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Full Length Research Paper

Effect of storage materials on seed quality and health in Jute variety O-9897

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The experiments were conducted in Jute Agriculture Experimental Station (JAES) and Kishoregonj Regional Station (KRS) of BJRI during the period April 2012 to January 2013. The present study was carried out with the objective was to find out suitable storage materials for quality jute seeds and fibre production. Six different types of containers viz. tin pot, plastic pot, poly bag, gunny bag lined with polythene, cloth bag, and International Rice Research Institute (IRRI) innovated poly bag were used for the present study. Seeds stored in tin pot had the best performance in respect of germination, plant height, plant/m^2, base diameter, number of branch, number of pod, stick yield, fibre yield and seed yield. Health condition of seeds were also superior compared to other storage materials. The highest total disease incidence (12.84%) at KRS was recorded by using seeds of plastic pot. Lowest disease incidence (6.35%) was observed at KRS by using seeds stored in tin pot. The highest fibre yield (2.98 ton/ha), stick yield (5.91 ton/ha) and seed yield (368.44 kg/ha) were recorded by using seeds of tin pot. Quality of jute seeds can be maintained by storage in tin pot and proper moisture content (9.5%).

Key words: Container, disease, seed quality.

INTRODUCTION

Jute is one of the mainstay of Bangladesh economy. It accounts for about 6% of the foreign currency earnings from exports (Islam, 2009). The crop is versatile and environmental friendly biodegradable natural fibre widely grown in Asia, particularly in Bangladesh, India and China. It is a rapid growing renewable biomass and photo-reactive crop with only 120 days harvesting period. It is mainly grown for fibre rather than the seed. Two species of jute (*Corchorus capsularis* and *Corchorus olitorius*) are cultivated in Bangladesh. The land and climatic conditions of Bangladesh are congenial for the production of high quality jute (Islam, 2009). In Bangladesh, about 0.709 million hectares of land was under jute cultivation and the total yield was 8.40 million bales (BBS, 2011; IJSG website, 2012-2013). Jute suffers from more than 13 different diseases (Fakir, 2001) and 10 of them are seed borne. Seeds having higher seed borne infection results to significantly higher amount of disease

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development in the field such as spot gradually increased lengthwise, encircled the stem, which internally rots and broken the plant is called stem rot, lesions coalesced to form a big canker, sometimes girdling the stem and shredded the fibre is called anthracnose, in case of die back plant dry from the tip downwards at almost full-grown stage. Among the seed-borne fungal diseases, stem-rot, black-band, and anthracnose caused by *Macrophomina phaseolina* (Tassi, Goid.), *Botryodiplodia theobromae* and *Colletotrichum corchori*, respectively are frequently transmitted through jute seeds (Fazli and Ahmed, 1960; Ahmed, 1966; Fakir et al., 1991).

M. phaseolina alone can cause 10% yield loss (Ahmed, 1968). Stem rot, black band, anthracnose, foot rot and wilt (*Rhizoctonia solani*) and leaf mosaic (virus) are responsible for seed rot, pre and post emergence damping off seedlings, spread of the diseases to standing crops and loss and deterioration of quality of fibre (Ahmed, 1966; Ahmed and Islam, 1980; Biswas et al., 1985). Yield loss due to seed borne diseases of jute is 8 to 20% depending on the severity of jute diseases from year to year (Ahmed and Sultana, 1985). Infected jute seed fail to germinate or the young seedlings emerging from the infected seed die. Infection of jute seed causes germination failure, post emergence damping off and seedling blight (Fakir, 1989). Jute seedlings or growing plants produced in the field from the infected seeds and escaping early infection may often be infected at the later stages of their growth by the primary seed borne inocula grown and multiplied on the infected dead seeds and seedlings. Later on, these inocula may be transmitted to the healthy growing plants of the same or neighboring plants or even neighboring fields resulting to disease outbreak, often in epidemic form. Seed borne pathogens causing diseases on the growing jute plants in the field quite often attack the capsules or pods and subsequently infect the seed, resulting to production of infected or unhealthy seeds. Considering the above facts, the present study was carried out with the objective was to find out suitable storage materials for quality jute seeds and fibre poduction.

MATERIALS AND METHODS

Experimental sites and period

The experiments were conducted in Jute Agriculture Experimental Station (JAES), Manikgonj and Kishoregonj Regional Station (KRS), Kishoregonj of BJRI during the period of April 2012 to January 2013.

Containers used

T_1 = Tin pot, T_2 = Plastic pot, T_3 = Poly bag having 25 µm thickness, T_4 = Gunny bag lined with polythene, T_5 = Cloth bag and T_6 = IRRI Poly bag (Super Grain bag II Z) having 78 µm thickness seeds were stored for 12 months.

Experimental design

The experiments were conducted in the field with Randomized Block Design (RCBD) having three replications. The size of the unit plot was 10 m^2 (5 m × 2 m) and the distance between plots and replications were 1.0 m and 1.0 m, respectively.

Soil characteristics and nutrient status

The soil characteristics and nutrient status of the two experimental stations are shown in Table 1.

Application of fertilizers

Urea 180 kg (3 times), Triple Super Phosphate 50 kg and Muriate of Potash 25 kg per hectare were applied according to previous report (Islam, 2009; Islam and Rahman, 2008).

Sowing of seeds

Seeds were sown in line on 20 April, 2012 in Kishoregonj Regional Station (KRS), Kishoregonj and 2nd May, 2012 in Jute Agriculture Experimental Station (JAES), Manikgonj. Row to row and plant to plant distance were maintained as 1 M and 1 M, respectively. The seed rate for O-9897 was 4 kg per hectare.

Data collection

Data on different parameters were collected as shown:

1. Field emergence (germination %);
2. Plant stand/ plant population;
3. Incidence of diseases (%);
4. Plant height (M);
5. Base diameter (mm);
6. Fibre yield per plant (gm) and per hectare (ton);
7. Stick yield per plant (gm) and per hectare (ton);
8. Average number of branch per plant;
9. Average number of fruits per plant;
10. Seed yield per plant (gm) and per hectare (kg).

Disease incidence

Seedling blight (*R. solani* and *C. corchori)*

At seedling stage the basal portion of the plant showed brownish to blackish lesion and finally the plant died. Seed and soil borne pathogen were responsible for this disease.

Stem-rot (*M. phaseolina)*

Leaf turned pale gray color in the mid rib and turns black. The spot gradually increased lengthwise, encircled the stem, which internally rots and broken the plant. As a result the plants died.

Anthracnose (*C. corchori*)

This disease is confined only to *C. capsularis* variety. Lesions coalesced to form a big canker, sometimes girdling the stem and shredded the fibre.

Table 1. Soil characteristics and nutrient status of the two experimental locations in 2012.

Experimental location	AEZ	Soil characteristics		Nutrient status				
		Land type	Soil type	pH	% OM	% N	P (ppm)	K (meq/100)
JAES	Active Brahmaputra and Jamuna Flood Plain (AEZ-7)	Medium land	Sandy and Silty	6.69	1.79	0.35	14.38	0.138
KRS	Old Brahmaputra Flood Plain (AEZ-9)	Medium land	Loam	6.11	1.24	0.39	14.98	0.15

Black-band (*B. theobromae*)

The lesion first appeared as small blackish brown patch, which gradually enlarged and encircled the stem making a black band around. This disease is seed, soil and air borne.

Die back (*Glomeralla cingulata*)

Jute and kenaf plants usually the olitorius varieties begin to dry from the tip downwards at almost full-grown stage. This fungus is seed and air borne.

Wilting (*R. solani*)

Root system of affected plant becomes infested with a soil borne fungi. All the leaves become flaccid at a time and after few days dropping occurs.

Soft-rot (*Sclerotium rolfsii*)

The disease appeared first near the ground level. Profuse white cottony mycelial growth occurs at the collar region of jute crop.

Leaf mosaic (Virus)

Yellow mosaic spots regular or irregular appeared usually on capsularis plants at any stage of growth and affected formation of chlorophyll.

Root knot (*Meloidogyne javanica* and *M. incognita*)

Attack at early stage caused stunted and poor growth of plants with abnormal swollen tip and also produced severe gall formation in root systems.

Field emergence (germination %)

Four hundred seeds were taken randomly from the well mixed seed samples. The working samples were divided into four replications and thus one replication contains 100 seeds. To ensure adequate spacing, the seeds were germinated on soil in experimental plots. Seeds were counted as germinating seeds after four days. The results were expressed in percentages.

Harvesting of fibre

Jute crop of both species were harvested at field duration of 120 days from the jute plants grown in different blocks. The crop was harvested after 120 days of sowing. After being harvested, bundles of plants leave were heap in dry jute field for four days to make defoliation. Fibre yield per plant and hectare were recorded.

Harvesting of stick

Fibre stick yield of both species were harvested from the jute plants grown in different blocks. Stick yield per plant and hectare were recorded.

Harvesting of pods

The ripening pods (65 to 75%) were harvested from the jute plants grown in different blocks as per different seed production methods. Seeds were extracted from the harvested pods, dried and seed yield per plant and hectare were recorded.

Statistical analysis

Data were analysed statistically and treatments effects were compared by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Disease incidence in O-9897 at JAES and KRS, BJRI

Altogether six seed borne fungal diseases (seedling blight, stem rot, black band, die back, soft rot and root knot) were recorded. Anthracnose and mosaic diseases were not found in olitorius varieties for their cell structures. Total disease incidence such as well as individual disease incidence varied independently each other with respect to different types of storage containers, variety and locations (Table 2). The highest stem rot (3.73%), black band (2.73%), die back (3.25%) and soft rot (1.96%) were recorded in the field by using seeds stored in poly bag, plastic pot, cloth bag and poly bag, respectively at KRS and lowest stem rot (1.64%) and soft rot (0.50%) were recorded using seeds stored tin pot

Table 2. Effect of seeds stored in different types of containers on disease incidence in O-9897 at JAES and KRS, BJRI following line sowing method in the field.

Container	% Major disease incidence recorded in													
	JAES							KRS						
	Seedling blight	Stem rot	Black band	Die back	Soft rot	Root knot	Total disease	Seedling blight	Stem rot	Black band	Die back	Soft rot	Root knot	Total disease
T_1	0.00 (0.71)	1.67^{bc} (1.47)	1.42^{cd} (1.39)	1.72^{c} (1.49)	0.50^{c} (1.00)	1.64^{b} (1.46)	10.51^{d} (3.32)	0.39^{c} (0.94)	1.64^{b} (1.46)	1.63^{c} (1.46)	1.63^{d} (1.46)	1.06^{b} (1.25)	0.00 (0.71)	6.35^{d} (2.62)
T_2	0.00 (0.71)	1.97^{abc} (1.57)	2.34^{a} (1.69)	2.72^{a} (1.79)	1.40^{b} (1.38)	2.43^{a} (1.71)	23.09^{b} (4.86)	1.54^{a} (1.43)	3.49^{a} (2.00)	2.73^{a} (1.80)	3.13^{ab} (1.91)	1.95^{a} (1.57)	0.00 (0.71)	12.84^{a} (3.65)
T_3	0.00 (0.71)	2.46^{a} (1.72)	1.78^{bc} (1.51)	2.55^{a} (1.75)	1.41^{b} (1.38)	2.33^{a} (1.68)	21.92^{b} (4.73)	1.60^{a} (1.45)	3.73^{a} (2.06)	1.96^{b} (1.57)	2.22^{c} (1.65)	1.96^{a} (1.57)	0.00 (0.71)	11.47^{b} (3.46)
T_4	0.00 (0.71)	2.31^{ab} (1.68)	2.02^{ab} (1.59)	2.18^{b} (1.64)	1.42^{b} (1.39)	2.18^{a} (1.64)	26.07^{a} (5.15)	1.09^{ab} (1.26)	3.50^{a} (2.00)	2.55^{a} (1.75)	2.66b^{c} (1.78)	1.59^{ab} (1.45)	0.00 (0.71)	11.39^{b} (3.45)
T_5	0.00 (0.71)	2.07^{abc} (1.60)	1.18^{d} (1.30)	1.24^{d} (1.32)	1.23^{b} (1.32)	2.13^{a} (1.62)	18.40^{c} (4.35)	0.82^{bc} (1.15)	3.54^{a} (2.01)	2.23^{a} (1.65)	3.25^{a} (1.94)	1.09^{ab} (1.26)	0.00 (0.71)	10.93^{b} (3.38)
T_6	0.00 (0.71)	1.43^{c} (1.39)	1.72^{bc} (1.49)	2.54^{a} (1.74)	1.29^{a} (1.34)	2.16^{a} (1.63)	16.98^{c} (4.18)	0.50^{c} (1.00)	1.80^{b} (1.52)	2.42^{a} (1.71)	2.77^{ab} (1.81)	1.12^{ab} (1.27)	0.00 (0.71)	8.61^{c} (3.02)
Level of significance	NS	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	NS	0.05

T_1 = Tin pot; T_2 = Plastic pot; T_3 = Poly bag; T_4 = Gunny bag lined with polythene; T_5 = Cloth bag; T_6 = IRRI poly bag; JAES = Jute Agriculture Experimental Station (JAES), Manikgonj, KRS = Kishoregonj Regional Station (KRS), BJRI. Figures in parentheses indicate the transformed values Data in column having common letter(s) do not differ significantly at 5% level of significance. NS = Not Significant.

at KRS and JAES, respectively, lowest black band (1.18%) and die back (1.24%) were recorded in the field by using seeds stored cloth bag at KRS. The highest total disease incidence (12.84%) at KRS was recorded by using seeds of plastic pot and the lowest disease incidence (6.35%) was observed at KRS by using seeds stored in tin pot (Table 2).

Effect of seeds stored in different types of containers on field emergence (germination), plant stand, plant height and base diameter in O-9897 at JAES and KRS, BJRI following line sowing method in the field

Different types of storage containers differed significantly in respect of seed germination in O-9897 grown at JAES and KRS of BJRI (Table 3). The highest germination (61.17%) at KRS was recorded by using seeds of tin pot. The lowest seed germination (53.83%) at JAES was recorded by using seeds stored in cloth bag. The highest mean germination of seeds (59.59%) and lowest mean germination (54.75%) of two locations were recorded by using seeds that stored in tin pot and gunny bag lined with polythene, respectively. Increasing of storage time resulted decrease in moisture content, germination and viability. Similar results were reported by Bhattacharyya and Dutta (1972) and Khare et al. (1974).

The highest total number of plant/m^2 (31.73) and lowest plant/m^2 (15.77) were recorded by using seeds stored in gunny bag lined with polythene at JAES and KRS, respectively. Mean total number of plant/m^2 was highest (23.75) and lowest (19.45) of both locations by using seeds of gunny bag lined with polythene and cloth bag, respectively.

The highest plant height (2.97 M) at JAES was recorded by using seeds stored in tin pot. The lowest plant height (2.65 M) at KRS was recorded by using seeds that are stored in tin pot. The highest mean plant height (2.84 M) and lowest mean plant height (2.75 M) of two locations was recorded by using seeds stored in IRRI poly bag and poly bag, respectively and they were statistically not significant.

Highest base diameter (15.70 mm) at JAES and

Table 3. Effect of seeds stored in different types of containers on field emergence (germination), plant stand, plant height and base diameter in O-9897 at JAES and KRS, BJRI following line sowing method in the field.

Treatment	% Field emergence			Number of plant/m^2			Plant height (M)			Base diameter (mm)		
	JAES	KRS	Mean	JAES	KRS	Mean	JAES	KRS	Mean	JAES	KRS	Mean
T_1	58.00^a	61.17^a	59.59^a	26.60	20.53^b	21.92	2.97	2.65	2.81	15.70^a	14.45^b	15.08
T_2	55.50^{ab}	56.83^{bc}	56.17^{ab}	23.33	16.50^c	19.92	2.87	2.67	2.77	15.34^a	13.95^b	14.65
T_3	57.67^a	58.50^{abc}	58.09^{ab}	21.93	23.10^a	22.52	2.76	2.73	2.75	15.46^a	14.23^b	14.85
T_4	54.50^{ab}	55.00^c	54.75^b	31.73	15.77^c	23.75	2.85	2.77	2.81	15.06^{ab}	15.31^a	15.19
T_5	53.83^b	60.50^{ab}	57.17^{ab}	22.40	16.50^c	19.45	2.75	2.76	2.76	15.03^{ab}	13.76^b	14.40
T_6	57.67^a	59.33^{ab}	58.50^{ab}	23.33	17.23^c	21.93	2.92	2.76	2.84	14.55^b	14.35^b	14.45
Level of significance	0.05	0.05	0.05	NS	0.05	NS	NS	NS	NS	0.05	0.05	NS

T_1 = Tin pot; T_2 = Plastic pot; T_3 = Poly bag; T_4 = Gunny bag lined with polythene; T_5 = Cloth bag; T_6 = IRRI poly bag; JAES = Jute Agriculture Experimental Station (JAES), Manikgonj, KRS = Kishoregonj Regional Station (KRS), BJRI. Data in column having common letter(s) do not differ significantly at 5% level of significance. NS = Not Significant.

lowest base diameter (13.76 mm) at KRS were recorded by using seeds that stored in tin pot and cloth bag, respectively. The highest mean base diameter (15.19 mm) and lowest mean base diameter (14.40 mm) of two locations were recorded in gunny bag lined with polythene and cloth bag storing seeds, respectively (Table 3).

Effect of seeds stored in different types of containers on fibre and stick yield per plant and hectare in O-9897 at JAES and KRS, BJRI following line sowing method in the field

The highest fibre yield/plant (13.33 gm) at JAES was recorded by using seeds that stored in plastic pot and IRRI poly bag and fibre yield/ha (3.16 ton) at KRS was recorded when seeds stored in gunny bag lined with polythene. The lowest fibre yield/plant (7.00 gm) and fibre yield/ha (1.39 ton) at KRS were recorded by using seeds stored in IRRI poly bag. The highest mean fibre yield/plant (10.75 gm) and fibre yield/ha (2.98 ton) of both locations were recorded by using seeds of gunny bag lined with polythene. Highest stick yield/plant (24.83 gm) and stick yield/ha (6.14 ton) at JAES were recorded when seeds stored in tin pot and plastic pot, respectively. The lowest stick yield/plant (19.33 gm) and stick yield/ha (4.33 ton) at KRS were recorded by using seeds stored in gunny bag lined with polythene and poly bag, respectively. The highest mean stick yield/plant (24.67 gm) and stick yield/ha (5.91 ton) of both locations were recorded when seeds stored in IRRI poly bag and plastic pot, respectively (Table 4).

Effect of seeds stored in different types of containers on number of branch and pod per plant in O-9897 at JAES and KRS, BJRI following line sowing method in the field

The highest branch (3.67) at JAES was recorded by using seeds of tin pot and highest pod/plant (24.67) at JAES was recorded with seeds stored in plastic pot. The lowest branch (2.67) was recorded by using seeds stored in gunny bag lined with polythene and IRRI poly bag storing seeds at KRS and JAES, respectively and pod/plant (17.67) at JAES was recorded by using seeds of gunny bag lined with polythene (Table 5). The highest mean branch (3.50) and pod/plant (22.34) of two locations were recorded by using seeds that stored in tin pot and plastic pot, respectively. The lowest mean branch (2.67) and pod/plant (17.90) of two locations were recorded by using seeds stored in IRRI poly bag and cloth bag, respectively.

Effect of seeds stored in different types of containers on seed yield per plant and per hectare in O-9897 at JAES and KRS, BJRI following line sowing method in the field

Different types of storage containers differed significantly in respect of seed yield in O-9897 grown at JAES and KRS of BJRI (Table 6). The highest seed yield/plant (5.20 gm) and seed yield/ha (388.12 kg) at KRS were recorded when seeds were stored in IRRI poly bag and tin pot,

Table 4. Effect of seeds stored in different types of containers on fibre and stick yield per plant and hectare in O-9897 at JAES and KRS, BJRI following line sowing method in the field.

Treatment	Fibre yield (gm/plant)			Stick yield (gm/plant)			Fibre yield (t/ha)			Stick yield (t/ha)		
	JAES	KRS	Mean	JAES	KRS	Mean	JAES	KRS	Mean	JAES	KRS	Mean
T_1	10.00^{b}	7.50^{cd}	8.75^{c}	24.83^{ab}	23.33^{a}	24.08^{a}	2.80^{ab}	3.16^{a}	2.98^{a}	6.14^{a}	5.67^{a}	5.91^{a}
T_2	13.33^{a}	8.00^{c}	10.67^{a}	21.50^{cd}	19.50^{c}	20.50^{bc}	2.33^{b}	2.02^{bc}	2.18^{b}	5.58^{b}	5.18^{ab}	5.38^{b}
T_3	10.00^{b}	9.00^{b}	9.50^{bc}	23.17^{bc}	20.17^{c}	21.67^{b}	2.19^{b}	2.57^{b}	2.38^{ab}	5.05^{c}	4.33^{b}	4.69^{d}
T_4	10.00^{b}	11.50^{a}	10.75^{a}	21.00^{d}	19.33^{c}	20.17^{c}	3.08^{a}	2.48^{bc}	2.78^{ab}	4.95^{c}	5.14^{ab}	5.05^{c}
T_5	10.00^{b}	7.50^{cd}	8.75^{c}	21.00^{d}	22.16^{b}	21.58^{b}	3.08^{a}	1.90^{cd}	2.49^{ab}	5.63^{b}	4.63^{b}	5.13^{c}
T_6	13.33^{a}	7.00^{d}	10.17^{ab}	25.67^{a}	23.67^{a}	24.67^{a}	2.66^{ab}	1.39^{d}	2.03^{b}	5.91^{ab}	4.91^{ab}	5.41^{b}
Level of significance	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05

T_1 = Tin pot; T_2 = Plastic pot; T_3 = Poly bag; T_4 = Gunny bag lined with polythene; T_5 = Cloth bag; T_6 = IRRI poly bag; JAES = Jute Agriculture Experimental Station (JAES), Manikgonj, KRS = Kishoregonj Regional Station (KRS), BJRI. Data in column having common letter(s) do not differ significantly at 5% level of significance.

Table 5. Effect of seeds stored in different types of containers on number of branch and pod per plant in O-9897 at JAES and KRS, BJRI following line sowing method in the field.

Treatment	Number of branch/plant			Number of pod/plant		
	JAES	KRS	Mean	JAES	KRS	Mean
T_1	3.67	3.33	3.50	20.00^{b}	19.40^{ab}	19.70^{b}
T_2	3.33	3.00	3.17	24.67^{a}	20.00^{a}	22.34^{a}
T_3	3.67	3.27	3.47	19.00^{bc}	20.70^{a}	19.85^{b}
T_4	3.00	2.67	2.84	17.67^{c}	18.50^{bc}	18.09^{c}
T_5	3.00	3.00	3.00	18.00^{c}	17.80^{c}	17.90^{c}
T_6	2.67	2.67	2.67	17.67^{c}	19.50^{ab}	18.59^{bc}
Level of significance	NS	NS	NS	0.05	0.05	0.05

T_1 = Tin pot; T_2 = Plastic pot; T_3 = Poly bag; T_4 = Gunny bag lined with polythene; T_5 = Cloth bag; T_6 = IRRI poly bag; JAES = Jute Agriculture Experimental Station (JAES), Manikgonj, KRS = Kishoregonj Regional Station (KRS), BJRI. Data in column having common letter(s) do not differ significantly at 5% level of significance. NS = Not Significant.

respectively. The lowest seed yield/plant (3.50 gm) and seed yield/ha (304.55 kg) were recorded by using seeds stored in gunny bag lined with polythene and poly bag at KRS and JAES, respectively. The highest mean seed yield/plant (4.78 gm) and seed yield/ha (368.44 kg) of both locations were recorded by using seeds stored in tin pot (Table 6).

