agricultural marketing, the authors further explained, includes the selling to farmers of supplies needed for production such as fertilizers, pesticides and other agricultural chemicals, livestock feed, farm machinery, tools and equipment, and the distribution of produces to consumers after agreed terms of exchange. In this study, agricultural marketing are the series of activities which the crop farmer will carry out from the point of production till the farm produce gets to the consumer. The agricultural produce in their raw state are perishable, their perishability would be worsened by the excessive weather conditions unless the farmer is able to cope effectively with them. The purpose of this study therefore is to identify coping measures required by farmers in managing climate change stress for effective agricultural production in Abia State, Nigeria. Specifically this study sought to identify;

1) Coping measures at farm level practices required by farmers in managing climate change stress in Abia State, Nigeria.
2) Coping measures required by farmers for effective marketing of agricultural produce in Abia State, Nigeria.

Hypothesis 1: There is no significant difference between the mean ratings of farmers and extension agents on the coping measures at farm level practices required by crop farmers in managing climate change stress in Abia State, Nigeria.

Hypothesis 2: There is no significant difference in the mean ratings of farmers and extension agents on the coping measures required by farmers for effective marketing of agricultural produce in managing climate change stress in Abia State, Nigeria.

METHODS

Two research questions guided the study and two hypotheses were formulated and tested at probability level of 0.05. Descriptive survey research design was adopted for the study. Eboh (2009) explained that descriptive survey research design is a design employed for the study of a population to discover the relative incidence, distribution and inter relations of sociological and psychological variable through the use of interview or questionnaire. Descriptive survey design was found suitable for this study because questionnaire was used to collect data through the opinions of respondents. The study was carried out in the three agricultural zones in Abia State of Nigeria. The zones are Aba, Ohafia and Umuahia. The population for the study was 1,009 made up of 768 farmers and 241extension agents in Abia State. The sample for the study was 302 consisting of 203 farmers and 72 extension agents. The sample was obtained through proportionate (30%) stratified random sampling technique. A 30 item questionnaire was developed for collecting data from respondents. The questionnaire had two parts A and B. Part A was used to obtain information on personal data of respondents. That is, whether the respondent was a farmer or an agricultural extension agent. Part B was used to obtain data on the coping measures required by farmers for managing climate change stress. Each questionnaire item had a four (4) point response options of Highly Required (HR), Averagely Required (AR), Slightly Required (SR) and Not Required (NR) with corresponding values of 4, 3, 2 and 1 respectively. The agricultural extension agents and farmers responded to the questionnaire to provide information on coping measures that were required by crop farmers. The questionnaire was validated by three experts: one from Department of Agricultural and Bio-resources Education; one from Department of Agricultural Economics and one from Department of Crop Science, all from University of Nigeria Nsukka. Cronbach alpha method was used to determine the internal consistency of the questionnaire which yielded a coefficient of 0.81. Three hundred and two (302) copies of the questionnaire where administered to the respondents through the help of three research assistants. All the copies of the questionnaire were retrieved from the respondents and analyzed. Weighted mean and standard deviation were used to answer the research questions while t-test statistic was used to test the hypotheses at $P \leq 0.05$ level of significance. In taking decision on the coping measures that are required, the real limit was utilized as follows: 3.50 to 4.00 (highly required), 2.50 to 3.49 (averagely required), 1.50 to 2.49 (slightly required) and 0.50 to 1.49 (not required). Any item with a standard deviation between zero (0) and 1.96 indicated that the respondents were close to one another in their responses. The null hypothesis of no significant difference was accepted for any item whose t-cal is lower than the t-table value, while any item whose t-cal is greater than the t-table value was rejected at probability level of 0.05 and relevant degree of freedom.

RESULTS

Data on Table 1 revealed that all the 14 items had their means ranged from 2.78 to 3.42. This showed that the means were above the real limit of 1.5 which indicated that all the 14 items were required as coping measures by farmers in managing climate change stress in the production of agricultural crops. Table 1 also revealed that all the 14 items had their standard deviations ranged from 0.39 to 0.79 which were below 1.96 indicating that the respondents were not far from the mean and were close to one another in their responses. The Table 1 also showed that each item had its t-calculated lower than the t-table (critical) value of 1.96 at probability of 0.05 level of significance and 300 degree of freedom. This revealed that there is no significant difference in the mean ratings of the responses of farmers and agricultural extension agents on the 14 items on coping measures at farm level practices required by farmers in managing climate change stress. The hypothesis of no significant difference was therefore, accepted for each of the items.

Data in Table 2 revealed that all the 16 items identified as coping measures had their means ranged from 2.71 to 3.46. This showed that the means were above the real limit of 1.5 which indicated that all the 16 items were required by farmers as coping measures for marketing of agricultural products in managing climate change stress. Table 2 also revealed that all the items had their standard deviations ranged from 0.26 to 0.85 which were below 1.96 indicating that the respondents were not far from the mean and were close to one another in their responses. This strengthened the value of the mean. Table 2 further revealed that each item had its t-calculated value lower than t-table (critical) value of 1.96 at probability of 0.05 levels of significance and 300 degree of freedom. This indicated that there is no significant difference in the mean ratings of the responses of farmers and agricultural extension agents on the 16 items on coping measures required by farmers for marketing of agricultural produce in managing climate change stress. Therefore the hypothesis of no significant difference is upheld for each of the items.