The reduction of seed yield, fibre yield and stick yield might be due to the diseases of jute (seedling blight, anthracnose, black band, stem rot, die back, mosaic, root knot and soft rot) causing death of seedling, spread of diseases to standing crops and killing of even matured plants. The loss in yield and quality of fibre and seed yield due to major disease of jute has also been reported by others (Ahmed, 1966; Ahmed et al., 1980).

Table 6. Effect of seeds stored in different types of containers on seed yield per plant and per hectare in O-9897 at JAES and KRS, BJRI following line sowing method in the field.

Treatment	Seed yield (gm/plant)			Seed yield (kg/ha)		
	JAES	KRS	Mean	JAES	KRS	Mean
T_1	4.56^{a}	5.00^{ab}	4.78	348.75^{a}	388.12^{a}	368.44^{a}
T_2	4.00^{bc}	4.00^{bc}	4.00	314.34^{bc}	345.62^{ab}	329.98^{bc}
T_3	3.67^{c}	4.33^{abc}	4.00	304.55^{c}	334.55^{ab}	319.55^{c}
T_4	3.60^{c}	3.50^{c}	3.55	313.65^{bc}	313.65^{b}	313.65^{c}
T_5	3.66^{c}	4.00^{bc}	3.83	334.25^{ab}	324.65^{b}	329.45^{bc}
T_6	4.20^{ab}	5.20^{a}	4.70	337.56^{ab}	355.12^{ab}	346.34^{ab}
Level of significance	0.05	0.05	NS	0.05	0.05	0.05

T_1 = Tin pot; T_2 = Plastic pot; T_3 = Poly bag; T_4 = Gunny bag lined with polythene; T_5= Cloth bag; T_6 = IRRI poly bag; JAES = Jute Agriculture Experimental Station (JAES), Manikgonj, KRS = Kishoregonj Regional Station (KRS), BJRI. Data in column having common letter(s) do not differ significantly at 5% level of significance. NS = Not Significant.

Therefore, the following conclusion may be drawn for quality seed and fibre production from the findings of this study:

i. Quality and maximum seed and fibre production depend upon storage containers, duration and environmental condition,
ii. Fibre and seed yield were found to decrease with the increase of seed borne infection of fungal pathogens.

So, the following recommendation may be drawn for quality seed and fibre production from the findings of this study:

i. Quality of jute seeds can be maintained by storage in tin pot and proper moisture content (9.5%).

Conflict of Interest

The authors declare they have no conflict of interest.

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Curricular greening is deficient in universities

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The objective is to describe the environmental awareness of undergraduate courses at Federal Institute of Education in Goias State, Brazil. The data are described using qualitative and quantitative approaches. It is a non-experimental descriptive research. Among the 201 disciplines from courses of Animal Science, Chemistry and Biology and Bachelor Degree areas, only 17 were found, that is, 8.4% had features that characterize the concern with the commitment to the transformation of relations between society and nature.

Key words: Curriculum, network environmentalization, sustainability in Higher Education.

INTRODUCTION

Tbilisi Conference (1977) achieved in the domain of International Environmental Education Programme (PIEA), coordinated by the United Nations for Education, Scientific and Cultural Organization (UNESCO) and United Nations Environment Programme (UNEP), and has summoned Member States to include curricular adjustment in their policies of environmental suitability. The conference recommended that the Environmental Education (EE) should understand the entire context of the levels of school education and adopt a global focus and marked out a wide interdisciplinary basis, from which one takes the interdependence of ecological, social economic and cultural factors.

With support in the Chicago Statement, prepared at the International Conference of Holistic Educators, it appeared in 1997 the term Holistic Education (Perini-Santos, 2004). According to this Declaration, the educational processes of the twenty-first century should be supported in the fundamentals of holism. It emphasizes the challenge of promoting a sustainable, equitable and peaceful society in harmony with the earth and its life. The holistic view seeks to enhance the way we visualize and the interdependence we have with the world, magnifying our innate human potential: The intuitive, emotional, physical, imaginative and creative as well as rational, logical and verbal.

The environmentalization of the university covers besides teaching, research and extension also human relations and environmental management of the campus, because a dynamic process of sustainable educators

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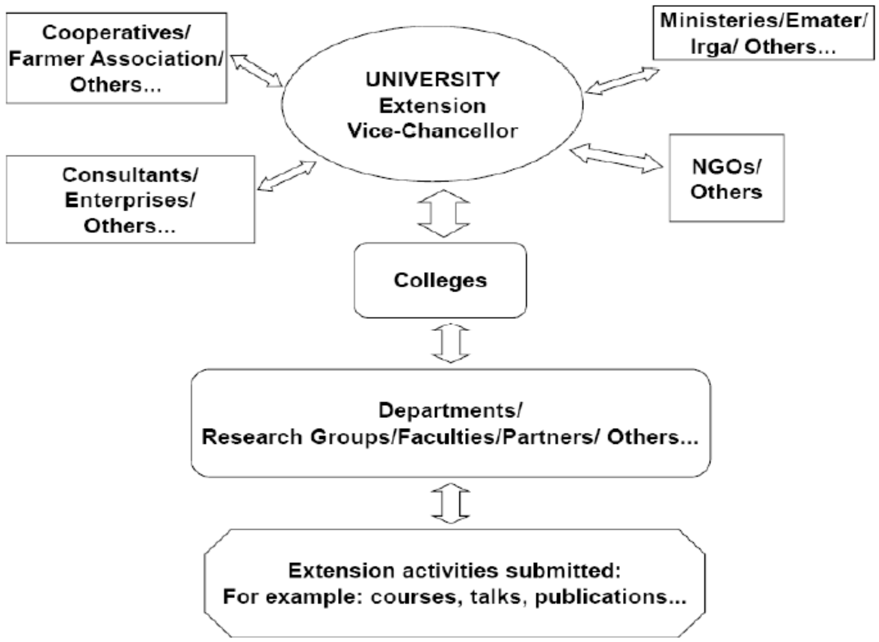

Figure 1. Experimental approach to transfer research information in a Brazilian public university system. Source: adapted from Marchesan et al. (2010).

spaces (Guerra, 2014).

Since the 90s of the twentieth century a cumulative number of higher education institutions (HEIs) have been engaged in incorporating and institutionalizing sustainable development (SD) into their curricula, study, actions, outreach, rating and reporting. In spite of a number of efforts by HEIs, SD is still an innovative idea in most universities, and has not yet permeated into all disciplines, scholars, and university managers, or throughout the curricula (Lozano, 2010).

The lack of communication between researchers of institutions and various users of technology limited the usefulness of research done to initially develop the technology. The interactions between the various users allow for anticipation of future potential needs, identifying new agribusiness opportunities (Marchesan et al., 2010).

According to the authors technology validation is fundamental, not only to producers and technicians, but also to researchers. In some cases, technology adaptations are necessary due differences in climate conditions, soil characteristics, field management methods, farm culture.

There are several systems of technology transfer for rural areas. One is the Training and Visiting (T&V) was used in many developing countries from 1975 to 1998, especially in Africa and Asia with the objective of helping increase the adoption of Green Revolution technologies. It was a rigorous training program demanding discipline and leadership. The system was called top down technologies, without interaction with the community where it was implemented (Marchesan et al., 2010). In this respect, the objective of this study was to describe the environmental awareness in the curriculum and the curriculum of undergraduate courses of the Goiano IF, Rio Verde Campus, Goias State, Brazil.

The question is how to effect a plan of action for the Brazilian agricultural systems. An approach is presented below (Figure 1), in which there research groups consolidated within the Brazilian university system.

The research problem arose from question: what characteristics of greening nine graduate courses in the Goiano IF, when considering Network Greening Curriculum in Higher Education.

MATERIALS AND METHODS

To describe the curricular environmentalization, reports coming from the web site of discipline plans and courses plans were carried out. The data is described using diffusion of innovation theory. The level of adjustment in the formation of undergraduates was verified to know about the introduction level on thematic areas of environmental nature. This information was obtained by describing the curriculum and teaching plans of undergraduate disciplines to diagnose the theme environment. The descriptionof the subjects occurred at two levels of complexity. Condition 1: Environmental characteristics of teaching plans (menus, objectives, contents and references) from the disciplines of the undergraduate courses. Condition 2: Environmental characteristics of the curriculum (menus, objectives, contents and references) of undergraduate courses.

The investigation about the adjustment of education in Rio Verde Campus, was conducted with all nine undergraduate courses that existed on campus in 2011. It was taken as reference of two sources of information of institutional nature, namely the

Table 1. Ten characteristics of an environmentalized course.

Characteristics	Understanding of its meaning	P	M
Commitment to transform society-nature relations	Reconstruction of attitudes, individual and collective practices that generate actions to transform the socio-cultural and natural environment		
Complexity (worldview)	Presence of complex thought and of the interdisciplinar paradigm in the way of looking, feeling and being in the world		
Disciplinary order: flexibility/ permeability	Facilitate dialogue with the differences of philosophical, metaphysical and epistemological positions in a permanent analysis of the training processes		
Contextualize the local-global-local	Integrate the knowledge / concepts to daily social life		
Consider the subject in building knowledge	Build diverse environment for the manifestation of personality differences, which ensures the participation of students in the intellectual and emotional field		
Consider cognitive / affective aspects of those involved	Provide material, structural, pedagogical, psychological support to form skills, construct knowledge and produce forms of expression (art, philosophy, religion, politics)		
Consistency and reconstruction of theory and practice	Exercise of reflection in knowledge production that combines theoretical and practical movements		
Forward-looking of alternative scenes	Commitment with building visions of science, society, technology and environment in a responsible perspective with the current and future generations		
Methodological adequacy	Link between educational practices and theories that justify them, from evaluative models that support the link		
Space for reflection and democratic participation	Creation of strategies for democratic participation, with autonomy to make decisions and implement them (political, administrative, material, economic support)		

Source: Adapted from Freitas et al. (2003).

Curriculum Matrix (M) and Plans for Teaching Subjects (P).

From the explicit understanding of the ten characteristics (Table 1), was adapted the theory proposed by Lozano (2010), because the author focuses on the SD incorporation into curricula.

Taking as references the scales M (curriculum of undergraduate courses) and P (teaching plans of undergraduate courses) sought to identify the presence of indicators for the ten characteristics to nine undergraduate courses that the Rio Verde Campus offers to the community. For the scale M, which described the number one characteristic of an environmentalized course, it described the curriculum menus, objectives, contents and references; to the scale P, which described the other nine features which verified the characteristics of an environmentalized course, it described the menus, objectives, contents and references of the disciplines that constitute the undergraduate courses.

Data description was performed using a IBM SPSS Statistics software 19.0 and Microsoft Office Excel 2007 software.

RESULTS

From the curriculum description (menus, objectives, contents and references) it was found that environmental management course showed greater integration into a curriculum characteristic 1: Commitment to the transformation of society-nature relations. This is probably is related to the nature of knowledge since the objective of study in this area has an extremely close connection with issues related to the relationship between society and nature. In view of this specificity, the number of subjects which had an explicit concern with this characteristic was significant (66.6%), that is, of the 54 subjects that were analyzed, 36 of them study the relationship between society and nature (Figure 2).

On the other hand, when looking at areas of Bachelor (animal science, chemistry and biology) Licenciature (chemistry and biology), Engineering (agronomy) and Technology (agribusiness, environmental management and grain production), it was found that the number of environmentalized subjects in the curriculum per area was very low. Among the 201 disciplines from courses of Animal Science, Chemistry and Biology, Bachelor Degree areas, only 17 were found, that is, 8.4% had features that characterize the concern with the characteristic 1 (commitment to the transformation of relations between society and nature) (Figure 2). Among 133 disciplines

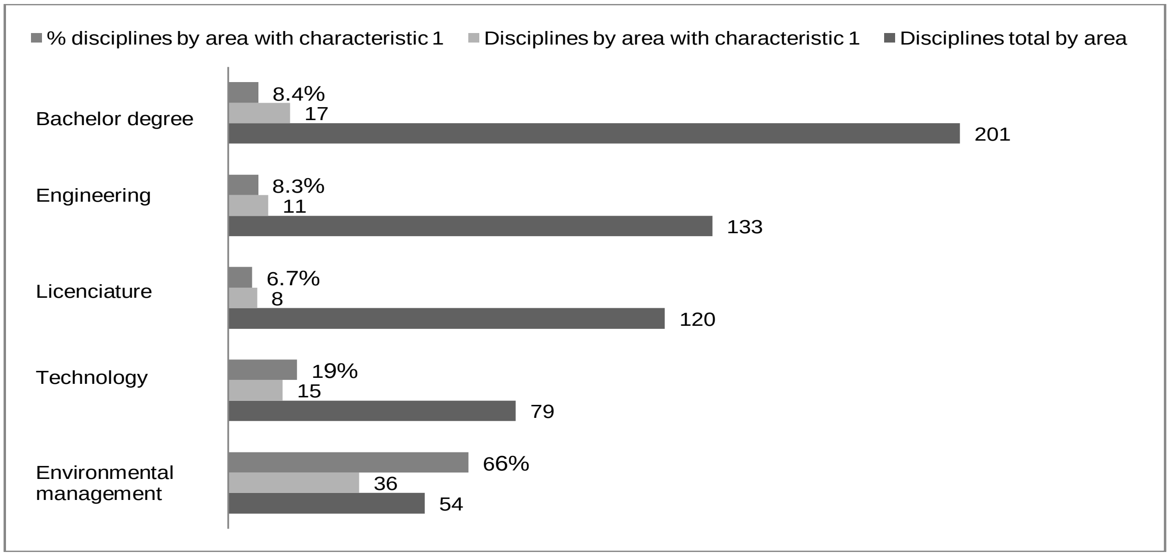

Figure 2. Subjects in the curriculum of nine undergraduate courses in Rio Verde Campus in 2011, which had a concern with the characteristic 1 for an environmentalized course. Source: Survey data using the Microsoft Office Excel 2007 software and IBM SPSS Statistics software 19.0.

Table 2. Teaching plans of 10 undergraduate courses concerned with 9 characteristics for an environmentalized course in 2011.

Área	Technology	Engineering	Bachelor degree	Licenciature	EM
Total of 9 characteristics	77	68	55	40	175
Average of 9 characteristics	8.5	7.5	6.1	4.4	19.4
% average of 9 characteristics	7.9	11.0	11.1	11.0	11.1

Source: Survey data using the Microsoft Office Excel 2007 software and IBM SPSS Statistics software 19.0.

from courses of Agronomy and Food Science, Engineering area, only 11 have characterized this concern with the characteristic 1 or 8.3%. Among the 120 subjects analyzed in Chemistry and Biology courses, Licenciature area in Rio Verde Campus, had eight points that characterize the concern with the characteristic 1, that is, only 6.7%.

Among the 79 disciplines from courses of Agribusiness and Grain Production in the area of Technology, 15 subjects, that is, 19% of the subjects marked the characteristic one (Figure 2). Among the 54 subjects of the Environmental Technology course, 36 subjects, or 66% of the subjects marked the characteristic one. For the classification of necessary information on teaching plans in the other nine characteristics, it was analyzed the disciplines of the undergraduate courses.

Among the 79 disciplines from courses of Agribusiness and Grain Production, Technology area, the average was 8.5 characteristics for the other nine characteristics of an environmentalized undergraduate course, whose average was equivalent to 7.9% of 77 characteristics (Table 2).

Among 133 disciplines from courses of Agronomy and Food Science, Engineering area, the average was 7.5 characteristics for the other nine characteristics of an undergraduate course environmentalized, whose average was equivalent to 11% of the 68 characteristics. Then from 201 subjects of Animal Science, Chemistry and Biology, Bachelor Degree courses, the average was 6.1 characteristics for the other nine characteristics of an undergraduate course environmentalized, whose average amounted to 11.1% of the total 55 characteristics. From 120 subjects analyzed in Chemistry and Biology, courses of Technology, the average was 4.4 for the other nine characteristics of an undergraduate course environmentalized, whose average was equivalent to 11% of 40 characteristics. Among the 54 subjects from the of Environmental Management course (GA), the average was 19.4 characteristics for the other nine characteristics of an undergraduate course environmentalized, whose average amounted to 11.1% of the total of 175 characteristics. Analyzing the percent average of these 9 characteristics, it was found that the lowest value was Technology area, with a value of 7.9%. For the other four areas these percentages were equivalent to 11%.

DISCUSSION

A fact which may help interpret this significant result of Environmental Management course was the marked presence in offering disciplines about environmental chemistry, environmental biology, environmental management, agroecology and solid waste.

A fact that could help interpret this result slightly lower in Licenciature area compared to other areas is the marked absence in offering disciplines about environmental chemistry, environmental biology, environmental management, agroecology and solid waste in teaching plans of Licentiateship in Chemistry and Biology.

For all areas analyzed, did not occur the offering of elective subjects. Elective subjects were offered only for the Agronomy course from the second half of 2010. The compulsory subjects corresponded to approximately 100% of the curriculum of all other undergraduate courses.

In a study conducted in teaching plans of undergraduate courses at the University of Santiago de Compostela in Spain, Garcia (2001) found that teaching plans of the degree in Biology, Technical Engineering in forestry and degrees in Pharmacy and Chemistry were those who had the highest levels of environmentalization, with values that reached 27.4, 18.2, 11.9 and 10.7% of subjects, respectively. On the other hand, the curriculum of the Degrees in Law and Political Science did not have environmentalized disciplines, while a degree in Economics had 0.83% of subjects environmentalized. Averaging environmentalized disciplines of all undergraduate courses, this author found that the average total was equal to 10.2%.

In a research carried out in a Brazilian public university, Zuin et al. (2009) found that the total number of subjects (sample = 43) which composed the curriculum of the undergraduate course in Chemistry, 30% were directed to curricular environmentalization.

These results are similar to those obtained by Lozano (2010) on that study conducted in teaching plans of undergraduate courses; this author reported that the percentage of courses relating to SD has an important influence on the school's adopter categories. This indicates that the contribution to SD and its diffusion throughout the curricula is a fairly complex phenomenon that requires the consideration of economic, environmental, social, cross-cutting themes, and their inter-connectedness, as well as the percentage of courses in a school that relate to SD.

Conclusions

Between 201 disciplines from courses of Animal Science, Chemistry and Biology and Bachelor Degree areas, only 17 were found, that is, 8.4% had features that characterize the concern with the commitment to the transformation of relations between society and nature. Between the 54 subjects from the of Environmental Management course (GA), the average was 19.4 characteristics for the other nine characteristics of an undergraduate course environmentalized, whose average amounted to 11.1% of the total of 175 characteristics. The ten characteristics for an undergraduate degree considered with environmentalization have low percentages in technology courses in Agribusiness and Grain Production. The presence of the Technology courses suggested that this factor is determinant in the process of curricular environmentalization. The campus did not develop a policy that allows connection to empower the process environmentalization of the different undergraduate courses. There is definition of a set of elective subjects only in the course of Agronomy, occurring only from the second half of 2010. It is essential to reconstruct the practices of teaching and learning that occur in Goiano IF and in rural extensions. Given the premise that the processes of teaching and learning need to aim to methodology that results in a more sustainable society and more collective and humanitarian, becomes necessary a practice centered on dialogic communication together with farmers, in order to organize a new reality for the rural environment. The demarcation of new policies for sustainable agricultural development suggests that it is fundamental a method of production that is not only rooted in the transfer of technology through extension of the traditional and frequent exercise. The Federal Institutes of Education in Brazil should employ in their daily teaching participatory methods of joint construction of new knowledge between extension agents and farmers; the description provided in this research indicates that there is insecurity in the standing interconnections synergies that exist between the economic, social and transversal themes. The figure is indispensable for educators and teachers in continuing education for professionals with undergraduate course focusing on the extension aimed at disseminating environmental technologies directed to rural areas of Brazil.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

The organizational capabilities of rural enterprises, incremental innovation, and the university's contribution

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This paper analyzes the relationship between the market orientation and the entrepreneurial orientation in regards to the business performance of rural enterprises, considering the mediation of incremental innovation process and the moderation of the amount of employees with university level, as well as the collaboration needed between the university and the enterprise in terms of organizational capabilities. A survey using Likert scales was employed, composing items of latent variables of a reflective-formative structural model. The sample of 208 Brazilian rural enterprises was processed using the structural equation models by the partial least squares method in predicting the results. The verification of empirical data provides evidence to confirm the theoretical model and hypotheses. The strong use of organizational capabilities leads to an improved business performance. Incremental innovation has no mediating effect on organizational capabilities and business performance. The university staff does not moderate the organizational capabilities to improve business performance. The collaborative relationship between the university and the enterprise moderates the relationship between entrepreneurial orientation and business performance. The limitation of the study is the restriction of the sample and that the results should not be generalized to other regions; however, they present significant practical implications of the importance of relationships between the university and the enterprise.

Key word: Entrepreneurial orientation, market orientation, incremental innovation, business performance, partial least squares.

INTRODUCTION

In order to obtain greater competitive advantage and remain in agribusiness, rural businesses must implement a set of actions to explore opportunities, adjust and adapt production processes and products to buyers' needs through continuous attention to innovation efforts, leading to a better business performance (Hult et al., 2004).

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Changes in the competitive environment, along with new demand from buyers and the incorporation of new technologies and products have led to uncertainties and turbulent environments (Atuahene-Gima and Ko, 2001). The market orientation is a company's response to improving its efficiency and effectiveness (Narver and Slater, 1990). In addition, an entrepreneurial posture emerges with prospects of new opportunities in either processes or products, assuming calculated risks (Wiklund and Shepherd, 2005). These organizational capabilities must be balanced and combined with the innovation process, so that its effects are reflected in the business outcome. On the other hand, for the innovation process, companies need to acquire trained personnel who bring in knowledge, such as a stronger link with institutions like the university that facilitates innovative efficiency. This study focuses on Brazilian rural enterprises, as they represent a key sector in the Brazilian economy. Rural businesses are the producers of the agriculture and livestock sectors and account for 23% of GDP, 27% of jobs, and 44% of Brazilian exports (CEPEA, 2014). Brazil is the third largest global producer of chickens, has the second largest cattle herd in the world, occupies the top ranking in soybean foreign sales, and its grain production is estimated to reach 193.8 million tons in 2014 (Brazil, 2013). With the growth of management and technology in rural enterprises, this sector has gained economies of scale with rural entrepreneurs becoming specialized, and the industry of agricultural equipment expanding and new production technologies introduced (Buainain et al., 2014).

Given these featured observations of the Brazilian agribusiness, this research seeks to understand the processes of competitive development in rural enterprises, adjusting them to the market and innovations; considering the support and provision of qualified personnel and the transfer of knowledge offered by the university. The objectives of this paper are to analyze rural enterprises relationships based on the use of market orientation, entrepreneurial orientation, and the mediation of incremental innovation in business performance; and analyze the effect of moderating university staff training as well as the university-enterprise relationship based on organizational capabilities and business performance.

The results achieved provide a substantial basis for the establishment and strengthening of public policy, technology and management, adding to the possible connections of universities using the triad of teaching, research and extension, effectively and contributory way the development of rural enterprises.

The main contribution of this paper comes from the analysis of the strategic capabilities of rural enterprises, an economic sector of great importance to a developing country, with few specific academic studies in the empirical understanding of how they get the knowledge and skills necessary to extend the technology and management, joint with input suppliers, machinery and equipment, and how to incorporate knowledge by hiring university graduates and, the use of infrastructure and research universities

Organizational capabilities

Organizational capabilities are those that give the company an understanding of its business environment and of competitive actions that are essential to support the needs and desires of buyers, taking advantage of opportunities that arise for new processes and products.

Market orientation

The market orientation (MO) has the characteristic of providing maximum value to the buyer, which results in determining the competitive advantage and the focus on innovation. For Narver and Slater (1990), MO is an ongoing process in the pursuit of efficiency and organizational effectiveness that develops organizational behaviors as a response to exogenous factors of the market that affect current and future needs and desires of buyers (Lee and Tsa, 2005). Thus, the market orientation contributes to the organizational capabilities of the company when it delivers the most value to the buyer, optimizing its internal and external processes (Hult et al., 2004), which influence the improvement of the company's operation (Beheshti, 2004) and has a tendency to improve business performance (Kohli and Jaworski, 1990).

Entrepreneurial orientation

The entrepreneurial orientation (EO) from the company's point of view is to adopt strategies that differ from the others. Covin and Slevin (1991), Lumpink and Dess (1996), and Wiklund and Shepherd (2005) agree that EO is a combination of three sub-dimensions: Innovation, proactiveness, and risk acceptance. The welcoming of entrepreneurial strategies reflects the combination of competitive actions and creativity in order to achieve higher levels of technology and business management, capitalizing on opportunities to be a pioneer before competitors (Venkatraman, 1989).

In entrepreneurial orientation (EO), innovation applied in the company and understood as the power of originality and creativity, reflects the competitive actions to support new ideas, discoveries, experiments, and the creation of processes and products different from existing practices and technologies (Wiklund and Shepherd, 2005). If there is an understanding that EO is a competitive feature of the company, it can contribute to business performance.

Incremental innovation

Incremental Innovation (II) can be understood as the action of the company in making small changes in technology and management, enabling improvements in customer benefits. This innovation arises because of the reduction in risk due to the certainty of the common market and the objective related to clients' needs (Valle and Vázquez-Bustelo, 2009). This type of innovation is characterized by small technical changes supported by knowledge, experience, and existing capabilities in the company. II contemplates adding value to the company through the incorporation of new processes and products; improved relationships with suppliers and buyers; and new procedures and methods of management, marketing, organization and market strategies. Incremental Innovation has aspects related to processes, products, and management that are also linked to MO. In addition, when looking outside of the company in regards to changes in competitors and buyers, their competitive strategies may include EO. The assumption of mediation relationships between II, MO, and EO suggests the following hypotheses:

H_{1a}: The incremental innovation (II) can mediate the relationship between market orientation (MO) and business performance (BP).
H_{1b}: The incremental innovation (II) can mediate the relationship between entrepreneurial orientation (EO) and business performance (BP).
H_2: Incremental innovation (II) positively influences Business Performance (BP).

The university's role in business performance improvement

The university is recognized as the main generator of knowledge and of its dissemination to interested parties. It has the necessary infrastructure and complementary resources to meet the needs of the research and development demanded by entrepreneurs for both the basic and specific knowledge (Bjerregaard, 2009); necessary foundations in order to reinforce technical competences of firms and to collaborate in the resolution of concrete problems of the innovation process (Minshall et al., 2007). Assuming this consideration, the university also plays the role of an economic development agent when interacting with companies and provides means of fostering knowledge transfer. Enterprises establish non-competitive agreements with the university, leveraging cooperative research in order to deepen or solve a real problem, or obtain advantage in a determined market opportunity (Benedetti and Torkomian, 2009).

In general, the university's main contribution to enterprises is the provision of qualified people with basic university education. These graduates may specialize in major activities of the rural business, offering knowledge and skills that will positively reflect on the efficiency and implementation of innovation, as well as on business results. Graduates have solid and flexible education enough to adapt to the needs of technological changes and new requirements of the buyers and society. These professionals transfer to rural business potential for sustainable knowledge to implement any activity in introducing innovation (Audretch and Lehmann, 2006). It is understood that the higher is the staff with university level, the greater the innovation process in rural business (Leiponen, 2006). With this, the following hypotheses are presented:

H3: The higher the number of employees (NE) with a university education, the better the business performance (BP).
H_{4a}: The number of employees (NE) with a university education moderates the positive relationship between market orientation (MO) and business performance (BP).
H_{4b}: The number of employees (NE) with a university education moderates the positive relationship between entrepreneurial orientation (EO) and business performance (BP).

Another contribution made by the university to companies is the provision of professional services, such as consulting, technical support, research, continuous education, and the use of equipment and infrastructure. When determining the cooperation between the university and companies, the provision of solutions occurs through an exchange of technical-scientific knowledge and through business practice, requiring considerable efforts from both parties to achieve expected results (Segatto-Mendes and Mendes, 2006). The use of university services and knowledge by companies can take place in many ways; contributing to developing innovation, which ranges from cooperation technology agreements, research contracts, use of scientific discoveries in new businesses, employment licenses for university patents, consulting, training services for technical and management staff, among others (Tecchio et al., 2010). The different collaboration methods between the university and rural enterprises evaluated in this study are shown in Table 1.

The various forms of cooperation, which may be required by the university, lead to the easiness and the intensity with which a company develops its organizational capacities and its innovation processes. We propose the following hypotheses:

H_5: The greater the collaborative link between the university and the company (Univ), the better the business performance (BP).
H_{6a}: The collaboration between the university and the company (Univ) moderates the positive relationship between market orientation (MO) and business

Table 1. Possible collaboration methods between the university and the rural enterprise.

Type of collaboration	Collaboration factors	Description
Consulting services	Consulting services, technical support	Assistance in different areas of the company
Academic research	Cooperative research; hiring for research; development and innovation (R&D+i). Products licensing; University *spin-off* or *spin-out*	Participation in R&D+i projects; new technologies, processes or products; improvements that are transferred to the market; Creation of businesses based on findings originated in the university
Continuous education and training services	Academic education specific to the professional area; trainings and specific courses; lectures and conferences	Incorporation of academic and scientific personnel in the rural enterprise; Education and training specific to the working personnel, inside or outside the rural enterprise
Infrastructure and equipment	Utilization of infrastructure, laboratories, and scientific equipment	R&D+i activities facilitated through the provision of material resources; offering solutions to technological problems; offer information and services for innovation development
Incorporation of academic scholars	Supply university professionals.	Professional staff made up of university graduates; Offer academic graduates internships and opportunities to put in practice.

Source: Adapted from Rapini (2007) and Ferraretto and Muñoz (2009).

performance (BP).

H_{6b}: The collaboration between the university and the company (Univ) moderates the positive relationship between entrepreneurial orientation (EO) and the business performance (BP).

Proposed theoretical model

Given the considerations obtained from literature and the suggested hypotheses, a proposal for a reflective-formative theoretical model of second order is proposed as shown in Figure 1, in which all variables are treated as latent, without the representation of their reflective items.

MATERIALS AND METHODS

The study began with a review of existing and available literature correlated to the subject. With the theoretical argument obtained, we opted to use the method of hypothetical-deductive research of quantitative nature, testing sets of hypotheses with the primary data collected in rural enterprises in the state of Mato Grosso do Sul, Brazil.

For data collection, a survey was conducted through a questionnaire with items that make up the latent variables used in this paper based on previous studies of organizational capabilities and services provided by universities, containing the identification of the demographic characteristics of rural enterprises. The questionnaire was reviewed by specialized teachers in the subject, and examined and approved by the Ethics Committee for Human Beings (Protocol 440,909 of September 16^{th} 2013). The form was given to rural entrepreneurs or their representatives from February to April 2014, by intermediaries of scholars on their last semester of management, agronomy, and veterinary, as well as by Master's students in production and agribusiness management. The database considered of 208 complete and verified questionnaires collected in 45 out of the 79 existing municipalities in Mato Grosso do Sul, from a collection of 61,664 agricultural establishments (IBGE, 2007). The sampling error is estimated at 6.8% for a 95% confidence level, and has a 50% probability of positive responses. All respondents were assured confidentiality of their responses, and that data would be combined and processed as a whole and used in scientific research.

The latent variables and their independent items followed the main measurement proposals of the explored literature. Collaboration between business-university (Univ) was measured by a dichotomous scale: 1 = Yes, 0 = No, with the possibility of cooperation between them. The NE with a university education is a percentage ratio scale of people with a university degree and the total employees in the rural enterprise. The latent variable of EO was measured by six items proposed by Naman and Slevin (1993), and nine items for MO were indicated by Narver and Slater (1990), both variables using the Likert scale and the 7 points of agreement (1 = strongly disagree to 7 = strongly agree). For II, six items from Wang and Ahmed (2004) were recommended, using the Likert 7-point scale (1 = no innovation to 7 = many innovations). The perceived BP followed the proposal of Gonzáles-Benito et al. (2009) with the Likert 7-point scale (1 = much worse than the competitor to 7 = much better than the competitor). In Table 3 are presented the items that compose the latent variables MO, EO, II, and BP of theoretical model.

A first assessment of the data collected from the 208 questionnaires was carried out to confirm the unidimensionality of the reflective latent variable; in other words, if it could be represented by a factor using the statistical technique of factor analysis, with the varimax rotation method, using SPSS v. 22. The fit of the observed items followed the criteria proposed by Hair et al. (2009). It was considered as a good fit for the latent construct when: The Kaiser-Meyer-Olkin test (KMO) > 0.5 and Bartlett test of sphericity significance with $p < 0.05$; factor loadings > 0.5; Cronbach's alpha, $\alpha > 0.7$; measure of sampling adequacy, MSA > 0.5; communality > 0.5; variance explained (ve) > 50%.

Afterwards, the theoretical model, reflective-type formation (Figure 1), was tested using the SmartPLS 2.0, a software for solving structural equation modeling using the method of partial least squares (Ringle et al., 2005). The choice was based on the characteristics of the proposed model; that of presenting latent variables and items that did not meet the assumption of the normal

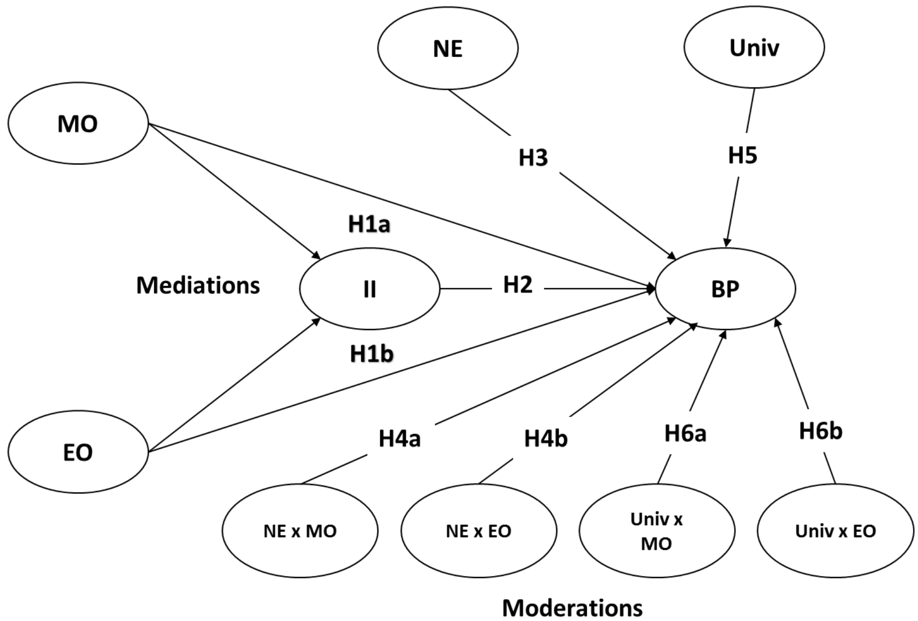

Figure 1. Structured reflective-formative theoretical model of second order and proposed hypotheses.

distribution, and the goal being the prediction of relations of the following latent variables: MO, EO and BP (Hair et al., 2014). This concept of partial least squares provides greater robustness when using the matrices of variance, for this purpose, rather than based on the estimated covariance matrix model, for example, using the AMOS software.

In order to verify the fitting of the measurement model, the procedures and reference values recommended by Ringle et al. (2014) were employed. The convergent validity was verified by the average variance extracted (AVE), accepting the latent variables with AVE > 0.5. The discriminant validity was obtained by comparing the square root of the AVE value of the latent variable with the Pearson linear correlation of other latent variables. There is discriminant validity when the square root of the AVE is greater than the correlation of other latent variables. The reliability of the model was verified by Cronbach's alpha ($\alpha > 0.70$) and the composite reliability (CR) of CR> 0.70.

The consistency of the structural model was performed by verifying the following: The path coefficient, the Pearson coefficient of determination (R^2), and the predictive validity (Q^2), as proposed by Hair et al. (2014). The path coefficients (Γ) represent the links between the latent variables, and are the hypothetical relationships proposed in the model. As the model is tested using correlations (r) and linear regressions, the null hypotheses are for the linear correlations Ho: r = 0, and for the path coefficients Ho: $\Gamma = 0$. If p < 0.05, the null hypothesis is rejected. Thus, these values are standardized and their significance is assessed by the empirical value *t* statistic compared to the two-tailed critical value (t = 1.96) with a 5% significance level, obtained with the bootstrapping technique using 1,000 resampling. The Pearson coefficient of determination (R^2) evaluates the amount of variance that the endogenous variables explain in the model. In the R^2 classification, values of 0.25, 0.50 and 0.75 are considered respectively as weak, moderate and substantial evaluation levels (Hair et al., 2014:175). The predictive validity (Q^2) measures the accuracy of the model, whereas values of 0.02, 0.15 and 0.35 indicate that an exogenous latent variable respectively has a small, medium or large predictive relevance (Hair et al. 2014: 184).

The analysis of the influence of mediation between the independent and dependent variables was performed using the Sobel test, described by Hair et al. (2014), rejecting the hypothesis that the effect is null; therefore assuming the statistic value *z* should be greater than ± 1.96. To obtain the values of path coefficients and of their standard errors, the mediation variable was inserted and removed in the model; both cases being performed.

RESULTS AND DISCUSSION

Sample characterization

The rural business is typified as a production unit with economic activity in the agriculture sector, using to a greater or lesser extent, technologies and management methods in the production process without distinguishing it as a family, employer or business unit or even by their civil classification: Private or limited company. Table 2 summarizes the main segments of the responding companies.

Out of the 208 responses, 71.5% of respondents considered themselves partner or owner, which strengthens the quality of evaluations of organizational capabilities and the relationship with external agents and universities, since they are responsible for the external environmental analysis and their competitive strategies (Porter, 2009) and the use of different skills and resources of companies for the development of new capabilities when facing environmental changes (Barney and Hesterly, 2008).

In regards to their employees' university education, 51.2% have not completed this level. When checking the

Table 2. Demographic characteristics of the sample of rural enterprises.

Indicator	Variable	Nº	Variable %
Respondent	Partner/owner	149	71.5
	Director/supervisor/manager	48	23.2
	Other position	11	5.3
Area of rural enterprise	Up to 100 ha	56	27.1
	101 to 1,500 ha	102	48.8
	More than 1,500 ha	50	24.2
Number of employees	Up to 9	156	74.9
	10 to 19	27	13.0
	20 to 49	17	8.2
	More than 50	8	3.8
Percentage of employees with a university degree	0%	106	51.2
	1 to 20%	55	26.6
	21 to 40%	25	12.1
	41 to 80%	22	10.1
Activity sector of the rural enterprise	Agriculture	65	31.2
	Livestock	143	68.8

crossing between categorical variables of the rural business area versus the percentage of employees with a university education using the chi-square test, it was observed that there are significant differences between them (χ^2 = 28.867, gl = 12, p = 0.004); indicating that the larger the area of the rural business, the higher the number of staff with a university degree. These results may indicate the possible difficulty of implementing innovations (Tecchio et al., 2009) or to provide the basis of scientific knowledge for exploring the external technologies and their relationship with universities (Reis, 2008; Leiponen, 2006), especially for small rural enterprises.

Exploratory factor analysis of the latent variables

A factorial evaluation separate of the latent variables EO, MO, II and BP was performed, calculating Cronbach's measure of alpha reliability for the set of items at the discretion of the elimination of the item that would undermine the reliability of the set. The concepts NE and Univ are composed of only one item; therefore their reliability indicators and factoring were not calculated (Table 3). Items that have not reached communalities ≥ 0.500 were removed. It appears that the extracted indicators of the exploratory factor analysis provide higher values than those considered as a good fit of the data; accepting the reflective measurement model of the latent variable with its items, assuming the EO, MO, II, and BP unidimensionalities.

Analysis of theoretical model

The theoretical model was verified with the help of SmartPLS 2.0 and converged after five interactions, when a stable model was found. The discriminant validity in the estimation of independence among latent variables was performed using the Fornell-Larcker criterion, described in the works of Ringle et al. (2014: 63) and Hair et al. (2014:105-106). The values indicated in Table 4 provide evidence of discriminant validity, since the square roots of AVEs are greater than the Pearson correlations between the latent variables.

The convergent validity of the model as indicated in Table 4 and verified by the AVEs of the latent variables, are greater than 0.50. The values of AVEs explain that the items are positively correlated with their respective latent variables, assuming the model is directed towards a satisfactory result. The internal consistency assessed by composite reliability (CR) and by Cronbach's alpha has values above 0.70, appropriate to state that the sample is reliable to represent the model.

Still in Table 4 in the evaluation of the structural model, the Pearson coefficients of determination (R^2), which determine the portion of variance explained in the exogenous variables, have values considered as moderate effect according to Hair et al. (2014) for II (R^2= 0.426) and for BP (R^2= 0.362). The quality of the prediction of the model evaluated by Q^2 indicates that for both endogenous latent variables BP (Q^2= 0.240) and II (Q^2= 0.262), the predictive relevance is between medium and high, justifying a good model. Therefore, with the

Table 3. Measurements for commonalities and reliability of latent variables and its items.

Latent variable	Items	Commonalities	Indicators
Incremental innovation (II)	Q15a Strategy	0.623	KMO = 0.866
	Q15b Management	0.714	Bartlett = 617.32
	Q15c Organization	0.689	p ≤ 0.001
	Q15d Marketing	0.575	MSA ≥ 0.843
	Q15e Productive Processes	0.639	ve = 63.3%,
	Q15f Product	0.557	α = 0.880
Entrepreneurial orientation (EO)	Q19a Release of new agricultural products	0.814	KMO = 0.867
	Q19b Change in agricultural production method	0.699	Bartlett = 756.98
	Q19c Anticipate competitors' actions	0.876	p ≤ 0.001
	Q19d Competitive posture	0.889	MSA ≥ 0.816
	Q19e High risk projects with high benefits	0.841	ve = 68.5%,
	Q19f Courageous and aggressive posture	0.833	α = 0.907
Market orientation (MO)	Q20a Market information	0.654	
	Q20b Information about competitors' strategies	0.541	KMO = 0.851
	Q20c Information about buyers' satisfaction	0.707	Bartlett = 836.84 p ≤ 0.001
	Q20d Information about structure and tendencies of the rural market	0.718	MSA ≥ 0.762
	Q20e Internal discussion about tendencies of the rural market	0.594	ve = 64.3%,
	Q20f Complaints and suggestions from buyers	0.612	α = 0.906
	Q20g Analysis of anticipating changes in the environment	0.671	
Business performance (BP)	Q21a Revenue/profit	0.662	KMO = 0.859
	Q21b Production growth	0.748	Bartlett = 662.25
	Q21c Growth in sales' revenue	0.673	p ≤ 0.001
	Q21e Buyers' satisfaction	0.697	MSA ≥ 0.823
	Q21f Company's image and reputation	0.652	ve = 66.10%,
	Q21g Success of new products	0.533	α = 0.894

KMO, Kaiser-Meyer-Olkin test; Bartlett, Bartlett sphericity test; MSA, Measure of Sampling Adequacy; ve, variance explained; α, Cronbach's alpha measure of reliability.

results of $R^2$and Q^2, it is evident that these variables are important to fit the model.

Verification of hypotheses

After analyzing the data for the latent variables and the consistency of the model, the latter was submitted for verification of the hypotheses. The results of the hypotheses are presented in Table 5.

The values of t-statistics indicated in Table 5 support that the organizational capacities consisting of the MO and EO positively influence the BP, as indicated in the academic work of Lumpkin and Dess (1996) and González-Benito et al. (2009). In hypotheses H1a and H1b, the mediation for II between the latent variables MO→II→BP and EO→II→BP respectively, the statistics for the Sobel test were z = 1.63 for the mediation of MO and z = 1.60 for EO. These values are less than 1.96, rejecting the hypothesis that II is a mediator of MO and EO to BP. Hypothesis H2 is rejected (t = 1.551 and p> 0.05) indicating that the II in rural business does not influence BP. It is assumed that this is due to the structure of the production chain in agribusiness, where oligopsony and seasonality of production set the price of the product, which implies a low attention to marketing, such as sales force and distribution channel (Neves and Castro, 2011), and the strategy when related to many competitors and products (such as commodities), focusing more on the management of the production process and the product itself (Batalha, 2009).

Hypotheses H3 and H5 are rejected based on t-statistic not being significant at $p < 0.05$. These indicators allow us to infer that NE does not influence BP. Whatever may be the type of collaboration between the university and rural business (Univ), this does not stimulate better BP. The explanation may be that these rural enterprises are closer to their raw materials and equipment suppliers and

Table 4. Discriminant validity between latent variables and the quality of the theoretical model fit.

Latent variable	Discriminant validity				Quality of the model					
	BP	II	EO	MO	AVE	CR	R^2	Q^2	α	Communality
BP	**0.804**				0.647	0.917	0.372	0.240	0.890	0.647
II	0.473	**0.788**			0.621	0.907	0.426	0.262	0.877	0.621
EO	0.535	0.587	**0.811**		0.657	0.920			0.895	0.657
MO	0.547	0.589	0.625	**0.793**	0.629	0.922			0.901	0.629

The values diagonal in bold correspond to the square root of the average variance extracted (AVE).

Table 5. Hypotheses of the proposed model, results, and significance levels.

Path	Hypothesis	Path coefficient	Standard deviation	t-statistic	Hypothesis support
MO→BP		0.291	0.122	2.41**	
EO→BP		0.306	0.101	3.00***	
MO→II		0.367	0.069	5.32***	
EO→II		0.361	0.066	5.47***	
II→BP	H2	0.138	0.086	1.55	Rejected
NE→BP	H3	-0.090	0.314	0.32	Rejected
NE x MO→BP	H4a	-0.398	0.384	1.01	Rejected
NE x EO→BP	H4b	0.546	0.286	1.91*	Rejected
Univ→BP	H5	-0.114	0.234	0.44	Rejected
Univ x MO→BP	H6a	0.568	0.305	1.81*	Rejected
Univ x EO→BP	H6b	-0.390	0.194	1.99**	Accepted

Legend: Two-tailed significance levels: * p< 0.10; ** p< 0.05; *** p< 0.01.

closer to buying markets than the universities; and that the pressure from the inputs segment at the beginning of the production chain with its technological packages and guidelines for production drives BP improvement (Batalha, 2009).