DISCUSSION

A close look at the means of the strategies in Tables 1

Table 1. Mean ratings and t-test analysis of the respondents on coping measures at farm level practices required by crop farmers in managing climate change stress in Abia State, Nigeria (N=302).

S/N	Item statement	$\bar{X}$	SD	$\bar{X}$e	$\bar{X}$t	S_1^2	S^2_2	T-cal	Remarks	
									RQ	Ho
1	Construction of drainage system around the farmland.	2.79	0.59	2.94	2.7	0.50	0.47	0.27	Required	N.S
2	Making of bunds in the farm.	3.26	0.43	3.18	3.34	0.35	0.38	0.47	"	N.S
3	Use of sand bags to divert movement of running water.	2.83	0.55	2.93	2.76	0.28	0.21	1.35	"	"
4	Making of ridges across slope to slow down water movement.	3.08	0.50	3.21	2.83	0.38	0.54	0.67	"	"
5	Planting of trees around and within farmland.	3.12	0.62	3.19	3.06	0.52	0.57	0.89	"	"
6	Planting of cover crops in the farm.	3.31	0.71	3.38	3.21	0.46	0.30	1.33	"	"
7	Use of organic manures for crop production.	3.22	0.44	3.08	3.37	0.55	0.28	-0.61	"	"
8	Use of high yielding and tolerant crop varieties.	3.38	0.76	3.62	3.49	0.64	0.46	0.84	"	"
9	Multicropping using appropriate or recommended spacing.	3.21	0.43	3.18	3.94	0.58	0.71	0.27	"	"
10	Mulching soil surface using plant materials.	3.41	0.49	3.32	3.38	0.44	0.35	-1.15	"	"
11	Harvesting water for irrigation purposes.	2.78	0.59	2.73	2.88	0.61	0.53	-1.02	"	"
12	Use of irrigation facilities.	3.37	0.79	2.97	3.42	0.56	0.41	-1.25	"	"
13	Use of insecticides, rodenticides and herbicides to check crop damages.	3.42	0.39	3.49	3.44	0.42	0.39	0.46	"	"
14	Adopting rotational cropping.	3.36	0.43	3.58	3.42	0.25	0.42	0.26	"	"

Df=300, T-tab=1.96, $\bar{X}$=mean for items required SD=standard deviation, $\bar{X}$e=mean for extension agents on each item, $\bar{X}$t=mean for farmers on each item, S^2=variance.

and 2 reveals that items 6, 8, 10, 12, 13 and 14 from Table 1 and items 1, 12 and 16 from Table 2 had mean range of 3.28 to 3.46. These items happen to have high mean ratings by the respondents. For items 6 and 10 in Table 1 (planting cover crops in the farm and mulching soil surface using plant materials) with mean values of 3.31 and 3.41, cover cropping and mulching have been known to help conserve soil water for ease of nutrient circulation and absorption thus favouring production and market values and reducing climate stressing for the farmers. These approaches in turn reduce the direct impact, especially sunlight intensity, of climate change on the soil. Using high yielding and tolerant crop variety as indicated in Table 1 item 8 with a mean value of 3.38 helps to cover up for the crop failure that could have occurred in a climate trouble cultivation. The extra yields could cover for loses that would have occurred in normal cultivates that could not tolerate the change weather. With the changed rainfall pattern relying on irrigation (Table 1 item 12 with 3.37 mean) would be a good adaptation strategy in areas with prolonged drought. However, the cost to own and run irrigation facility for the indigent farmers in Abia state will strongly discourage this strategy except in the case of interventions by governmental and/or non-governmental bodies. Crop rotation and use of insecticides/herbicides/rodenticides (Table 1 item 13 and 14 with 3.36 and 3.42 means) have been known to control pests and insects of particular crops. In climate change era efficient use of these approaches could reduce farmers' physical efforts in pest and insect control thus reducing farming stress. Result of the study in Table 1 revealed that the 14 items identified as coping measures at farm level practices were required by farmers in managing climate change stress. The measures include making of bunds, use of sand bags to divert water movement, planting of cover crops, use of organic manures, mulching soil surface using plant materials and rotational cropping.