The effect of moderation of NE versus MO, and NE versus EO in terms of the outcome of BP, is not significant, t = 1.01 and t = 1.91, respectively, to the level of $p < 0.05$; rejecting hypotheses H4a and H4b. The number of college graduates in rural enterprises does not moderate its organizational capabilities. The results indicate that the rural enterprise does not perceive that university graduates can collaborate in the efficient implementation of management and technology, participants of the innovation process (Reis, 2008), adding knowledge that may reflect on BP. It is possible to propose an understanding of this result based on the natural feature of rural business, whose demand for knowledge and innovation is associated with each production target; and that knowledge and learning can be obtained from external agents such as suppliers and buyers (Batalha, 2009). The desired organizational capacity can be acquired with the diffusion of external knowledge integrated into economic activity through the acquisition of a new machine or a new product (Zuin and Queiroz, 2006).

The moderating effect of Univ versus MO is not significant at the $p < 0.05$ level, rejecting hypothesis H6a. The forms of collaboration between the university and rural business do not moderate MO positively to BP. However, hypothesis H6b is supported, indicating that Univ moderates EO in achieving better results for BP. Among the moderations of Univ versus EO items, it stands out that when the rural business by using the collaboration of university tries to anticipate its competitors in introducing new products and processes, adopting a more competitive and courageous position, and exploring possible market opportunities.

Conclusion

The set of results indicate that rural businesses use their organizational capabilities to achieve higher business performance. However, with respect to incremental innovation, management and technology, these do not appear as strategies to support better business outcomes. The rural business does not recognize the importance of personnel with a university degree among their staff. The collaboration between the university and rural business is perceived to be important only for the improvement of entrepreneurial strategies when needed to achieve proactivity, innovation, and take calculable risks. The rural business does not resort to the university when it needs to improve its processes and products; instead, it is assumed that its resorts to external agents, such as suppliers and buyers.

Final considerations

The findings and conclusions of this study have important implications for rural entrepreneurs and universities. The limited collaboration between the studied parties indicates that there is a gap of knowledge and interest that must be identified. On one hand, the rural business can use their relationship with the university to expand their knowledge and their competitive advantage. On the other hand, the university can go beyond in providing staff with university education, expanding their cooperative research and interacting with the real market. It can be noted from the causal relationships of the model proposed in this research, that there is a strong link in business performance improvement when organizational capabilities are expanded. This is related to the possibility of understanding the internal and external environment of the rural business, and can be strengthened by the collaboration of the university in the areas of teaching, research and extension.

It should be recognized that this empirical research has its limitations and restrictions. The sample of units analyzed was obtained in a region with a market and technology typical of agriculture and livestock, which can give rise to different findings in other business groups in the agribusiness sector. The expansion and diversification of the sample may extend the research with new arguments on organizational capabilities, incremental innovation and collaboration with universities. The expansion of this research is recognized by the authors as necessary to capture the degree of homogeneity or diversification of how the relationships between rural businesses and universities are perceived in order to improve competitiveness and productivity. It is hoped that this research awakens new issues and interests that will help in the understanding of the agricultural sector.

Conflict of Interest

The authors declare they have no conflict of interest.

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Full Length Research Paper

Characterısatıon of volatıle compounds by spme and gc-fıd/ms of capers (*Capparis spinosa* L.)

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***Capparis spinosa* L. has highly biologically active natural substances. *C. spinosa* L. is rich in volatile components, and is becoming increasingly popular because of its components' potential role in contributing to human health. In this study, *s*olid phase microextraction (SPME) was used to analyze the volatile compounds identified in *C. spinosa* L. Seventeen compounds, constituting 93.5% of the oil composition of *C. spinosa* L. were isolated and characterized using GC-FID/MS. The most abundant chemical classes identified were aldehydes (18.2%) and monoterpene hydrocarbons (4.4%). Common components of *C. spinosa* L. identified were benzyl alcohol, octanoic acid, benzoic acid, α-terpinolene, carvacrol, zingerone and 4-fluoro benzaldehyde.**

Key words: *Capparis spinosa* L., essential oil, solid-phase microextraction/gas chromatography-mass spectrometry (SPME-GC-MS).

INTRODUCTION

Capparis spinosa L. (Capparaceae) is a widespread perennial shrub found both wild and cultivated in Mediterranean regions. It is known to possess medicinal and aromatic properties. While the ancient habitat is thought to be arid parts of western or central Asia, the plant is naturally distributed right along the Mediterranean Sea basin coast. Its habitat extends from the Canary Islands and the Atlantic coast of Morocco to the Black Sea to the Crimea and Armenia, and from there to the Caspian Sea and Iran in the east. Traditional Iranian medicine uses the fruits and root of *C. spinosa* to treat gout, as well as for their diuretic, astringent and tonic properties (Afsharypuor et al., 1998). Medicinal properties have also been ascribed to the flower buds, which are used to ameliorate hepatic functions or as a renal disinfectant. One study reported pronounced anti-inflammatory activity against carrageenan-induced edema in a rodent model (Al-Said et al., 1988).

C. spinosa L. is a popular aromatic in Mediterranean cuisine. The floral buds are familiarly known as capers. These are harvested in spring, prior to blossoming, and then kept in salt-water. They are used to add a spicy flavor to salads, pasta, meat, sauces and garnishes, and occupy an increasingly significant place in the food industry. The number of reports investigating caper flavor is minimal. Brevard et al. (1992) investigated the flavor profile of Moroccan capers, and Afsharypuor et al. (1998) that of capers from Iran. These two studies employed

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used distillation-based, volatile extraction techniques. Focus of late has been on developing sample preparationmethods without the use of solvents, while investigations of flavor in different foods is of increasing interest due to its association with food product quality.

The caper is believed to be rich in volatile organic compounds. The aim of this study was to determine semi quantitative differences in volatile organic compounds of *C. spinosa* L. by using SPME-GC-FID/MS analysis. Solid phase microextraction is an alternative technique for the extraction of organic volatiles from different sample, compared with traditional methods (Yaylı et al., 2014). Solid phase microextraction (Arthur and Pawliszyn, 1990) offers reliable analysis of highly complex mixtures of volatile organic compounds. This is the first detailed report on the volatile organic compound composition for the *C. spinosa* L. based on SPME and capillary GC-FID/MS analyses.

MATERIALS AND METHODS

Plant material

C. spinosa L. samples were purchased from herb markets in Gaziantep, Turkey, in June 2013.

Solid-phase microextraction

A manual SPME device including fiber was obtained from Supelco (USA). The fiber used to obtain volatile components was polydimethylsiloxane/divinyl-benzene (PDMS/DVB, 65 µm-blue hub plain).

The SPME fibers were conditioned for 5 min at 250°C in the GC injector. Conditioning time for subsequent assays was set at 4 min of desorption after each extraction. Extractions were performed at 50°C using an incubation time of 5 min and an extraction time of 10 min. Each sample was analyzed, and means were then calculated.

Gas chromatography-mass spectrometry (SPME-GC-MS)

To perform the SPME procedure, ~1.00 g of tree plant was placed in a 10 mL vial. The fiber coating was located on the head space for temperature and time (incubation and extraction times) values set on the basis of the experiment. Extractions took place with magnetic stirring. Fibers with extracted aroma compounds were subsequently injected into the GC injector (split mode). Thermal desorption then took place at 250°C for 4 min.

A Shimadzu 2010 Plus gas chromatograph coupled to a Shimadzu QP2010 Ultra mass selective detector was used for GC analysis. Separation took place with a Restek Rxi-5MS capillary column, 60 m length, 0.25 mm i.d. and 0.25 µm phase thickness. Split mode was employed. Initial oven temperature was 60°C for 2 min. This was then raised to 240°C at 3°C min^{-1}; 250°C was maintained for 4 min. Helium (99.999%) was employed as carrier gas at a constant flow-rate of 1 mL min^{-1}. Electronic impact mode (EI) was used for detection with the ionization voltage stabilized at 70 eV. Scan mode (40-450 *m/z*) was used for mass acquisition. Volatile compounds were identified by comparison of their RIs (relative to C7-C30 alkane standards), matching mass spectral data with those held in the FFNSC1.2 and W9N11 library of mass spectra and comparing the results with the literature (Bicchi et al., 2008; Mondello et al., 2008; Zellner et al., 2008).

RESULTS

SPME was used to obtain volatile organic compounds. These were subsequently analyzed with GC-FID/MS. Identification was made on the basis of comparison of GC Kovats retention indexes (RIs), with reference to a homologous series of *n*-alkanes, and of a comparison of mass spectral fragmentation patterns with data from the literature (Formisano et al., 2011). The chemical composition of the essential oils obtained from *C. spinosa* L. is presented in Table 1. The chemical class distributions of the volatile constituents are summarized in Table 2. Compounds were classified as terpenoids (monoterpene hydrocarbons, monoterpenoids), aldehydes, hydrocarbons and others (Table 2). The main components in the essential oils of *C. spinosa* L. are shown as benzyl alcohol, benzaldehyde, carvacrol, carvone, and terpinolene (Figure 1).

DISCUSSION

Aldehydes represented the main constituents of *Capparis spinosa* L., at 18.2%. The most common aldehydes were 4-fluoro benzaldehyde and benzaldehyde, at 12.9 and 3.5%, respectively. Romeo et al. (2007) reported that cinnamaldehyde (X = 396.63 ppm) and benzaldehyde (X = 311.34 ppm) were the most abundant aldehydes. Benzaldehyde is commonly found in volatile oils. This is explained by the presence, in parts of plants, of various glucosides which yield benzaldehyde, hydrocyanic acid and glucose at hydrolysis.

Benzyl alcohol, an aromatic alcohol and natural component of various plants, represented 39% of volatile constituents of *Capparis spinosa* L. Benzyl alcohol is normally oxidised rapidly to benzoic acid. Benzyl alcohol is conjugated with glycine in the liver and excreted as hippuric acid. Benzyl alcohol is used in a wide variety of cosmetic formulations as a scent component, and as a preservative in many injectable drugs and solvents, solvent and viscosity-lowering agent. Benzyl alcohol has been reported to establish time-, dose- and temperature-dependent hemolysis of erythrocytes in vitro. Critical hemolytic levels of benzyl alcohol to membranes have been calculated at approximately 500 nmoles/mg protein (approximately 54 microgram/mg protein) (Ohmiya and Nakai, 1978). Octanoic acid and benzoic acid represented the main components among the free acids in our study, constituting 18.2 and 6.6% of the identified chemical constituents, respectively. Most fatty acids naturally occur as esters or else are converted to alcohols, aldehydes, olefins, hydrocarbons and other secondary metabolites. Alcohols and aldehydes, the product of oxidative degradation of fatty acids, comprise the green leaf volatile complex of many plants. Alcohols a

Table 1. Isolation of volatile compouds from *Capparis spinosa* L. used SPME method with GC-FID-MS.

Compounds	%Area	Retention time	Retention İndex
4-Fluoro benzaldehyde	12.9	14.07	957
Benzaldehyde	3.5	14.39	982
β -Pinene	0.7	15.42	995
Octanal	0.8	15.92	1006
p-Cymene	0.2	17.15	1030
Benzyl alcohol	39.0	17.32	1038
α -Terpinolene	3.5	20.04	1101
Nonanal	0.8	20.22	1106
Benzene ethanol	1.8	20.79	1119
Benzoic acid	6.6	22.63	1161
Octanoic acid	18.2	22.94	1168
7-Hexadecenal	0.2	24.56	1206
Carvone	0.9	26.44	1251
Neryl acetate	0.4	26.65	1256
Carvacrol	1.8	28.64	1304
Tetradecane	1.0	32.42	1398
Zingerone	1.4	41.91	1656
Total	93.5		

Table 2. The chemical class distribution of the essential oil components of *C. spinosa* L.

Constituents	% Area	NC[a]
Monoterpene hydrocarbons	4.4	3
Monoterpenoids	2.7	2
Aldehyde	18.2	5
Hydrocarbones	1.0	1
Others	67.4	6
Total	93.7	17

[a]NC, Number of compound.

nd aldehydes, the product of oxidative degradation of fatty acids, comprise the green leaf volatile complex of many plants. The majority of fatty acids appear in the form of esters. They may also be converted into various alcohols, aldehydes, olefins, hydrocarbons and other secondary metabolites. Especially alcohols and aldehydes resulting from oxidative degradation of fatty acids constitute the green leaf volatile complex of a wide range of plants.

Terpenes constitute 4.4% of the aroma identified in *C. spinosa* L., the major representative being α-Terpinolene. Terpinolene is also used as a synthetic flavoring additive and scent enhancer. This means that humans are frequently exposed to it. Terpinolene is present in sage and rosemary, and has been reported to significantly lower the protein expression of AKT1 in K562 cells and to suppress cell proliferation (Okumura et al., 2012). Romeo et al. (2007) determined that terpenes constituted 5.8% of the aroma. That study also reported the presence of five sesquiterpenes (C-15) and 10 monoterpenes (C-10) in capers, the most important being the acyclic sesquiterpene trans-nerolidol, followed by the monoterpene 4-terpineol. In an earlier study, Brevard et al. (1992) described the monoterpene linalool and the sesquiterpene b-ionone as the only terpenes identified in capers from Morocco. The C-10 monoterpenes are frequently partly responsible for plant odor. The production of these monoterpenes frequently takes place in non-photosynthetic tissues in non-pigmented plastids known as the leucoplast during these cells' brief metabolic activity (Gershenzon and Croteau, 1990). Investigation of volatile terpenes has been highly significant in terms of resolving systematic problems. Several of these terpenes act as chemical

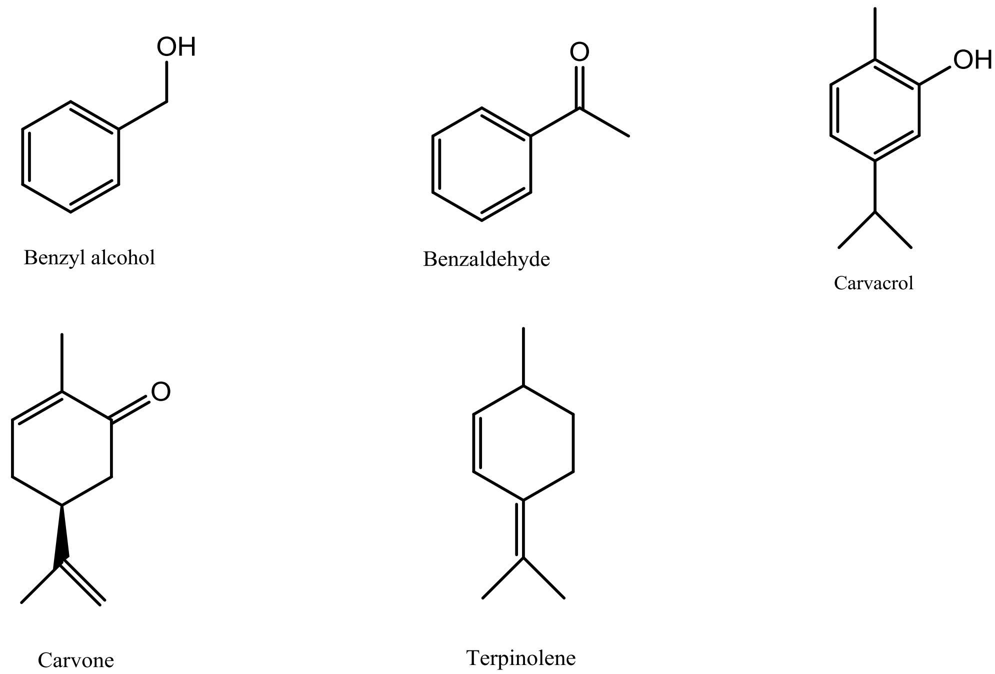

Figure 1. Main components in the essential oils of *Capparis spinosa* L.

communications for insects and other life forms. Their antimicrobial activity has also led to monoterpenes being used in the medicine and food industries (Beir and Nigg, 1992).

Carvacrol accounted for 1.8% of volatile constituents of *C. spinosa* L. Carvacrol is responsible for the biological activities of oregano, an important element in the food, spice and pharmaceutical industries. Carvacrol has been reported to exhibit antimicrobial, antitumor, antimutagenic, antigenotoxic, analgesic, antispasmodic, anti-inflammatory, angiogenic, antiparasitic, antiplatelet, antielastase, insecticidal, antihepatotoxic and hepatoprotective activities. It has also been demonstrated to be capable of use as a feed additive, in apiary and in the treatment of gastrointestinal disorders (Baser, 2008).

Zingerone constituted 1.4% of the volatile constituents of *C. spinosa* L. The free radical scavenging and antioxidant properties of the essential oils zingerone and eugenol, extracted from ginger and cloves, are well known (Kabuto and Yamanushi, 2011). Zingerone is currently used to treat a range of medical disorders. It reacts with free radicals responsible for injury and inflammation. As an antioxidant, it is also involved in lipid oxidation. In the presence of iron (III) and ascorbate, zingerone has a weak inhibitory effect on the oxidation of phospholipid liposomes to prevent heart-attacks. Zingerone has thus become a highly significant molecule, manufactured and synthesized for use in the pharmaceutical industry. Environmental factors, geographical locations and the parts of the plant used all have a powerful effect on essential oil chemical composition.

Conclusion

In our results, we generally observed aldehyde compounds with different ratios. A comparison with literature data on the chemical composition of volatile organic compound is difficult because of the great variability of the volatile compositions. The presence of volatile components depends on several parameters such as locality, the climatic conditions, season, extraction technique and analytical methods (Flamini et al., 2003).

Conflict of Interest

The authors declare they have no conflict of interest.

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Full Length Research Paper

Yield responses of grain amaranth (*Amaranthus cruentus* L.) varieties to varying planting density and soil amendment

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Field experiments were conducted at the Experimental Farm of the National Horticultural Research Institute (NIHORT), Ibadan, Nigeria (7° 30' N, 3° 50' E), at altitude 168 m above the sea level, during the 2010 and 2011 cropping seasons, to assess the yield responses of two grain amaranth varieties (TE81/28 and CEN 18/97) to planting densities (100,000, 60,000 and 40,000 plants ha^{-1}) and soil amendments (0, 25, 50, 75 and 100 kg N ha^{-1} organic fertilizer and 100 kg N ha^{-1} inorganic fertilizer). The experiment, designed as 2 x 3 x 6 factorial and fitted to randomized complete block design (RCBD) was laid out in split-split-plots and replicated three times. Measurements were taken on yield components (dry matter, biological yield, unthreshed seed weight and harvest index) and grain yield. All data were analyzed using the analysis of variance (ANOVA) with the split-split-plots model and significant means separated by the least significant difference at five percent probability level ($LSD_{0.05}$). The results revealed that grain amaranth gave optimum grain yield responses when grown at a planting density of 60,000 plants ha^{-1} and with the application of soil amendment at 100 kg N ha^{-1} inorganic fertilizer, while the grain yield was significantly ($p < 0.01$) higher with the CEN18/97 amaranth variety than in the TE81/28 across soil amendment and planting density treatments in both years of assessment. However, significant second order interaction effects of variety x planting density x soil amendment observed in the study revealed that grain yield was best with variety TE81/28 planted at 60,000 plants/ha density with the application of 100 kg N/ha of inorganic soil amendment. In conclusion, results of this study revealed that the application of inorganic fertilizer was the best soil amendment treatment for the grain amaranth production. Nevertheless, the results suggested that the use of organic fertilizer at the rate higher than 100 kg N ha^{-1} holds a great potential as an alternative, where the use of inorganic fertilizer has an issue, especially for environmental and health reasons.

Key words: Grain amaranth (*Amaranthus cruentus* L), responses to, organic and inorganic fertilizers, planting density.

INTRODUCTION

Like many other vegetables, grain amaranth (*Amaranthus cruentus* L.), is a widely cultivated plant which produces grain as well as leaves for human and animal utilization. It is a pseudo-cereal crop with high protein content that has great potential for sustainable food security among the poor population of Nigeria. Grain amaranth has served as a staple to the Aztecs who had also incorporated it into their religious ceremonies. Amaranth, generally, has been cultivated as leafy vegetable crop by early civilization, and it is still essentially being utilized as such world-wide (NRC, 2006; O'Brien and Price, 2008). In the cultivation of grain amaranth, the recommended planting density varies considerably worldwide, depending on a number of factors such as the environment, the production system and the variety involved (Weber et al., 1990; O'Brien and Price, 2008). This fact is further corroborated by the work of Henderson et al. (2000) who observed a significant environment × population effect on the grain yield of grain amaranth, suggesting that different planting density should be adopted in different environments. Although high planting density of grain amaranth may result in high yield, O'Brien and Price (2008) have pointed out that low planting density results in larger heads and vice versa. Thus there appears to be an optimum where the yield is not affected by planting density.

Despite the huge nutritional benefits of grain amaranth, there is a dearth of information with regards to its requirements for optimum productivity, especially in this part of the world where amaranth is grown mainly for its leaves by resource-poor farmers who have little knowledge on the potential benefits of the grain types. According to O'Brien and Price (2008), grain amaranth does not have a high nitrogen requirement like maize, but responds well to appropriate soil amendment. In order to obtain good yield, soil amendment then becomes necessary if the crop is to be grown in the tropics where the maintenance of soil fertility and productivity over long periods with inorganic fertilizer have resulted in increased soil degradation and nutrient imbalance, leading to deleterious effects on crop growth, quality, ecosystem and soil health (Avery, 1995).

This study was carried out to evaluate the effects of organic and inorganic soil amendments on the grain yield and other yield components, in view of its enormous benefits and potential role in improving the nutritional quality of man, especially those of the teeming rural populace in Nigeria. The study was also aimed at determining the appropriate planting density that will result in optimum grain yield in two grain amaranth varieties under the environmental condition of this study area.

MATERIALS AND METHODS

The experiment was conducted at the Experimental Farm of the National Horticultural Research Institute (NIHORT), Ibadan, Nigeria (7° 30' N, 3° 50' E), located at an altitude of 168 m above sea level, during the 2010 and 2011 cropping seasons. The experiment was designed as a 2 × 3 × 6 factorial, laid out in split-split-plots arrangement, and replicated three times. Grain amaranth varieties (TE81/28 and CEN18/97) were allotted to the main plots, planting density (100,000, 60,000 and 40,000 plants ha^{-1}) to the sub-plots and soil amendments (0, 25, 50, 75 and 100 kg N ha^{-1} organic fertilizer and 100 kg N ha^{-1} inorganic fertilizer) to the sub-sub-plots. Pretreatment soil physico-chemical analyses of the experimental site for the periods of the study were carried out, and the rainfall distribution and mean temperature data of the area were obtained.

The field was ploughed twice and harrowed thrice to give a well pulverized flat surface. The field was then divided into thirty six raised beds per replicate with each plot measuring 2 m × 2 m, separated by alleyways of 1 m between plots. Seeds were sown directly on the 5th and 7th July in 2010 and 2011 respectively and later thinned to obtain the required densities. The application of the organic and inorganic fertilizer was done two weeks after sowing. Weed control was achieved by the pre-emergent application of Pendimethalin (500EC) at the rate of 2.5 kg ha^{-1} immediately after planting. This was later supplemented by manual weeding at 6 and10 weeks after sowing, and occasional hand-pulling throughout the period of the experiments. Insect pests were controlled using Karate® 2.5CE (Lambda-cyhalothrin) at the rate of 25 gL^{-1} of water at 4, 8 and 12 weeks after sowing.

Dry matter samples were obtained at 6 weeks after sowing from randomly four selected plants from the inner rows per plot. The samples were oven-dried at 80°C and then used for estimating the dry matter yield per plot. At maturity, two randomly selected plants from the inner rows were uprooted and weighed, and the average weight recorded as the biological yield per plot. Heads of the plants used for estimating biological yield were sundried for about five days, weighed and the average weight recorded as the unthreshed seed weight per plant which was then used to estimate the unthreshed seed weight per plot. Dried heads were threshed and the grains obtained were sundried for about three days. The weight of the grains were recorded and used to estimate the grain weight per plot, which was later converted to grain yield per hectare. Harvest Index (HI) was obtained by using the expression:

$$HI = GY\ (BY) - 1 \times 100$$

Where GY is the grain yield and BY is the biological yield at harvest.

All data obtained were subjected to analysis of variance (ANOVA) using Genstat Discovery 4 statistical package (Genstat, 2011) and means separated using the least significant difference, at 5% probability level.

RESULTS AND DISCUSSION

The agro-meteorological data for the two years of the experiment revealed that there was adequate rainfall which was well distributed throughout the growing period in both years (Figure 1a and b). Maximum temperature decreased progressively from May to its lowest values in August and then increased thereafter. The result of the pre-sowing soil analysis indicated that soil of the experimental site was loamy sand in texture with low level of organic carbon (Table 1). The soil was also shown to be low in major macro nutrients such as nitrogen, phosphorus and potassium. This was a proof that the soil is suitable for soil amendment experiment.

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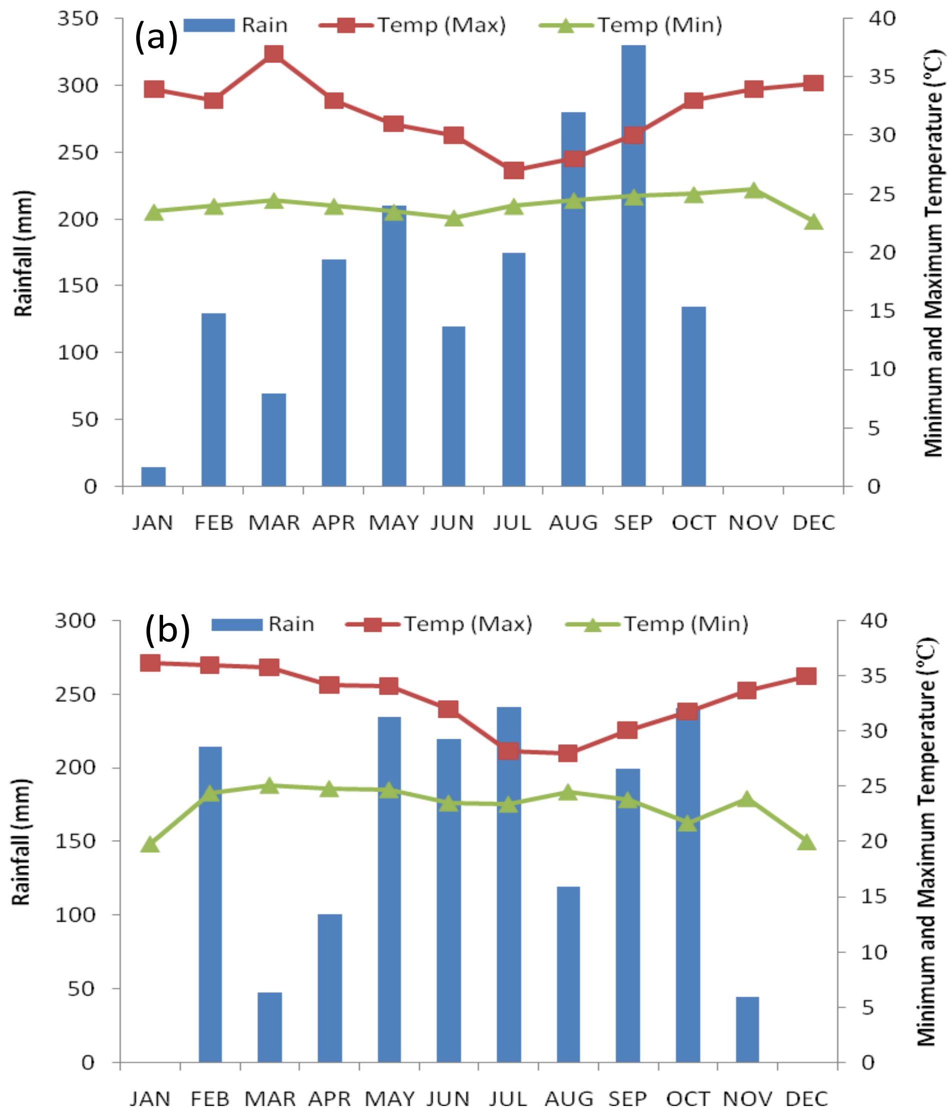

Figure 1. Rainfall distribution and the maximum and minimum temperature of the experimental in 2010 (a) and 2011 (b) cropping seasons.

The soil pH was 5.5, indicating a slightly acidic soil suitable for grain amaranth production (Putnam et al.,1989).

The results of the analyses of variance (Table 2a and b) for the yield parameters indicated that the effects of variety, density and fertilizer application on the DM and BY of grain amaranth were highly significant (<0.01) in 2010. This situation is only true for DM in 2011. While the various order of interaction were significant for DM in both years of the experiment, only variety × planting density interaction was significant for BY in 2010, and none in the year 2011. In the year 2010, both harvest index and grain yield were significantly affected by planting density and fertilizer application. This situation was however, only repeated in grain yield in 2011; harvest index was only significantly affected by fertilizer application. In 2010, all the orders of interaction showed significant effects on the grain yield. This was not the case in 2011 where only the highest interaction order (Variety × Density × Fertilizer) and Density × Fertilizer were significant for grain yield. Variety × Density interaction was also significant for harvest index in the year 2010. The effects of soil amendment and variety were highly significant ($p<0.01$) for the unthreshed seed weight, while there were no significant effects due to planting density in both 2010 and 2011. These effects were also qualified by interaction effects except variety × density in 2010 and variety × density × fertilizer in 2011.

The results of this study revealed that the yield components examined increased significantly with increased application rate of the organic soil amendment, and the highest values were obtained with the application

Table 1. Pre-planting soil physical and chemical characteristics of the experimental site at 0 – 30 cm depth in 2010.

Soil properties	Value
Sand (g/kg)	812
Silt (g/kg)	98
Clay (g/kg)	90
Textural Class	Loamy Sand
pH(H_2O)	5.5
Exchangeable Ca (cmol/g)	0.68
Exchangeable Mg (cmol/kg)	0.26
Exchangeable Na (cmol/kg)	0.11
Exchangeable K (cmol/kg)	0.13
ECEC (cmol/kg)	1.47
% Base Saturation (mg/kg)	59.3
% OC (organic carbon)	0.35
Total N (g/kg)	1.2
Available P (mg/kg)	9.13
Exchangeable Cu (mg/kg)	1.51
Exchangeable Zn (mg/kg)	1.76
Exchangeable Fe (mg/kg)	5.35
Exchangeable Mn (mg/kg)	10.02

Table 2a. ANOVA table showing mean squares from the analysis of variance for dry matter (DM), harvest index (HI), biological yield (BY) weight of unthreshed seed (USW) and grain yield (GY) of grain amaranth in 2010.

Source of variation	DF	DM	HI	BY	USW	GY
Variety (Var)	1	472.75***	67.64ns	6.44***	5200833***	745944ns
Error (a)	2	4.00	11.11	1.52	35625	110716
Density (Den)	2	3297.27***	10.15**	1.93***	81927ns	27991664***
Var x Den	2	228.14***	11.93***	2.07***	512552ns	499640*
Error (b)	8	0.0001	1.78	1.05	141181	108528
Fertilizer (Fer)	5	27021.36***	120.82***	4.44***	98544583***	23447880***
Var x Fert	5	106.48***	2.20ns	7.05ns	234208**	1017469***
Den x Fert	10	949.18***	2.85ns	8.81ns	537927***	426131***
Var x Den x Fer	10	117.72***	1.35ns	8.94ns	482052***	334170***
Error (c)	60	1.33	3.82	1.94	82806	109971

*, ** and *** denote effects significant at 5, 1 and 0.1 percent probability level, respectively ns denotes effects no significant

of 100 kg N ha^{-1} of inorganic fertilizer in both years of the experiment (Table 3a and b). The effects of soil amendments on the dry matter yield as recorded in this study were in accordance with the findings of Nyankanga et al. (2012) who, in a similar study, obtained the highest dry matter in grain amaranth in Western Kenya with the application 100 kg N ha^{-1} inorganic fertilizer. Gupta et al. (1996) and a host of others who have also reported significant increase in plant dry matter accumulation per plant with corresponding increase in the fertility level up to a certain level (Kushwaha, 2001; Kalmani et al., 2002; Olaniyi and Ajibola, 2008). Ejieji and Adeniran (2010) have, however, contrarily reported that N fertilizer application had no significant effect on the dry matter yield of grain amaranth.

The results of this study also showed positive relationship between fertilizer application and the harvest index of grain amaranth. This result is contrary to an earlier report of Gunda et al. (2005) who recorded no significant differences in the harvest index with the application of N at different rates from 0 up to 120 kg N ha^{-1}, and Ejieji and Adeniran (2010) who similarly reported that N fertilizer application had no significant effects on the harvest index of grain amaranth.

Table 2b. ANOVA table showing mean squares from the analysis of variance for dry matter (DM), harvest index (HI), biological yield (BY) weight of unthreshed seed (USW) and grain yield (GY) of grain amaranth in 2011.

Source of variation	DF	DM	HI	BY	USW	GY
Variety (Var)	1	151.70***	0.47ns	3.38ns	303.34***	213689ns
Error (a)	2	0.12	0.35	1.08	0.93	132753
Density (Den)	2	2137.04***	0.01ns	2.28ns	113.12ns	1646652***
Var x Den	2	1041.37***	3.52ns	2.90ns	70.95***	478870ns
Error (b)	8	1.33	2.09	8.70	2.26	118367
Fertilizer (Fer)	5	55317.04***	239.24***	4.16**	5978.79***	29179241***
Var x Fert	5	832.24***	2.57ns	1.72ns	23.45***	150196ns
Den x Fert	10	1358.70***	0.95ns	8.53ns	14.40***	588067***
Var x Den x Fer	10	433.30***	2.96ns	1.61ns	15.47ns	1016561***
Error (c)	60	4.99	3.00	1.56	1.17	104518

*, ** and *** denote effects significant at 5, 1 and 0.1 percent probability level, respectively ns denotes effects no significant

Table 3a. Effects of variety, planting density and soil amendments on the dry matter (DM), harvest index (HI), biological yield (BY) weight of unthreshed seed (USW) and grain yield (GY) of grain amaranth in 2010.

Treatment	DM (g plant^{-1})	HI	BY (kg ha^{-1})	USW (kg ha^{-1})	GY (kg ha^{-1})
Variety					
TE81/28	152.11	9.11	13952	4254	3030
CEN18/97	147.93	10.69	12407	4693	3196
SED	0.22	0.64	150.1	36.3	64.0
LSD $_{(0.05)}$	0.45	ns	323.1	156.3	ns
Planting Density (plants ha^{-1})					
100,000	139.11	10.51	12350	4435	2799
60,000	153.94	9.67	13456	4527	3330
40,000	157.01	9.53	13733	4458	3211
SED	0.272	0.31	241.0	88.6	77.6
LSD $_{(0.05)}$	0.58	0.73	ns	Ns	160.6
Soil amendment (kg N ha^{-1})					
0 (Organic)	101.00	6.76	6335	2058	1818
25 (Organic)	118.96	7.91	9511	2608	2216
50 (Organic)	138.98	9.06	11711	3321	2765
75 (Organic)	157.57	10.33	14732	4425	3080
100 (Organic)	176.48	11.37	16988	6292	3855
100 (Inorganic)	207.11	13.99	19801	8138	4946
SED	0.31	0.65	464.0	95.9	110.0
LSD $_{(0.05)}$	0.67	1.30	928.3	191.9	221.1

SED = standard error of difference, LSD = least significant figure, ns = not significant.

Biological yield, the total above ground plant components including leaves and stem, contributes significantly to the economic yield, and is known to be affected by various environmental and genetic factors. In accordance with the results of this study, Olofintoye et al. (2011) had earlier reported significant variations in biological yield due to planting density, even though their results revealed that high planting density produced higher biological yield. Although planting density did not show significant effect on the biological yield in this study in both years, the values increased with decrease in planting density (Table 3a and b).

Table 3b. Effects of variety, planting density and soil amendments on the dry matter (DM), harvest index (HI), biological yield (BY) weight of unthreshed seed (USW) and grain yield (GY) of grain amaranth in 2011.

Treatment	DM (g plant^{-1})	HI	BY (kg ha^{-1})	USW (kg ha^{-1})	GY (kg ha^{-1})
Variety					
TE81/28	347.04	8.50	29272	8689	3712
CEN18/97	344.67	8.37	29335	10195	3801
SED	0.45	0.35	62.8	132.9	63.0
LSD $_{(0.05)}$	0.91	ns	ns	Ns	Ns
Planting Density (plants ha^{-1})					
100,000	337.33	8.45	28738	9750	3536
60,000	352.31	8.45	29483	10082	3963
40,000	347.89	8.42	29691	9994	3770
SED	0.25	0.31	56.4	237.6	92.8
LSD $_{(0.05)}$	0.52	ns	ns	Ns	187.5
Soil amendment (kg N ha^{-1})					
0 (Organic)	257.17	3.59	22867	5958	2194
25 (Organic)	318.33	5.17	25600	7635	2830
50 (Organic)	337.94	7.94	28213	8810	3295
75 (Organic)	361.17	9.50	30825	10761	3841
100 (Organic)	384.00	11.00	32778	12247	4695
100 (Inorganic)	416.50	14.00	35540	14221	5681
SED	0.99	0.67	85.6	312.8	107.8
LSD $_{(0.05)}$	2.19	1.49	190.7	697.0	215.8

SED = standard error of difference, LSD = least significant figure, ns = not significant

Grain yield has been affected by various production and environmental factors on the field. In the present study, increased soil amendments resulted in significant increase in grain yield. The application of 100 kg N ha^{-1} of inorganic soil amendments produced the highest grain yield. The results support the findings of Elbheri et al. (1993), Myers (1998), and Bruce and Philip (2008) who have variously reported a linear response of grain amaranth grain yield to N fertilization. The increase in grain yield as fertilizer application rates increased is a direct result of the effects of the fertilizer on growth performance of the crop. This responsiveness of grain amaranth yield to nitrogen fertilization was also comparable to the findings of other researchers such as Myers (1996) and Bruce and Philipe (2008). Apaza-Gutierrez et al. (2002) had also reported that grain amaranth yield revealed a linear response to chemical and organic fertilizers. Nyankanga et al. (2012) reported that the rate of increase in grain amaranth yield rose steadily as the rates of organic and inorganic N was raised from 0 to 100 kg N ha^{-1}. On the contrary, Law-Ogbomo and Ajayi (2009) reported that increase in organic soil amendment decreased the grain yield of grain amaranth.

The 60,000 plants ha^{-1} planting density produced the highest grain yield values in both years (Table 3a and b). These results are at variance with the findings of Henderson et al. (2000) who suggested that the plasticity of grain amaranth morphology may limit its response to row spacing. Aufhammer et al. (1995); Myers (1996) and Gimplinger et al. (2007) similarly did not observe significant yield responses to row spacing. A Missouri study that compared different row spacing at Thomas Jefferson Agricultural Institute found that the widest row spacing (lowest planting density) produced the highest grain yield. It was suggested that amaranth plants seem to compete excessively with each other when planted at high planting density (narrower spacing), leading to shorter, less vigorous plants and smaller grain yield. The result of this study was however, contrary to the findings of Malligawad and Patil (2001) who reported that grain yield increased with an increase in planting density in grain amaranth. It would be noted that the grain yield obtained in the second year across the soil amendment levels were greater than the ones obtained in the first year of the study. This is probably because the average monthly rainfall around the period of active growth of the crop was higher in the second year than what was obtained in the first year (Figure 1).

The interactive effects Table 4 revealed that at fertilizer

Table 4. Interactive effects of planting density, variety and soil amendments on dry matter production and grain yield of grain amaranth in 2010 and 2011 cropping seasons.

Planting density ('000 plants ha)	Dry Matter (g plant $^{-1}$)				Grain Yield (kg ha^{-1})			
	2010		2011		2010		2011	
	TE81/28	CEN 18/97	TE81/28	CEN 18/97	TE81/28	CEN 18/97	TE81/28	CEN 18/97
0 Kg N ha^{-1}								
100	100.00	100.00	265.00	260.00	2101	1700	2225	2200
60	92.00	100.00	271.00	268.00	1938	1938	2428	2125
40	110.00	104.00	279.00	200.00	1344	1604	2080	2105
25 kg N ha^{-1} (organic)								
100	113.67	110.00	316.00	325.00	2167	2227	2915	2917
60	116.33	114.67	318.00	316.00	2371	2505	2620	3005
40	130.12	129.00	315.00	320.00	1579	2450	2572	2952
50 kg N ha^{-1} (organic)								
100	142.33	124.00	332.00	339.00	2911	2936	3145	3176
60	143.23	139.00	335.00	336.00	2506	3205	3422	3592
40	142.30	143.00	348.00	338.00	2221	2810	3072	3365
75 kg N ha^{-1} (organic)								
100	154.00	144.33	354.00	359.00	3057	3376	4062	3483
60	160.10	150.00	360.00	360.00	2833	3433	3953	4030
40	169.00	168.00	368.00	366.00	2662	3116	3665	3852
100 kg N ha^{-1} (organic)								
100	170.00	152.33	365.00	370.00	3602	4684	5065	5097
60	190.24	165.00	382.00	398.00	3978	3557	4480	4885
40	185.33	196.00	390.00	399.00	3308	3998	4065	4580
100 kg N ha^{-1} (inorganic)								
100	180.33	178.33	379.00	384.00	5177	4590	4541	6415
60	237.67	239.00	438.00	446.00	6406	5010	7405	5607
40	201.33	206.00	432.00	420.00	3308	4111	5095	5025
SED	0.91		1.74		270.6		266.8	
$LSD_{(0.05)}$	1.82		3.50		539.9		532.0	

SED = standard error of difference, LSD = least significant figure.

rate of 0 kg N ha^{-1}, the variety TE 81/28 produced significantly higher dry matter values at the rate of 40,000 plants ha^{-1} than CEN 18/97 in both years. But in terms of grain yield, CEN 18/97 surpassed TE 81/28 at the same planting density and fertilizer level in both years. Although no specific trend was noted at higher fertilizer levels in the dry matter yield, it would be noted that variety CEN 18/97 had higher grain yield at all the levels of organic fertilization and most of the planting densities in both years. The best grain yield values of 6,406 kg ha^{-1} (2010) and 7,405 kg ha^{-1} (2011) were however, obtained from variety TE 81/28 at 100 kg N ha^{-1} inorganic fertilizer application and population rate of 60,000 plants ha^{-1}. The better grain yield obtained in the second year, especially with the application of inorganic fertilizer, could also be attributed to the better rainfall pattern during the active growing period of the crop. Also, the highest grain yield values of 4,684 kg ha^{-1} (2010) and 5,097 kg ha^{-1} (2011) was obtained in the variety TE 81/28 with organic fertilizer applied t 100 kg N ha^{-1} and at 100,000 plants ha^{-1}. It should be noted that the highest grain yield obtained for this variety (TE 81/28) was in plants that received 100 kg ha^{-1} inorganic fertilizer at 100,000 plants ha^{-1}.

Conclusion

The results of this study revealed that grain yield increased with increase in organic soil amendments even though the values were significantly lower than the values obtained with the application of 100 kg N ha^{-1} inorganic fertilizer. Thus, the application of inorganic soil amendment (NPK fertilizer) was observed to be the best for grain amaranth productivity. Nevertheless, where the use of the inorganic fertilizer is an issue, especially for environmental and health reasons, the results suggested that the use of organic fertilizer possibly at the rate higher than the 100 kg N ha^{-1} holds a great potential as an alternative to the inorganic fertilizer. Planting at 60,000 plants ha^{-1} was found to be most appropriate, and CEN 18/97 amaranth variety appeared to be more promising.

Conflict of Interest

The authors have not declared any conflict of interest.

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Genotype x environment interaction on sesame (*Sesamum indicum* L.) seed yield

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Sesame is an oilseed crop grown for its seed and oil for local and export markets and is a great source of income for farmers, traders, processers and the national economy of Ethiopia. However, its productivity and production are influenced by environmental factors. This experiment was, therefore, carried out to estimate the nature and magnitude of interaction of genotypes with the environment and to identify stable sesame genotypes in Eastern Amhara Region. Twelve sesame genotypes were studied at eight environments: namely: Chefa, Kobo and Shewarobit in 2010 and 2011; Jari and Sirinka in 2011 main cropping seasons using randomized complete block design with three replications. Data were analyzed for individual location and across locations using GenStat, and stability using Agrobase softwares. The highest seed yields were obtained from genotypes Acc.00047, NN-0143 and Acc.202-344 (712.8, 679.2 and 639.9 kg ha^{-1}), respectively. There were highly significant difference (P<0.01) among genotypes, environments and Genotype by Environment Interaction (GEI), indicating that genotypes performed differently across locations and the need for stability analysis. Based on stability models, genotype Borkena was stable genotype, but genotype Acc.00047 had specific adaptability at potential environment (Kobo). In Additive Main effect and Multiplicative Interaction (AMMI) analysis, the proportion of variance captured by environment 51.2%, genotypes 12.9% and GEI 31.9% of the total variation. The Interaction Principal Component Axis 1&2 (IPCA1&2) of AMMI model were highly significant (P<0.01) and captured the largest portion of variation (74.7%) from the total GEI, indicated that the AMMI model 1 was the best for the data evaluate. AMMI 1 biplot graph showed that Shewarobit and Kobo were potential and favorable environments; Sirinka was an average, while Chefa and Jari were unfavorable environments for sesame production and also Shewarobit and Chefa were the most discriminating environments, while local variety and genotype Acc.00047 were the most responsive genotypes.

Key words: Additive Main Multiplicative Interaction (AMMI), location, specific adaptation, stability, wide adaptation.

INTRODUCTION

Sesame (*Sesamum indicum* L.) belongs to the genus *Sesamum*, order Tubiflorae and family pedaliaceae and is a diploid species with 2n = 2x = 26 chromosomes and it has numerous wild relatives in Africa and small

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numbers in India (FAO, 2012). It is the oldest self-pollinating annual oilseed originated in Africa, Ethiopia domesticated over 5000 years ago. Although originated in Africa, it was spread early through West Asia to India, China and Japan which became secondary distribution centers and it is now cultivated in many parts of the world (Yamanura, 2008). Sesame is an oilseed crop grown for its seed and oil of local and export markets is a great source of income for farmers, traders, processers and the national economy of Ethiopia. It is used in local consumptions; for cooking, salad and margarine. It is also used in the manufacture of soaps, paints, perfumes, pharmaceuticals and insecticides. The meal, left after the oil is used as feed for poultry, livestock and as fertilizer (Khanna, 1991).