Items at Table 2 aim at organizing and improving the farmer's sales and income during crop marketing in climate change era. The prolonged cultivating period coupled with farming difficulties and increased labour cost probably informed the need for growing fast maturing crops (Table 2 item 1 with 3.32 mean). Grading farm product improves pricing and market values of agricultural produce. Agricultural products are never of the same size weight and quality thus grading enhances sales and reduces loss and marketing stress. This strategy seems to be the most favoured approach as suggested by the mean rating of the item. The item has the highest mean value (3.46) of all the 30 strategies mentioned both in practice and marketing of agricultural products in managing climate change stress. It is not out of place for this strategy to rank high as the focus of any enterprise is to make profit through improved product marketability. So even in climate change scenario, the focus of the farmers as suggested by the respondents would be to increase product sales, attract more profit and raise fund for production continuity while adopting other strategies. Result of the study in Table 2 showed that the 16 items were coping measures for marketing of agricultural produce required by farmers in managing

Table 2. Mean ratings and t-test analysis of the respondents on coping measures required by farmers for effective marketing of agricultural produce in managing climate change stress in Abia state, Nigeria (N=302).

S/N	Item statement	$\bar{X}$	SD	$\bar{X}$e	$\bar{X}$t	S_1^2	S^2_2	T-cal	Remarks	
									RQ	Ho
1	Grow fast maturing crops.	3.32	0.77	3.42	3.36	0.21	0.30	0.45	Required	N.S
2	Harvest farm produce at the appropriate time.	2.84	0.63	3.31	2.93	0.57	0.28	1.33	"	N.S
3	Access processing facilities.	3.16	0.74	2.98	3.23	0.29	0.32	-0.66	"	"
4	Access good storage facilities.	2.71	0.59	3.08	2.88	0.53	0.26	1.35	"	"
5	Store farm produce before selling.	2.68	0.67	3.18	2.86	0.37	0.52	0.68	"	"
6	Membership to a cooperative society.	3.24	0.71	3.37	3.19	0.48	0.30	1.33	"	"
7	Access good transport facilities.	2.86	0.60	2.96	2.92	0.58	0.31	0.28	"	"
8	Advertise agricultural produce.	3.31	0.43	3.49	3.28	0.42	0.29	1.38	"	"
9	Make contact with buyers.	3.08	0.69	3.20	3.11	0.52	0.34	0.38	"	"
10	Access to market channels.	2.90	0.85	2.84	3.22	0.35	0.29	-0.68	"	"
11	Sort farm produce based on size, weight and quality for appropriate grading.	2.88	0.70	3.27	2.96	0.58	0.26	0.29	"	"
12	Grade farm produce based on size, weight and quality for appropriate pricing.	3.46	0.26	3.62	3.48	0.64	0.47	0.82	"	"
13	Package graded farm produce.	3.22	0.44	3.58	3.37	0.50	0.42	0.27	"	"
14	Fix price on farm produce based on grade.	3.19	0.50	3.34	3.22	0.49	0.38	0.28	"	"
15	Sell off farm produce before they spoil at reasonable prices.	2.81	0.71	2.94	3.16	0.56	0.36	-127	"	"
16	Keep record of sales of farm produce in order to check profits and losses.	3.28	0.62	3.32	3.20	0.54	0.48	1.57	"	"

Df=300, T-tab=1.96, $\bar{X}$=mean for items required SD=standard deviation, $\bar{X}$e=mean for extension agents on each item, $\bar{X}$t=mean for farmers on each item, S^2=variance

climate change stress. Some of the measures are harvest farm produce at the appropriate time, access processing facilities, store farm produce before selling, access good transport facilities, make contact with buyers and access to market. The findings of this study is in line with the findings of Nicholls et al. (2007) in a study where measures similar to the findings of this study was recommended. The findings of this study is also in conformity with that of Enete and Amusa (2010) that farmers require the use of irrigation facilities, drainage infrastructures, access to information on climate change, drought resistant and short duration high yielding crops and extension services which are all crucial for coping with climate change stress. The findings of this study further resonant that of UNESCO (2012) report on 'climate change education for sustainable development in small Island developing states' where it was found out that farming communities need to strengthen their adaptive capacity through such measures like accessing information on climate change, providing education to local communities in areas on climate related threats, use of indigenous resources and knowledge among others. The results of the hypothesis tested revealed that there is no significant difference in the mean ratings of the two groups of respondents on the 30 items on coping measures required by farmers at farm level practices and in marketing of agricultural products in managing climate change stress. This implies that the level of training or/and experiences of each of the two groups of respondents did not influence their responses significantly on the 30 items.

Conclusion

In Abia State most crop farmers make low returns from their farms due to the incidents of extreme weather conditions such as high and fluctuating rainfall patterns, flooding, droughts, high temperature, and other unfavourable weather conditions caused by climate change. These conditions in effect cause the loss of soil nutrients, planted crops, farm lands and spoilage of stored farm produce. This study therefore was carried out to identifying coping measures that are required by the farmers in managing climate change stress. It was found out by the study that, the farmers require the 30 coping measures identified in managing climate change stress. The most prominent practice was the use of insecticides/ rodenticides/herbicides and mulching while the most suggested marketing strategy was the sorting and grading of farm produces to enhance marketability and reduce both farming and marketing stress. It was therefore recommended that the identified coping measures be packaged into a training programme by relevant stakeholders for training or retraining farmers through seminars and workshops to enable them manage climate change stress for effective agricultural crop production and marketing in Abia State, Nigeria.

Conflict of Interests

The authors have not declared any conflict of interests.

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