Sesame world production is estimated at 3.24 million metric tons in 2007 and increased to 3.84 million metric tons in 2010 and almost 90% of production area was in Asia and Africa. Ethiopia was the 7th major sesame producing country in the world in the year 2004 with area coverage 65,000 ha, production about 49,000 tons and productivity about 479 kg ha^{-1} (IPMS-Ethiopia Farmers Project, 2005). Now, Ethiopia is the 4th with area coverage 384,682.79 ha, production about 327,740.92 tons and productivity is estimated as 852 kg ha^{-1} (CSA, 2011/2012).

Sesame seed is the second largest export earner for Ethiopia next to coffee due to it's excellent demand in the international market and then contributed significant role for the achievement of the country's economic growth over the last few consecutive years. The export of sesame seeds was 43,131 tons in the year 2007 and it was almost doubled 82,201 tons in the year 2011 and the major imported countries are: China, Japan, Turkey, Republic of Korea, USA, Saudi Arabia, Syrian Arab Republic and Mexico (Haile, 2009). It is also consumed by existing domestic large and small-scale oil mills (CSA, 2011/2012). The uses of sesame are:

(1). Edible oil: The oil is almost odorless with a distinctive nutty sweet flavor. Roasted sesame oil resists rancidity due to the antioxidants formed during seed roasting.
(2). Confectionary, biscuit and bakery industry: Mostly hulled clear white sesame is required for bakery products. Hulled sesame sticks to the bread or roll, while maintaining the white color after baking.
(3). Tahini industry: Tahini, a traditional Middle Eastern paste, is made from hulled sesame seed and is rich in protein.
(4). Halva industry: Halva is a sweet made of 50% tahini, boiled sugar and other ingredients.
(5). Sesame flour and sesame seed sprouts.
(6). Pharmaceutical ingredients (Wijnands and Biersteker, 2007).

Sesame oil is non-drying oil; highly stable and it is very rich in protein, a polyunsaturated fat used in margarine production and cooking oils. It is an ingredient in soap, cosmetics, lubricants and medicines. In general, sesame an oil seed involves in food, industrial, and pharmaceutical uses all over the world. Its agronomical uses include: - An excellent rotation crop of cotton, corn, peanut and sorghum, an excellent soil builder which improve soil texture, soil moisture retention, lessoning soil erosion and resistance to drought (Jewol, 2007). Its temperature requirement is 20 to 35°C. It is adaptable to many soil types but it performed best on well drained and medium textured fertile soil. It does not grow well on heavy clay soils and salty soil. It will die on water logged area (Haile, 2009).

The average productivity of sesame (*S. indicum* L.) is low as compared to other oilseeds, due to the complex yield constraints like abiotic and biotic factors. These factors are the main contributors for genotype x environmental interaction (GEI) in crops yield uncertainty. Genotype x environment interaction is a challenge for plant breeders and complicates cultivar recommendation because of the inconsistency of best-yielding material across cropping environments. However, it may also offer opportunities; it means yields can rise through growing materials specifically adapted to a given area or through using crop management practice, or preventing yield reduction in unfavorable years through the cultivation of stable-yielding materials.

In crop research, the most commonly used way to evaluate the effect of the uncontrollable environmental factors on crop response is to repeat the experiment at several sites in a single year, or over several crop seasons in a single site, or both. Genetic erosion would prevent by tested the genotypes adaptability over multi-environments at early strategy rather than testing done only in one environment (Gauch and Zobel, 1996). Assessing any genotype or agronomic treatment without including its interaction with the environment is incomplete and thus limits the accuracy of yield estimates (Crossa, 1990).

Clustering of the testing environments, identifying the degree of interaction of genotype by environment and recommending stable genotype(s) across the environments or specific adaptive genotype(s) for each environment can reduce the undesirable effect of GEI and increase the effectiveness of productivity. Several studies were carried out on GEI by different researchers on various oilseeds like sesame genotypes (Zenebe and Hussien, 2009; Hendawey and Farag, 2010), Linseed genotypes (Crossa, 1990), linseed and sesame genotypes (Hariprasanna et al., 2008).

In eastern Amhara Ethiopia, always a problem of yield instability due to diversified environmental conditions and there is no study about GEI on sesame production. Therefore, it is important to study the extent of the influence of the environment on the expression of a trait of interest, like seed yield using appropriate materials. Hence, this experiment was conducted to determine the magnitude of genotype and environmental interactions for seed yield and to assess the stable or specific sesame genotype(s).

MATERIALS AND METHODS

The experiment was carried out in two years (2010 and 2011) main cropping seasons (July to December) at the following five representative sesame growing areas of Eastern Amhara Region, Ethiopia, such as: (i) Chefa representing the lowland areas of south Wollo zone with an altitude of 1465 masl, global position 10°37'N 39°47'E, annual rain fall 850 mm, minimum temperature 12.5°C, maximum temperature 29.9°C and soil type vertisol (for two years), (ii) Kobo representing the lowland moisture deficit areas of north Wollo zone with an altitude of 1465 masl, global position 11°09'N 39°36'E, annual rain fall 634 mm, minimum temperature 15.9°C, maximum temperature 30.5°C and soil type Eutric Fluvisol (for two years), (iii) Jari representing the mid altitude with terminal moisture deficit areas of south Wollo zone with an altitude of 1680 masl, global position 11°21'N 39°38'E, annual rain fall not available, minimum temperature not available, maximum temperature not available and soil type vertisol (for one year), (iv) Sirinka representing the mid altitude relatively normal rainfall areas of north Wollo zone with an of altitude 1850 masl, 11°45'N 39°36'E, annual rain fall 876 mm, minimum temperature 13.6°C, maximum temperature 26.3°C and soil type Eutric vertisol (for one year) and (V) Shewarobit representing the lowland moisture deficit areas of north Shewa zone with an altitude of 1300 masl, 10°59'N 39°53'E, annual rain fall 597 mm, minimum temperature 13.1°C, maximum temperature 32.5°C and soil type not available (for two years) totally eight environments.

In this experiment, twelve sesame genotypes were used namely Local variety (from eastern Amhara farmer), Acc. 00035, Acc. 00044, Acc. 00046, Acc. 00047, Acc. 018, Hirhir-Kibe, (from Werer Agricultural Research Center), Acc.202-344, NN-0143, Acc.202339, Acc.202340 (from Institute of Biodiversity Conservation) and Borkena from (from Sirinka Agricultural Research Center).

The trial was laid down in randomized complete block design (RCBD) with three replications. The size of the experimental plot was five rows with five-meter long. The row - to - row and plant-to-plant distances was 40 and 10 cm, respectively. Sowing was done by hand drilling at moist soil in the rows with a seed rate of 5 kg ha^{-1} and thinning was done after 25 days of sowing, fertilizer was not applied. Weeding and other practices were applied for all the plots uniformly. To reduce border effects, data were recorded from the three central rows and the net harvested area was 6 m^2.

Statistical analysis

The twelve genotypes of variance at each environment and combined analysis of variance at eight environments were subjected using general statistics (GenStat) program version 13 (Payne et al., 2006) software to observe the difference among genotypes in their performance in seed yield and seed yield related traits. The statistical significance of ANOVA components and homogeneity test of the error mean squares from the individual analysis of variance were determined using the application of the F-test (Gomez and Gomez, 1984).

The different stability parameters; Wricke's ecovalence (Wi) (1962) and Eberhart and Russell (1966) regression coefficient (bi) and deviation from regression (S^2di), cultivar superiority measure (Pi) of Lin and Binns (1988), Additive Main effect Multiplication Interaction (AMMI) and AMMI Stability Value (ASV) Purchase (1997) models were carried out using Agrobase (2000) software. Although data were collected on various characters such as oil content (%), oil yield (kg ha^{-1}), thousand seeds weight (gm), flowering and maturity days, etc. only seed yield (kg ha^{-1}) was considered in stability analysis and presented for a paper to avoid bulkiness of the data in a manuscript and seed yield is the result of the contribution of all seed yield related traits.

RESULTS AND DISCUSSION

The experiment was conducted in eight environments at five representative sesame growing areas of eastern Amhara. The rainfalls (mm) during the growing seasons of the locations of the two cropping seasons were recorded. The rainfall during the growing seasons of the locations ranged from 279.6 mm at Kobo 2010 to 837.2 mm at Chefa 2010. Maximum rainfall was recorded during the seedling and vegetative stages of the crops in July and August; however, there was shortage of rain at the flowering and pod setting stages of the crops in September and October, but at the maturity stage (November), there was high rainfall (Table 1). Minimum temperature of the locations ranged from 7.4°C in November at Chefa 2010 to 20.3°C in June at Kobo 2010 and maximum temperature ranged from 26.2°C in January at Chefa 2011 to 36.0°C in June at Shewarobit 2011.

Seed yield (kg ha^{-1}) and oil content (%)

The mean seed yield (kg ha^{-1}) of individual environment was presented in Table 2. The individual analysis of variance revealed that, this character was highly significant (P<0.01) indicated the presence of genetic variability among genotypes; hence, theses genotypes could be used as source of breeding materials to develop hybrid varieties.

Overall mean seed yield ranged from 217 kg ha^{-1} for genotype G1 at Chefa in 2010 to 1035 kg ha^{-1} for G6 at Shewarobit in 2011. The highest mean seed yields across environments were shown by genotypes; G1, G5, G8, G9, and G12 with overall mean seed yields (612.6. 712.8, 639.2, 679.2 and 636 kg ha^{-1}), respectively, and were higher than the grand mean (574.6 kg ha^{-1}) and national average (479 kg ha^{-1}); whereas the lowest mean seed yields were recorded for the G2, G10, and G11 (390.1, 487 and 443.1 kg ha^{-1}), respectively. The genotypes responded differently to the different environments for their seed yield with rank changed, this indicating that selection should be based on mean performances of the genotypes and similar result were reported by El-Bramawy and Shaban (2007) in sesame and Adane (2008) in linseed.

Regarding yield across environments the highest mean seed yields (kg ha^{-1}) were recorded at Shewarobit and Kobo both in 2010 and 2011 cropping seasons, this shows that the two locations are suitable for sesame production. At these locations, most of the genotypes had good performance and gave mean seed yields more than

Table 1. Monthly rainfalls (mm) during the growing seasons.

Months	E1	E2	E3	E4	E5	E6	E7
July	251.5(21)	112.9(15)	225.3(15)	184.3(15)	102.1(10)	112.9(14)	191.1(18)
Aug.	515.8(25)	121.9(16)	249.5(24)	256.9(24)	182.5(19)	298.9(25)	289.5(22)
Sep.	54.3(10)	7.6(5)	100.4(6)	96.3(11)	9.9(2)	99.8(5)	47.9(10)
Oct.	4.9(4)	17.2(5)	0.0	8(2)	13.4(5)	0.0	12.9(4)
Nov.	10.7(2)	20.0(6)	59.4(5)	56.7(7)	29.3(4)	55.9(3)	145.7(15)
Total	**837.2(62)**	**279.6(47)**	**634.6(50)**	**602.2(59)**	**337.2(40)**	**567.5(47)**	**687.1(69)**

Source: Dawa-Chefa, Sirinka and Shewarobit meteorology stations. E represents environments such as E1 = Chefa 2010, E2= Kob2010, E3=, Shewarobit 2010, E4 = Chefa 2011, E5= Kobo 2011, E6= Shewarobit 2011 and E7= Sirinka 2011; Numbers in parenthesisis indicate number of rainy days.

Table 2. Mean seed yield (kg ha^{-1}) of 12 sesame genotypes tested at 8 environments, 2010-2011.

Genotypes	Environments								Mean
	E1	E2	E3	E4	E5	E6	E7	E8	
G1	217^{f}	616^{b}	650^{abc}	503^{de}	666^{bcd}	1022^{a}	303^{de}	500^{ef}	612.6^{b}
G2	262^{de}	322^{f}	730^{ab}	260^{f}	473^{f}	293^{e}	266^{ef}	385^{g}	390.1^{d}
G3	307^{c}	544^{cd}	448^{f}	796^{b}	619^{cde}	610^{cd}	528^{a}	544^{de}	554.1^{bc}
G4	282^{d}	665^{b}	483^{def}	805^{b}	520^{ef}	716^{c}	430^{b}	579^{bcd}	578.5^{b}
G5	334^{b}	864^{a}	478^{ef}	1023^{a}	752^{b}	826^{b}	452^{b}	622^{abc}	712.8^{a}
G6	262^{de}	421^{e}	630^{abc}	421^{e}	716^{bc}	1035^{a}	255^{ef}	640^{ab}	580.8^{bc}
G7	280^{d}	484^{d}	759^{bc}	452^{de}	559^{def}	956^{a}	298^{de}	477^{f}	581.6^{bc}
G8	344^{b}	641^{b}	378^{f}	470^{de}	979^{a}	1027^{a}	363^{c}	563^{cde}	639.2^{ab}
G9	395^{a}	606^{bc}	612^{bcde}	570^{cd}	900^{a}	993^{a}	345^{cd}	567^{cd}	679.2^{ab}
G10	252^{e}	601^{bc}	434^{f}	246^{f}	685^{bc}	703^{c}	299^{de}	615^{abc}	487.0^{c}
G11	238^{ef}	486^{d}	507^{cdef}	241^{f}	640^{bcd}	546^{d}	234^{f}	580^{bcd}	443.1^{c}
G12	242^{e}	668^{b}	$624a^{bcd}$	640^{c}	718^{bc}	924^{ab}	369^{c}	644^{a}	636.0^{ab}
Env. Mean	285	577	569	519	686	721	345	560	574.6
CV (%)	4.6	6.3	3.7	14.0	8.8	7.7	7.7	6.5	9.18
LSD	22.05	61.70	130.3	63.33	102.6	105.3	44.89	61.3	73.93

E1= Chefa 2010. E2= Kobo 2010, E3= Shewarobit 2010, E4= Chefa 2011. E5= Kobo 2011, E6= Shewarobit 2011, E7= Jari 2011, E8= Sirinka 2011, CV= Coefficient of variability, Env. Mean= Environmental mean, LSD =Least significant difference; Values with the same letters in a column were not significantly different.

grand mean and national average (574.6 and 479 kg ha^{-1}), respectively; the reason might be these locations have warm conditions with sandy soil and short rain seasons. Hence, Shewarobit and Kobo are suitable for sesame production. Chefa, Jari and Sirinka have relatively high altitude with low temperature and clay soil. In these locations, most of the genotypes showed poor performance and gave low seed yields (kg ha^{-1}), therefore, Chefa, Jari and Sirinka are not suitable for sesame production. Sesame seed yield was increased at low altitude environments; indicated that this crop can well perform at low land areas and it is a warm lover crop.

Oil content was determined using Nuclear Magnetic Resonance method (Robbelen et al., 1989). Homogeneity test was carried out through the application of the F-test (Gomez and Gomez, 1984) and as the oil content showed heterogeneous error variance, therefore, arcsine transformation was done and figures in parenthesis were arcsine transformed value.

The mean oil content of the genotypes was ranged from 46.4% (42.9) by G12 to 53.4% (47.0) by G4. High oil content across environments were obtained from genotypes G4 [51.0% (45.0)], G3 [51.0% (45.6)], G8 [51.0% (45.6)], G5 [50.8% (45.5)], G10 [50.5% (45.3)], G11 [50.2% (45.1)], and G1 [50.1% (45.1)]. Genotypes G1, G3, G4, G5, G8, G10 and G11 are fulfill World export standard that is, their oil content records 50% and above. Across locations, Chefa, Jari and Sirinka gave high mean oil content, while Shewarobit and Kobo gave lower oil content. According to this finding, oil content of genotypes showed increasing trend to environments increasing in altitude and receiving better rainfall amount. On the other hand, oil content of genotypes drastically decreased in moisture-deficit environments. This is

Table 3. Mean values of seed yield related traits of 12 sesame genotypes.

Genotypes	DF	DM	PH	PBPP	PPP	SPP	TSW
G1	55.3^{ef}	120.0^{c}	93.4^{d}	3.0^{e}	44.1^{abc}	54.8^{a}	3.1^{b}
G2	71.7^{a}	132.2^{a}	101.2^{bcd}	4.8^{a}	36.3^{c}	50.8^{a}	2.6^{de}
G3	61.4^{cd}	121.4^{c}	107.7^{abc}	4.2^{abc}	55.5^{ab}	58.8^{a}	2.4^{e}
G4	62.8^{cd}	122.5^{bc}	109.7^{ab}	4.5^{ab}	55.8^{ab}	54.5^{a}	2.5^{e}
G5	62.8^{bcd}	120.3^{c}	112.4^{a}	4.1^{abcde}	59.2^{a}	55.2^{a}	2.6^{de}
G6	56.2^{ef}	120.2^{c}	99.2^{cd}	3.4^{cde}	48.9^{abc}	57.0^{a}	3.0^{bc}
G7	57.0^{ef}	120.5^{c}	94.9^{d}	3.2^{de}	43.4^{abc}	57.3^{a}	3.1^{b}
G8	54.8^{f}	119.9^{c}	83.3^{e}	3.0^{e}	48.8^{abc}	57.2^{a}	3.5^{a}
G9	59.1^{de}	121.3^{c}	98.0^{cd}	3.9^{abcde}	51.4^{abc}	55.5^{a}	3.0^{b}
G10	64.9^{bc}	128.5^{abc}	101.0^{bcd}	3.5^{bcde}	41.9^{bc}	55.0^{a}	2.7^{cde}
G11	66.7^{b}	130.3^{ab}	100.8^{bcd}	3.7^{bcde}	39.9^{bc}	53.7^{a}	2.7^{cde}
G12	61.1^{cd}	120.7^{c}	109.9^{ab}	4.2^{abcd}	51.0^{abc}	54.8^{a}	2.9^{bcd}
Gran mean	61.2	123.1	101.0	3.8	48.0	55.2	2.8
CV (%)	5.8	2.6	11.0	23.5	25.3	15.0	13.9
SLD	3.5	3.2	11.0	0.9	12.0	8.2	0.4

CV = Coefficient of variability, PBPP = Number of Primary branches per plant, DF = Days to flowering, DM = Days to maturity, PH = Plant height (cm), PPP = Number of Pods per plant, SPP = Numbers of Seeds per pod, SLD = Standard errors of the different, TSW = Thousand seeds weight (gm), and Values with the same letter in a column were not significantly different.

because in moisture-deficit environments genotypes would tend to synthesize proteins so as to cope up the unfavorable environments. As seed yield increases oil content decreases so, to improve the oil production of sesame, selection should be based on high seed yielder with relatively oil content producing genotypes or cross breeding of high seed yielder genotype with high oil content producer genotype. Similar result was reported by Zenebe and Hussien (2009) in sesame.

Seed yield related traits

The analysis of variance of seed yield related traits showed highly significant variability (P<0.01) among genotypes evaluated for all parameters except number of seeds per pod (SPP) in all environments (Table 3), this showed that, the genotypes had variability for phenological and agronomic traits. There were significant different between genotypes in days to flowering (DF), days to maturity (DM), plant height in cm (PH), thousand seeds weight in gram (TSW), number of primary branches per plant (PBPP) and number of pod per plant (PPP), this result agrees with the findings of Abou El-Nasr et al. (2006) in mustard, Adane (2008) in linseed and Nigussie (2012) in common bean. Genotypes G1, G6, G7, G8 and G9 were recorded 3.0 g and above for thousand seeds weight in gram (TSW) so they fulfill the requirement of international oilseed market standard.

Most genotypes were early flowered and matured at Shewarobit (56.5 and 103.7 days) and Kobo (58.4 and 114.7 days), respectively, but flowered lately at Jari and Chefa (66.3 and 68.4) and matured lately at Jari and Sirinka (146.2 and 146.9 days), in that order. All genotypes were flowered and matured earlier than local variety this showed that the improved varieties can escape short rain seasons than the local variety.

Combined ANOVA and estimation of variance components

Combined analysis of variance was also conducted for the traits considered. Homogeneity test of the error mean squares from the individual analysis of variance was carried out through the application of the F-test for all characters (Gomez and Gomez, 1984). The traits showed homogeneous error variances except for oil content (%). In order to conduct combined analysis, arcsine transformation for oil content was used as the variances tend to be proportional to the means (Table 4).

The result of the combined ANOVA indicated that there were highly significant variations among environments and among genotypes across all environments in the two cropping seasons. The environments had different impacts on the yield potential of the genotypes and genotypes showed rank difference; hence, the breeding strategy should be based on the performance of the genotypes. Similar results were reported by Adane (2008) in linseed, Zenebe and Hussien (2009) in sesame, Molla (2010) in finger millet and Nigussie (2012) in common bean.

Stability analyses

Twelve genotypes at eight environments were quantified

Table 4. Mean sum squares of combined ANOVA for 11 traits of 12 sesame genotypes.

Source	df	SY	OC	DF	DM	PH	PBPP	PPP	SPP	TSW
E	7	1009431**	38.44**(1.36)	742.4**	11232.2**	5082.9**	48.2**	15230.1**	6967.8**	2.9**
G	11	162079**	26.86**(1.49)	616.0**	474.7**	1634.5**	8.3**	1177.1**	115.0ns	2.2**
GEI	77	57176**	3.51**(1.41)	25.9**	19.8**	185.7*	1.6**	265.1**	84.1ns	0.3**
Error	176	2675	0.9(0.68)	12.4	10.5	123.0	0.8	147.0	68.3	0.2

*, ** = significant at 5 and 1%, respectively. DF = Days to flowering. DM = Days to maturity, OC = Oil content (%), PBPP = Number of Branches per plant, PH = Plant height (cm), PPP = Number of Pods per plant, SPP = Number of Seeds per pod, SY= Seed yield (kg ha^{-1}) and TSW = Thousand seeds weight (gm); Figures in parenthesis were square root transformed value.

using the following models:

Wricke's (W_i) ecovalence analysis

According to this model, genotypes with low value of Wi have smaller deviations from the mean across environments and are thus more stable. The lower the value of Wi the smaller will be the fluctuations from the predictable response in different environments so that the genotype with the least or zero ecovalence is considered to be ideal from the point of view of yield stability (Becker and Leon, 1988).

According to this stability parameter, the relatively stable genotypes were the fourth and the second high yielder genotypes G12 and G9. On the other hand the first top seed yielder genotype (G5) was the most unstable (Table 5). The result indicated that the highest yielder genotype (G5) have high ecovalence. According to Asrat et al. (2008) genotypes with high mean and large estimated value is suitable for high input environment. Hence genotype G5 was suitable for favorable environments, similar results were reported by Kassa (2002) in Ethiopian mustard and Alberts (2004) in common bean.

Eberhart and Russell's linear regression model

The mean squares for GEI was significant for seed yield (kg ha^{-1}) (P<0.01) (Table 6). This permitted the partitioning of GEI effects into environment linear, GEI (linear) interaction effects (sum squares due to regression, b_i) and unexplained deviation from linear regression (pooled deviation mean squares, S^2_{di}).

The analysis of variance for the regression model of seed yield (kg ha^{-1}) was presented in (Table 7). The stability analysis of variance revealed highly significant (P<0.01) different between genotypes, suggesting that there were considerable differential performance of the genotypes, this result was in line with Adane (2010) on linseed.

The GEI (linear) interaction of seed yield (kg ha^{-1}) was significant (P<0.05), indicating that the stability parameter (b_i) estimated by linear response to change in environment was different for all genotypes or genotypes had different slopes (Table 7). This confirms that GEI were in a linear function of environments indices as the mean of all the genotypes tested. The deviation from the regression (S^2_{di}) was not significant, indicating that, the nonlinear sensitivity in the expressions of these traits was not important. This result was agreed with the findings of Mahto et al. (2006) in finger millet.

The computed regression coefficients (b_i) and deviation from regression (S^2_{di}) of seed yield (kg ha^{-1}) of twelve sesame genotypes was presented in (Table 8). According to Eberhart and Russell (1966) model, a stable genotype should have high yield, unit regression coefficient (b_i) and deviation from regression (S^2_{di}) nearly equal to zero. Based on these three preconditions, there was no stable genotype in this study.

The genotypes with the regression coefficient (b_i) greater than one have below average stability, above average mean yield and highly sensitivity to environmental change, so these genotypes were best fit for specific adaptation in favorable or high potential environments, the genotypes with the regression coefficient less than one, have greater resistance to environmental change (above average stability), and thus increases the specificity of adaptability to low potential environments (Eberhart and Russell, 1966). As a result, genotypes: G1, G6, G7, G8, G9 and G12 had regression coefficients greater than unity, indicating their responsiveness to favorable environments, whereas, G2 and G3 had regression coefficient significantly lower than unity, showing their adaptation to low yielding environments. Other genotypes like G4, G5, G10 and G11had closer to unity; therefore, these genotypes had average responsiveness, and this result was in line with the findings of Firew (2003) in common bean.

Cultivar superiority measure (P_i) of Lin and Binns model

Lin and Binns (1988) stability measure by superiority index (P_i) defined as the deviation of the i^{th} cultivar relative to the genotype with maximum performance in

Table 5. Wricke's ecovalence value of seed yield (kg ha^{-1}) for 12 sesame genotypes.

Genotypes	W_i	R	Seed yield	R
G1	66428	3	612.6	5
G2	281530.3	12	390.1	12
G3	157532	9	554.1	9
G4	126959.8	8	578.5	8
G5	225320.8	11	712.8	1
G6	111067.6	7	580.8	7
G7	101980.7	6	581.6	6
G8	160279.6	10	639.2	3
G9	48168.5	2	679.2	2
G10	82993	4	487	10
G11	84443.8	5	443.1	11
G12	20808.9	1	636	4

Wi = Wricke's ecovalence and R= rank.

Table 6. Eberhart and Russell's ANOVA for seed yield (kg ha^{-1}) of 12 sesame genotypes.

Source	Df	Seed Yield MS
Total	287	
Genotypes	11	54026.4**
Env.+in Gen.xEnv.	84	45510.2
Env.in linear	1	
Gen. x Env. (linear)	11	30438*
Pooled deviation	72	15731.9
Residual	192	976.2

Grand mean = 574.6, R-squared = 0.7037, CV = 9.94%, MS = Mean of squares and df = Degree of freedom.

Table 7. Seed yield (kg ha^{-1}), regression coefficient (b_i), deviation from regression (S^2_{di}) and Cultivar superiority value (P_i).

Genotypes	b_i	S^2_{di}	P_i	R	Seed Yield	Rank
G1	1.42*	4398.5**	34364.9*	6	612.6	5
G2	0.25	27514.7**	115429.1**	12	390.1	12
G3	0.45	15431.6**	36382.0**	7	554.1	9
G4	0.68	16806.9**	31528.7	4	578.5	8
G5	0.93	36400.7**	11556.5	1	712.8	1
G6	1.44*	11159.6**	46072.1**	8	580.8	7
G7	1.16	15164.7**	47121.1**	9	581.6	6
G8	1.41*	20301.4**	33757.2	5	639.9	3
G9	1.27	4715.9**	21497.4	3	679.2	2
G10	0.97	12818.6**	65556.1**	10	487.0	10
G11	0.79	11716.5**	80589.0**	11	443.1	11
G12	1.24	639.6ns	20750.5	2	636.0	4

**,* =Significant at 1% and 5%, respectively and ns = Not significant.

each environment. The superior genotype would be the one with the lowest (P_i) value, that one which remained among the most productive in a given set of environments. The ranks of the (P_i) measure with mean seed yield (kg ha^{-1}) was given in (Table 7).

According to this model, the most stable genotypes

Table 8. AMMI's ANOVA for seed yield (kg ha^{-1}) of 12 sesame genotypes.

Source of variation	df	SS	MS	Sum of squares Explained (%)		
				Total V.E.	GEI E.	GEI cum.
Total	287	13813689	48131**			
Environments	7	7066020	1009431**	51.15		
Reps within Env.	16	64707	4044			
Genotypes	11	1782870	162079**	12.91		
Interactions	77	4402539	57176**	31.87		
IPCA 1	17	1890289	111193**		42.94	42.94
IPCA 2	15	1397613	93174**		31.75	74.69
IPCA 3	13	693680	53360**		15.76	90.45
IPCA 4	11	210548	19141**		4.78	95.23
IPCA 5	9	123852	13761**		2.81	98.04
IPCA 6	7	65463	52**		1.49	99.53
IPCA 7	5	21095	219		0.47	100
Residual	176	497553	2827			

** = significant at 1%, Total V.E. = Total variation explained, GEI E. = GEI explained and GEI cum. = GEI cumulative, SS = Sums of squares and MS = Means of squares.

With the lowest P_i were G5, G12 and G9 which ranked 1st, 4th and 2nd in mean seed yield (kg ha^{-1}). These stable genotypes had least contribution to the total variation due to GEI for seed yield. The most unstable were G2, G11 and G10 they ranked 12th, 11th and 10th for mean seed yield (kg ha^{-1}). These unstable genotypes contributed a large portion of the total variation of GEI for the seed yield (kg ha^{-1}). The most productive genotypes tended to be the most stable and hence (P_i) indicates the performance of the genotypes not actually an indication of stability. Similar results were reported by Lin and Binns (1988), Perreira et al. (2009) in bean, (Molla (2010) in finger millet and Nigussie (2012) in common bean.

AMMI analysis

The AMMI analysis of variance of seed yield (kg ha^{-1}) of twelve sesame genotypes tested at eight environments were presented in Tables 8. The result revealed that sesame genotypes were significantly (P<0.01) affected by environments (E), and GEI. The large sum of squares for environments indicated that the environments had different response for genotypes. From the total variation (Table 9), environment had taken the major share (51.15%), followed by GEI (31.87%), genotypes (12.91%), error (3.60%) and replications (0.47%). The larger portion of the sums of squares was contributed by environment and GEI to the total sums of squares as compared to the genotypes, indicated great influence of those environments on sesame production in eastern Amhara sesame growing areas, that means there is a significant different between locations and genotypes, and also genotypes showed rank changed in the two years data. The result indicating that, the breeding strategy should be based on the performance of the genotypes instead focusing stable or specific variety development. The investigation was in agreement with the findings of Adugna and Labuschagne (2002) and Adane (2008) in linseed.

The magnitudes of the GEI sum of squares were 2.5 times of the genotypes sum of squares for seed yield (kg ha^{-1}), indicating that there were substantial genotypic responses across environments. The AMMI1 model, the Interaction Principal Component Axes (IPCA1 and IPCA2) showed highly significant (P < 0.01) and explained 42.94 and 31.75% totally accounted 74.69% for seed yield of the GEI variation, using 17 and 15 degrees of freedom (32) from the total of 77 degrees of freedom available for the interaction.

Though, the higher interaction principal component axes (IPCA3 to IPCA6) of the interactions were significant for the model, the prediction assessment indicated that AMMI 1 with only two interaction principal component axes were the best predictive (Zobel et al., 1988). Further interaction principal component axes captured mostly noise and therefore, did not help to predict validate observations. This result was in harmony with the results of Molla (2010) in finger millet and Nigussie (2012) in common bean.

Partitioning of the total variances of oil content indicated that environment 25.59% (25.29), genotypes 28.10% (27.77), GEI 25.71% (26.23), replications within environment 1.67% (1.64) and error 12.49% (12.65) had contributed (Table 10). The contribution of sums of squares due to environment and GEI were relatively lower than the contribution of sums of squares due to genotypes on oil content as compared to seed yield (kg

Table 9. Percent contributions of different variance components for ten characters.

Characters	Env.	Rep (E)	Gen	GEI	Error
SY	51.15	0.47	12.91	31.87	3.60
OC	25.59	1.67	28.10	25.71	12.49
	(25.29)	(1.64)	(27.77)	(26.23)	(12.65)
DF	31.47	1.44	41.04	12.06	13.99
DM	90.00	0.21	6.00	1.75	2.07
PH	37.13	6.92	18.76	14.92	22.27
TSW	61.79	1.47	23.76	4.84	8.15
PBPP	48.15	1.74	13.09	17.35	19.67
PPP	63.39	2.13	7.70	12.14	14.64
SPP	69.93	0.17	1.84	9.11	14.91

DF = Days to flowering, DM = Days to maturity, Env. = Environment, OC = oil content (%), PBPP= Number of branches per plant, PH = Plant height (cm), PPP = Number of pods per plant, SPP = Number of seeds per pod, SY = Seed yield (kg ha^{-1}) and TSW = 1000- seed weight (gm); Figures in parenthesis were arcsine and square root transformed value.

Table 10. Genotypes mean of seed yield (kg ha^{-1}) and their IPCA1and IPCA2 scores.

Genotypes	Mean SY	IPCA1	IPCA2
G1	612.6	4.76	4.48
G2	590.1	1.13	-19.97
G3	554.1	-12.82	-2.64
G4	578.5	-12.06	0.03
G5	712.8	-15.38	6.34
G6	580.8	9.59	3.45
G7	581.6	6.40	-1.98
G8	639.2	5.40	11.09
G9	679.2	4.62	4.50
G10	487	4.80	-1.18
G11	443.1	4.09	-6.93
G12	636	-0.54	2.80

Mean SY= Mean seed yield (kg ha^{-1}).

ha^{-1}), indicated that environment and GEI influence on oil content were not as large as their influence on seed yield (kg ha^{-1}) (Table 9). Similar result was also reported by Adane (2008) in linseed.

In other agronomic traits, environment accounted for larger share of total sums of squares. It accounted for days to flowering 31.47%, for days to maturity 90.00%, for number of primary branches per plant 48.15%, for number of pods per plant 63.39%, for plant height (cm) 37.13%, for number of seeds per pod 69.93% and for thousand seeds weight (g). GEI contribution was higher than that of genotypes for most of the traits and had great influence on sesame seed yield (kg ha^{-1}) production, similar result was reported by Zenebe and Hussien (2009) in sesame.

The IPCA scores of the genotype in the AMMI analysis is an indication of the genotype adaptability over environments and association between genotypes and environments (Gauch and Zobel, 1996). The first and the second IPCA scores of genotypes of seed yield (kg ha^{-1}) were given in Table 10. Regardless of the positive or negative signs, genotypes with small scores close to zero have low interaction and stable, whereas genotypes with large scores have high interactions and were unstable (Zobel et al., 1988). By considering IPCA1 alone and despite the positive or negative signs, genotypes G2 and G12 had small scores close to zero were stable; whereas genotypes G3, G4 and G5 had large IPCA1 scores far from zero were unstable, this result was agreed with the findings of Crossa (1990), Molla (2010) in finger millet and Nigussie (2012) in common bean.

As the result was shown in Table 11, based on environmental index and environmental mean seed yield values (kg ha^{-1}), environments were classified into three

Table 11. Environment index of seed yield (kg ha^{-1}) and their IPCA1 and IPCA2 scores.

Env.	SY	Env. Index	IPCA1	IPCA2
E1	285	1.76	1.8	-6.6
E2	577	5.78	-5.8	3.4
E3	561	8.90	8.9	-15.7
E4	535	-20.83	-20.8	5.0
E5	685	7.35	7.4	5.1
E6	804	12.37	12.4	17.1
E7	345	-5.78	-5.5	-5.5
E8	561	2.01	-2.9	-2.9

Env. = Environment, Env. Index = Environment index, SY= Seed Yield (kg ha^{-1}), E1= Chefa 2010, E2= Kobo 2010, E3= Shewarobit 2010, E4= Chefa 2011, E5 = Kobo 2011, E6 = Shewarobit 2011, E7 = Jari 2011, and E8 = Sirinka 2011.

groups, Kobo and Shewarobit were the most favorable (potential) environments for the production of sesame which had the largest environmental index values (5.78 and 8.90), with mean seed yield (kg ha^{-1}) (577 and 561 kg ha^{-1}) in 2010 cropping season and (7.35 and 12.37) with mean seed yield (kg ha^{-1}) (685 and 804 kg ha^{-1}) in 2011 cropping season, respectively. Sirinka had average environment with environmental index and environmental mean seed yield values (2.01 and 561 kg ha^{-1}), respectively, whereas Chefa 2010/2011 and Jari 2011 were the most unfavorable environments since they had the smallest environmental index values (1.76, -20.83 and -5.78) with mean seed yield (285, 535 kg ha^{-1} and 345 kg ha^{-1}), respectively.

Environments with larger IPCA1 scores discriminate among genotypes more than environments with lesser scores (Zobel et al., 1988; Kempton, 1984). Accordingly, Shewarobit was the most discriminating environment than the others (Table 11) and this result was in agreement with the findings of Nigussie (2012) in common bean.

Genotypes with IPCA scores near zero had little interaction across environments (the more stable genotypes) and those far along the axis had high interaction (more unstable genotypes). Genotypes and environments with the same sign on the IPCA axis had positive interaction and vice versa (Zobel et al., 1988) (Table 11).

AMMI stability value (ASV)

The AMMI model does not provide a measure of quantitative stability. But quantitative stability measure is essential in order to quantify and rank genotypes according to yield stability. For this reason ASV was proposed by Purchase (1997). In this model, genotypes with least ASV were considered the most stable, whereas those which had highest ASV were considered unstable (Purchase, 1997). According to this model, genotypes with their seed yield (kg ha^{-1}) G12, G2 and G11 were stable, whereas genotypes G5, G3 and G4 were unstable (Table 12); similar result was reported by Adane (2008) in linseed.

In the AMMI model I biplot, the plot was helpful to visualizing the average productivity of the genotypes, environments, and their interaction for all possible genotype x environment combinations (Yan and Hunt, 1998). The AMMI1 biplot for seed yield (kg ha^{-1}) of twelve genotypes at eight environments presented in Figure 1 showed that Shewarobit and Kobo were potential and favorable environments; Sirinka was an average, while Chefa and Jari were unfavorable environments for sesame production and also Shewarobit and Chefa were the most discriminating environments, while Local variety and genotype Acc.00047 were the most responsive genotypes.

Comparison of stability parameters

Different stability parameters were used to compare the stability and ranking of sesame genotypes. Although there was change in ranking order of genotypes from one stability parameter to another, based on the information (Table 13), genotypes G12, G9 and G1 with mean seed yield of 639, 679 and 613 kg ha^{-1} were found stable by stability parameters Wricke's (1962) ecovalence and deviation from regression (Eberhart and Russell, 1966). These genotypes had high buffering capacity to environmental changes such as diseases and drought (Becker and Leon, 1988), while G2, G8 and G6 with mean seed yield of 390, 639 and 580.8 kg ha^{-1} respectively were unstable. This result was in agreement with the findings of Alberts (2004) in maize, Muluken (2007) in malt barley and Nigussie (2012) in common bean.

The fourth and second high yielder genotypes, G12 and G9 were the first and the second stable by most of the stability measures with mean seed yield of 639 and

Table 12. Twelve sesame genotypes seed yield (kg ha^{-1}), AMMI Stability Value (ASV), Ranks, IPCA1 and IPCA2 scores.

Genotypes	IPCA1	IPCA2	ASV	R^a	Seed Yield	R^y
G1	4.76	4.48	5.53	5	612.6	5
G2	1.13	-19.97	1.31	2	390.1	12
G3	-12.82	-2.64	14.91	11	554.1	9
G4	-12.06	0.03	14.02	10	578.5	8
G5	-15.38	6.36	17.88	12	712.8	1
G6	9.59	3.45	11.15	9	580.8	7
G7	6.40	-1.98	5.54	6	581.6	6
G8	5.40	11.09	6.28	8	639.2	3
G9	4.62	4.50	5.38	4	679.2	2
G10	4.80	-1.18	5.59	7	487.0	10
G11	4.10	-6.93	4.77	3	443.1	11
G12	-0.54	2.80	0.83	1	636.0	4

R^a = Rank by ASV, R^y = Rank by seed yield.

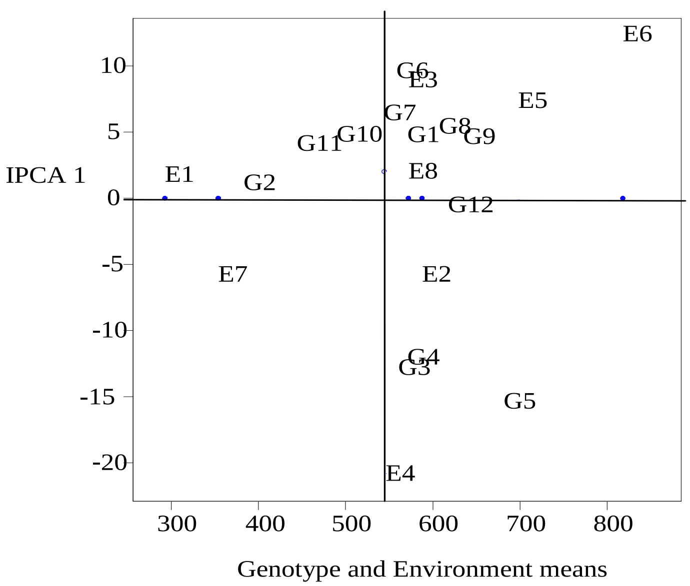

Figure 1. AMMI biplot of IPCA1 vs. Main effects using seed yield data. Genotypes: G1 = Acc. 00035, G2 = Local variety, G3 = Acc. 00044, G4 = Acc. 00046, G5 = Acc. 00047, G6 = Acc. 018, G7 = Hirhir-Kibe, G8 = Acc.202-344, G9 = NN-0143, G10 = Acc.202339, G11 = Acc.202340, G12 = Borkena; Environments: E1= Chefa 2010, E2 = Kobo 2010, E3 = Shewarobit 2010, E4 = Chefa 2011, E5 =Kobo 2011, E6 = Shewarobit 2011, E7 = Jari 2011 and E8 = Sirinka 2011.

679 kg ha^{-1}, respectively. The highest seed yielder genotype (G5) with mean seed yield (712. 8 kg ha^{-1}) was the most unstable except by the stability parameter cultivar superiority performance (Pi) (Lin and Binns, 1988) where it appeared as 1st stable cultivar (Table 8). This genotype had the highest value of ASV in seed yield (kg ha^{-1}) (Table 13). The high yielder genotypes had high ASV value and were positively correlated; this result was similar to the works of Carbonell et al. (2004) and Perreira et al. (2009) in bean.

Although, most of the genotypes showed inconsistency in ranking for stability measures, when compared on overall ranking, genotype G12 ranked 1st in stability parameter W_i, S^2_{di} and ASV; 2nd in P_i and it was found at the origin in the AMMI 1 biplot and genotype G9 was 2nd rank in stability parameter W_i, S^2_{di} ; 3rd in P_i and it was found relatively near the origin in the AMMI 1 biplot.

Yield stability is an important issue in cultivar testing and selection, but stability is meaningful for cultivar evaluation only when the genotypes are comparable in average yield. Stability alone is meaningless, that means a less stable cultivar that performs well on average is better than a cultivar that stable and performs consistently poor (Weikai, 1999), hence, G12 and G9: 4th and 2nd in their seed yield, respectively were 1st and 2nd stable genotypes and thus they could be grown in wide environments. Similar results were identified by Adugna and Labuschagne (2002) in linseed, Abou El-Nasr et al. (2006) in mustard, Gunasekera et al. (2006) in Indian mustard and Hariprasanna et al. (2008) in groundnut.

Duarte and Zimerman (1995) suggested that phenotypic stability should not be restricted to one method but personalized to the stability type of interest to the individual researcher. Inconsistency in ranking using a univariate approach was previously suggested to be difficult to reconcile into a unified conclusion by Lin et al. (1986). According to them, the basic reason for the difficulty is that a genotype's response to environments is multivariate. This problem has been overcome by using the AMMI model (Alberts, 2004; Adugna, 2007). Since it has a power of measuring the magnitude of the sums of squares of environments, GEI and genotypes, evaluate multivariate responses of the genotypes and also shows the potential and poor environments; high and low yielder as well as stable and unstable genotypes on the same biplot graph, that means AMMI model is the best model of the others for this study.

Table 13. Ranks of seed yield based on the various stability parameters.

Genotypes	SY	R	W_i	R	b_i	R	S^2_{di}	R	P_i	R	ASV	R	O.R.
G1	613	5	66428	3	1.42	11	4398.5**	3	34365	6	5.4	7	4
G2	390	12	281530	12	0.25	1	27514.7**	8	115429	12	2.2	3	12
G3	554	9	157532	9	0.45	2	15431.6**	11	36382	7	1.3	2	6
G4	579	8	126960	8	0.68	3	16806.9**	9	31529	4	10.6	11	8
G5	713	1	225321	11	0.93	5	36400.7**	12	11557	1	12.4	12	9
G6	581	7	111068	7	1.44	12	11159.6**	4	46072	8	9.2	10	10
G7	582	6	101981	6	1.16	7	15164.7**	7	47121	9	5.5	8	6
G8	640	3	160280	10	1.41	10	20301.4**	10	33757	5	6.0	9	11
G9	679	2	481669	2	1.27	9	4715.9**	2	21497	3	4.4	6	2
G10	487	10	82993	4	0.97	6	12818.6**	6	65556	10	4.3	5	5
G11	443	11	84444	5	0.79	4	11716.5**	5	80589	11	3.1	4	3
G12	636	4	20809	1	1.24	8	639.6ns	1	20751	2	0.1	1	1

ASV=AMMI stability value, b_i = Eberhart and Russell's (1966) regression coefficient, O.R. = Overall rank, P_i = Lin and Binns (1988) cultivar performance measure, R= Rank, Sd_i^2 = Eberhart and Russell's (1966) deviation from regression, SY= Seed yield (kg ha^{-1}), and Wi = Wricke's (1962) ecovalence.

Table 14. Correlations of stability measures with seed yield.

Variables	Yield	W_i	b_i	S^2_{di}	P_i	ASV
Yield		0.18ns	0.66**	0.08ns	-0.95**	0.44ns
W_i			-0.19ns	0.08ns	-0.02ns	0.08ns
b_i				-0.33ns	-0.56*	0.26ns
S^2_{di}					-0.04ns	0.60*
P_i						-.37ns
ASV						

*, ** significant at P<0.05 and P<0.01 respectively, ns = non-significant, Pi = Lin and Binns (1988) cultivar performance measure; Wi = Wricke's (1962) ecovalence; bi = Eberhart and Russell's (1966) regression coefficient; S^2_{di} = Eberhart and Russell's' (1966) deviation from regression and ASV=AMMI stability value.

Correlation of stability parameters

The correlation of different stability parameters was determined using General statistics (GenStat) program version 13 (Payne et al., 2006) for each of the possible pair wise comparisons of the ranks for the seed yield (kg ha^{-1}) (Table 14). The only regression coefficient (b_i) had highly significant positive rank correlation with seed yield with (r=0.66), the high correlation mean seed yield and regression coefficient (b_i) was expected as the value of this statistic was higher for high yielding genotypes, this result was in agreement with the findings of Molla (2010).

Lin and Binns (P_i) method showed a highly significant negative rank correlation (r = - 0.95) with seed yield, indicated that, high yielding and responsive genotypes like G5 had a tendency to lower P_i value, this result was in agreement with the works of Nigussie (2012) in common bean, but disagreed with the result of Molla (2010) in finger millet.

On the other hand, stability parameters (W_i, S^2_{di} and ASV) had non-significant correlation (r=0.18, 0.08 and 0.44) with seed yield. The non-significant correlation among yield and stability parameters indicated that, information cannot be collected from average yield alone (Duarte and Zimermann, 1995) in common bean. S^2di was positively significant correlated with Wi and ASV indicating that they can measure similar aspects of stability which in harmony with the work of Firew (2003). Therefore, it is possible to use only one of them as a measure of biological stability.

Conclusions

Sesame is a major oilseed crop cultivated mainly for its oil of local consumption and export purposes. It grows in many parts of the world from tropical to the temperate zones, but it grows best on fairly warm growing seasons on well drained moderately fertile soils and it requires 500 to 650 mm of rainfall per annum. However, in eastern Amhara Region the environments have variable altitude range, erratic rainfall, different soil types and also diverse management practices. Therefore, genotypes are exposed to GEI. Due to the differential response of genotypes in different environments describes a major challenge to plant breeders and cause of crop failures; hence, stability analysis is required in such situations.

The experiment was carried out using twelve sesame genotypes at eight environments in five locations of eastern Amhara Region namely: (Chefa, Kobo and Shewarobit for 2010 and 2011 cropping seasons; Jari and Sirinka for 2011 cropping season) with randomized complete block design (RCBD) in three replications to estimate the nature and magnitude of the genotypes, environments and their interactions on seed yield and yield related traits, and to identify wide and/or specific adaptability sesame genotype(s). The combined analysis of variance revealed significant different ($P<0.01$) among environments, genotypes and GEI for all the characters except seeds per pod (SPP). The mean seed yield ranged from 217 kg ha^{-1} for Chefa 2010 to 1035 kg ha^{-1} for Shewarobit 2011, the result indicated that, Shewarobit was favorable environment, while Chefa was unfavorable environment for sesame production.

Regarding oil content, among twelve genotypes, seven genotypes gave 50% and above. The mean oil content ranged from 46.4% with G12 to 53.1% with G3; based on environments, ranged from 48.0% for Shewarobit 2010 to 51.3% for Sirinka 2011, indicated that Sirinka was favorable, while Shewarobit was the least favorable site for oil content.

Over the two years Shewarobit and Kobo gave high seed yield (kg ha^{-1}), whereas Chefa, Jari and Sirinka gave the least, but in the oil content (%) they had the reverse result. The reason might be due to environmental conditions that have different altitude, temperature, rainfall and soil types. Shewarobit and Kobo have relatively low altitude with high temperature (warm conditions) and sandy soil types than the rest locations. To improve sesame production the breeding strategy or selection should be focused on high seed yielder with relatively oil content genotypes and production area should be in the lowland environments.

The only regression coefficient (bi) had highly significant positive rank correlation with seed yield with ($r=0.66$), the high correlation seed yield and regression coefficient (bi) was expected as the value of this statistic was higher for high yielding genotypes. Cultivar superiority performance (Pi) showed a highly significant negative rank correlation with ($r = -0.95$) in seed yield, indicated that, high yielding and responsive genotypes like G5 had a tendency to lower Pi value. On the other hand, stability parameters Wricke's (Wi), deviation from regression (S^2_{di}) and AMMI Stability Value (ASV) had non-significant correlation with seed and oil yields. The non-significant correlation among seed yield and stability parameters indicating that, information cannot be collected from average yield alone.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

Correlation of the least limiting water range with soil physical attributes, nutrient levels and soybean yield

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In soils that are compacted or undergoing compaction, the interval of water available to the plants can decline to zero, which according to the least limiting water range (LLWR) method is called the critical soil bulk density ($Bd_{critical}$), when LLWR = 0. The aim of this study was to determine the LLWR of a highly clayey typic dystrophic Red Latosol (Oxisol) and to correlate it with the soil physical attributes, nutrient levels and soybean yield, because hypothetically if there is a negative correlation, the use of the LLWR associated with spatial variability maps can help reach decisions regarding intervention or modification of soil management. We observed that in no-till farming, limitation of plant development can occur as the soil dries out, mainly due to the higher resistance to mechanical penetration. Besides this, we found that the $LLWR_{0-0.10m}$ and $LLWR_{0.10-0.20m}$ values were correlated in greater numbers with macronutrients and micronutrients analyzed, and also with the land slope, compared the correlation with the soybean yield data. Therefore, nutritional analysis of the grains complemented by physical analysis of the soil can be used to identify nutritional imbalances that are not otherwise observable and thus, the LLWR can be useful for planning corrective actions regarding soil and crop management, based on measurement of the $Bd_{critical}$.

Key words: No-tillage system, no-till farming system, soil physical quality indicator, spatial variability of soil water content.

INTRODUCTION

Soybean growing is of great socioeconomic importance in Brazil and has been expanding particularly in the Cerrado (savanna) biome, where in 1990s farmers started shifting to no-till planting with precision techniques instead of traditional farming methods, to reduce the need for inputs. However, no-till farming can cause problems of subsurface soil compaction and erosion (Altmann, 2010). Although these problems have been ameliorated through improved techniques, other problems can also occur due to the rapid decomposition of crop residues and the relative lack of economically feasible options for crop rotation. These drawbacks can

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hamper efforts to mitigate excessive compaction of the surface layer, which is one of the main hindrances to water availability to plants (Hamza and Anderson, 2005).

To maximize crop yields, the water in the soil must be maintained within optimal parameters (Rejani and Yadukumar, 2010; Benjamin et al., 2014). However, in soils that are compacted or undergoing compaction, the interval of available water to plants can narrow to zero in function of low aeration under inefficient drainage conditions and increased mechanical resistance to penetration as the soil dries out (Araújo et al., 2013; Moreira et al., 2014). This interval is called the least limiting water range (LLWR) (Silva et al., 1994). Determination of this range involves calculation of the critical soil bulk density ($Bd_{critical}$), when LLWR = 0. This value can hypothetically be used with other information to monitor the physical quality of the soil, also considering the correlation with the particular parameters for each crop (Klein and Camara, 2007; Benjamin et al., 2014).

In this respect, the aim of this study was to determine the LLWR of a highly clayey typic dystrophic Red Latosol (Oxisol) and to correlate it with the soil physical attributes, nutrient levels and soybean yield.

MATERIALS AND METHODS

The study was conducted on a farm in the municipality of Diamantino, Mato Grosso, at 14°07'0" S latitude and 56°58'39" W longitude, at an altitude of 539 m. The region's climate is Aw according to the Köppen classification, with well-defined seasons: rainy (October to April) and dry (May to September). The average yearly rainfall is 1,816.9 mm and the average annual temperature varies from 16.2 to 25.5°C. The soil in the experimental field is classified as highly clayey typic dystrophic Red Latosol (Oxisol), "A" moderate horizon, developed under semideciduous tropical forest, with flat relief (Santos et al., 2013). The forest was cleared in 1987 and rice was planted that same year (for harvest in 1988). After this crop, soybeans and corn were grown in succession until the 1999-2000 growing season, with the soil being mobilized by harrowing to a depth of 0.20 m every three years plus fertilization in the furrow. From the 2000-01 to the 2003-04 growing seasons, cotton was cultivated, followed by soybeans and corn in succession again until 2013-2014, but now without tillage, during which period lime and fertilizers were applied as side dressing. For this study, we evaluated the 2013-2014 soybean crop (*Glycine max* L.), Monsoy 7639 RR cultivar, in an experimental plot covering approximately 12 ha (300 by 405 m) out of 56 ha field planted with spacing of 0.45 m between rows and an average of 15 plants per linear meter. The sowing occurred on October 23, 2013 and the plants were harvested on February 5, 2014.

Undeformed soil samples were obtained at the end of the phenological stage of the crop (R7.2), using an Uhland auger to bore holes in the 0-0.10 m and 0.10-0.20 m layers for insertion of stainless steel cylinders (50 mm in diameter by 50 mm in height), to include the profile exploited by soy roots. The sampling layout was in an irregular mesh due to deviations of the level curves, oriented between the crop rows, with a total of 117 collection points for each layer. These points were georeferenced with maximum vertical and horizontal error of 5 mm using a Topcon HiPer® Pro GPS device. In the laboratory these samples were saturated with distilled water and submitted to different matrix potentials, using 14 repetitions: 2, 6 and 10 kPa, using a sandbox (Eijkelkamp Agrisearch Equipment, model 08.01), and pressures of 33, 66, 100, 300 and 1500 kPa, using a pressure plate extractor (Soilmoisture Equipment Corp. model 1500F1®), to determine the curves of water retention and penetration resistance, and consequently the LLWR (Moreira et al., 2014). After reaching the water balance at each potential, the samples were weighed on a scale with accuracy of 0.01 g and then transferred to an electronic bench penetograph operating at constant penetration velocity of 10 mm min^{-1} (0.1667 mm s^{-1}), with a load cell having nominal capacity of 196.13 N (20 kgf), shaft with cone of 3.7407 mm in diameter and semiangle of 30º. The device was connected to a computer to record the readings (Bianchini et al., 2013). Then, the samples were dried at 105°C for 48 h to calculate the bulk density (Donagema et al., 2011).

To determine the soil water retention curves and soil resistance to penetration, and consequently the LLWR followed the procedures described in Moreira et al. (2014). The lower limit of the LLWR was defined by considering the moisture corresponding to the permanent wilting point based on water tension of 1500 kPa (Silva et al., 1994) and the soil penetration resistance at a limiting value of 2.0 MPa (Silva et al., 1994). In turn, the upper limit was determined by the water content value related to the field capacity at tension of 10 kPa (Silva et al., 1994) and by aeration porosity of 10% (Silva et al., 1994).

The microporosity values were determined by the difference between the moist mass of the sample at tension equivalent to a 60 cm water column and the dry mass after the sample was dried in an oven at 105°C for 48 h. This difference was then multiplied by the soil bulk density. Next we determined the total soil porosity of the samples based on the respective particle density values of each sampling point. Finally, we measured the macroporosity by the difference between the total porosity and microporosity. From the deformed samples, we determined the percentages of sand, silt and clay by the pipette method, using a shaker table for 16 h to accelerate dispersion of the particles, and also measured the quantity of organic matter by the oxidation method with potassium dichromate and colorimetric measurement (Donagema et al., 2011).

The soybean yield (kg ha^{-1}) was estimated by harvesting plants along 4 linear meters at each sampling point, with the bean moisture corrected to 14%. Then we determined the levels of N of grains by acid digestion, distillation and titration – Kjeldahl method, as well as P, k, Ca, Mg, S, Zn, Cu, Fe, Mn and B by simultaneous multi-element measurement by inductively coupled plasma atomic emission spectrometry, or ICP-AES (Silva, 2009).

All the data were normally distributed according to the Shapiro-Wilk test ($P > 0.05$). We then calculated the pairwise bivariate correlations between the LLWR, soil bulk density, land slope and levels of macronutrients, micronutrients and the soybean grain yield by the Pearson and t-tests ($\alpha = 0.05$), utilizing the Sigma Plot Version 12.5 software, considering the 117 data pairs from each soil layer. Besides this, we analyzed and modeled the spatial structure of the LLWR by the method of ordinary kriging, in 2 × 2 m blocks (Yamamoto and Landim, 2013). The semivariogram model was fitted using the Gamma Design GS^{+TM} software: Geostatistics for the Environmental Sciences, version 10.0.

RESULTS AND DISCUSSION

At 5% probability, the adjustments explained over 90% of the soil volumetric moisture (θ) and more than 76% of the penetration resistance (PR), with mean residual standard error of at most 3.63% for θ, considering the mean total porosity value of each soil layer (0.51 for 0-0.10 and 0.47 m^3 m^{-3} for 0.10-0.20 m), and at most of 17.60%, considering the PR value of 1 MPa (Table 1). Besides this, the signs of the coefficients (negative or positive)

Table 1. Equations for fitting the water retention and mechanical penetration resistance curves.

Layers (m)	Equations (1)	F-test	R^2	SER
	Soil water retention curves			
0-0.10	$\theta = 0.452484^{***}. \lvert\Psi\rvert^{-0.091415^{***}}. Bd^{0.367267^{***}}$	P < 0.0001	0.9262	0.0186
0.10-0.20	$\theta = 0.359406^{***}. \lvert\Psi\rvert^{-0.073829^{***}}. Bd^{0.709454^{***}}$	P < 0.0001	0.9400	0.0131
	Soil penetration resistance curves			
0-0.10	$PR = 0.021079^{*}. \theta^{-3.411566^{***}}. Bd^{5.497318^{***}}$	P < 0.0001	0.7944	0.1760
0.10-0.20	$PR = 0.0011860^{*}. \theta^{-5.3030664^{***}}. Bd^{6.4934087^{***}}$	P < 0.0001	0.8418	0.1510

(1) ***(P < 0.0001), *(P < 0.05) = significant at 5% probability by the t-test; θ = volumetric moisture (m^3 m^{-3}); |Ψ| = matrix potential (kPa); Bd = soil bulk density (Mg m^{-3}); PR = soil penetration resistance (MPa); R^2 = coefficient of determination; SER = standard error of residuals for 109 degrees of freedom.

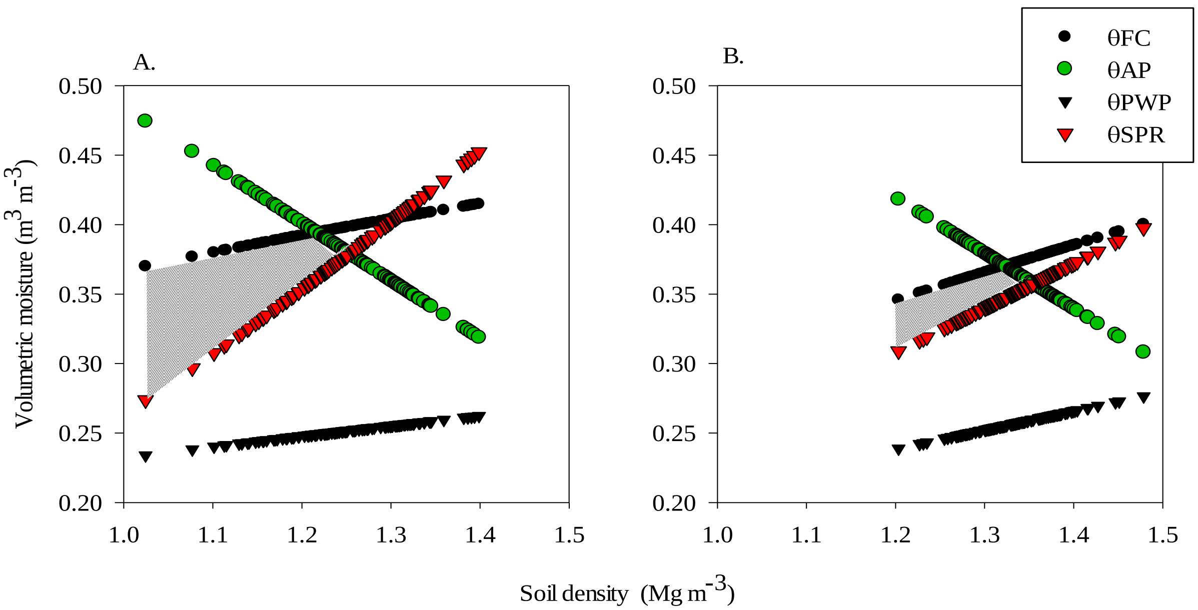

Figure 1. Volumetric moisture in function of soil bulk density at depths of 0-0.10 (A) and 0.10-0.20 m (B), with the gray shaded area representing the LLWR, considering the limits of field capacity (θFC), aeration porosity (θAP), permanent wilting point (θPWP) and mechanical penetration resistance (θSPR).

were in agreement with the theoretical signs (Araújo et al., 2013).

Based on the fitted data, we plotted graphs and observed that with increasing soil bulk density, the volumetric moisture equivalent to the critical levels of penetration resistance (θPR = 2.0 MPa) determined the largest portions of the lower limits of the LLWR (Figures 1A and B).

However, the impact of the θPR on reducing the LLWR was greater. This finding is in line with the hypothesis that as soils that are compacted or undergoing compaction dry out, this can limit plants' development, mainly due to the higher soil resistance to penetration (Collares et al., 2006; Safadousta et al., 2014). This greater influence of the θPR_{limit} in determining the LLWR has been reported for different soil classes (Collares et al., 2006; Klein and Camara, 2007; Araújo et al., 2013; Moreira et al., 2014; Safadousta et al., 2014).

In this respect, to check for a possible relation between the LLWR and the soil attributes and plant parameters, we carried out a correlation analysis (Table 2). Although the soybean yield was only correlated with the level of phosphorous and manganese in the beans, the $LLWR_{0-0.10\ m}$ and $LLWR_{0.10-0.20\ m}$ values were correlated in greater numbers with macronutrients and micronutrients analyzed.

During the growing cycle, events can occur, such as excess or deficit of water in the layer exploited by the roots, even for short periods, that can upset the balance of mobility, absorption and transport of nutrients in the soil-plant system (Gregory, 2006), as well as increase the availability of iron (Becker and Asch, 2005) and

Table 2. Pearson correlation coefficients between the variables.

Variables	Yield	LLWR_10	LLWR_20	Bd_10	Bd_20	Slope
Yield of grains()kg ha^{-1}	1					
LLWR _10 (m^3 m^{-3})	0.01	1				
LLWR _20 (m^3 m^{-3})	0.04	0.22*	1			
Bd _10 (Mg m^{-3})	-0.11	-0.79***	-0.15	1		
Bd _20 (Mg m^{-3})	-0.03	-0.18	-0.94***	0.16	1	
Slope (m)	-0.04	-0.23*	-0.26**	0.03	0.25*	1
N (g kg^{-1})	0.14	-0.09	0.02	-0.03	0.02	0.09
P (g kg^{-1})	0.28**	-0.29**	-0.03	0.04	0.05	0.28**
K (g kg^{-1})	0.04	0.25**	0.27**	-0.09	-0.20*	-0.42***
Ca (g kg^{-1})	0.06	0.04	0.28**	0.03	-0.22*	-0.35**
Mg (g kg^{-1})	0.08	-0.19	0.24*	0.05	-0.16	-0.11
S (g kg^{-1})	0.08	-0.22*	-0.17	0.08	0.17	0.33**
Zn (mg kg^{-1})	-0.06	-0.32**	-0.13	0.14	0.18	0.42***
Cu (mg kg^{-1})	-0.06	0.06	0.26**	0.03	-0.29**	-0.31**
Fe (mg kg^{-1})	0.05	0.15	-0.05	-0.13	0.06	-0.06
Mn (mg kg^{-1})	-0.24*	0.23*	0.00	-0.06	0.03	-0.10
B (mg kg^{-1})	0.10	-0.11	-0.01	0.03	0.01	0.19*

(1) *** (P < 0.0001), ** (P < 0.01), * (P < 0.05) = significant at 5% probability by the t-test.

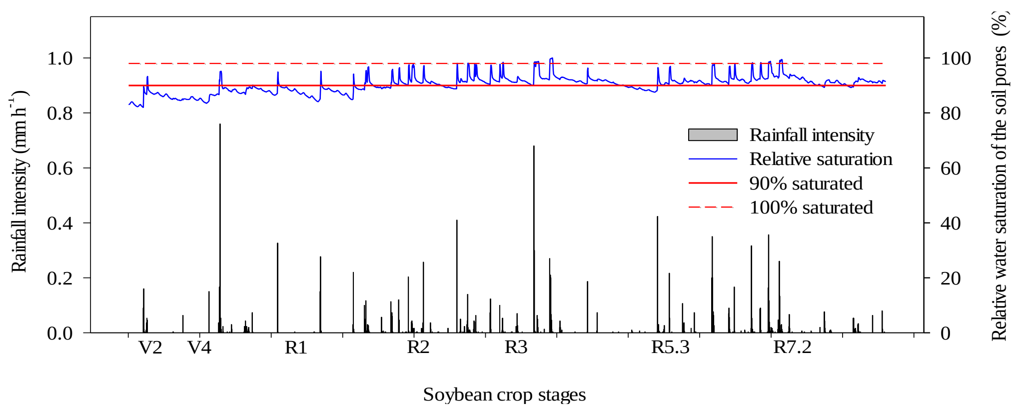

Figure 2. Rainfall intensity versus relative water saturation of the soil pores in the 0 to 0.20 m layer. Remark: The data were obtained every 5 min by sensors and recorded at an automatic weather station (HOBO® U30), located in the center of the experimental unit.

manganese (Millaleo et al., 2010). These elements can accumulate in the plant biomass, reaching toxic levels. In this study, we found that approximately 60% of the soil moisture measurements in the layer exploited by the root system were at below the critical limit of under 10% of free porosity for gas exchange, especially in the grain-filling phenological stage (Figure 2). This is a possible explanation for the negative correlation between the manganese level and soybean yield, not least because the Mn and Fe levels in the grains correlated positively (r = 0.32; P < 0.01) (Table 2).

With respect to the positive correlation between the level of phosphorus and the soybean yield, since the phosphate fertilization was applied as side dressing instead of incorporated in the layer used by the root system, latent deficiency in the uptake of this element by the plants might have occurred, without visible symptoms yet (Table 2). It is known that oxisols contain large amounts of more weathered minerals, such as kaolinite and iron and aluminum oxides, and also that phosphorus forms chemical bonds in the form of orthophosphate ions, especially $H_2PO_4^-$, with iron, aluminum and calcium. These bonds increase the adsorption and reduce the solubility of the phosphorus applied as fertilizer as time passes (Raij, 2011). Besides this, since the adsorption of phosphorus occurs by diffusion, resulting from the depletion of the element around the root system, the greater the extent and area of the root system (if the soil properties are adequate), the higher will be probability of phosphorus uptake (Raij, 2011). In light of this, the mentioned correlation might be due to the fact that most of the phosphate from fertilization was not available to the roots, or losses might have occurred due to surface runoff. Approximately 3% of the soil moisture measurements were above 100% of the total porosity, even during the grain-filling phenological stage (Figure 2). This result together with the negative correlation between phosphorous level and land slope can indicate loss of phosphorus by surface runoff, although the land slope is 2% only, (Table 2). Therefore, nutritional analysis of soybeans can be used to plan corrective actions.

Each nutrient has a unique mobility, uptake and transport pattern in the soil-plant system. These parameters are affected by the particular farming practices and edaphoclimatic factors (Kerbauy, 2012). Among the variables that influence the uptake of nutrients by plants, adequate water content in the soil is the most important. This factor, along with the atmospheric demand for water vapor, is the main cause of nutrient transfer from the soil to the roots (Gregory, 2006; Kerbauy, 2012). Besides this, since the LLWR is modeled with other parameters besides soil bulk density that also affect the development of plants, the LLWR is more sensitive to identify the variability of water readily available to plants. This explains the larger number of correlations found with the levels of nutrients in the soybeans (Table 2).

It was observed that the LLWR of each layer simultaneously correlated only with the level of potassium (K) of the grain and the land slope. In addition to this result, while the $LLWR_{0\text{-}0.10\ m}$ was positively correlated with manganese (Mn) and negatively with phosphorus (P), sulfur (S), zinc (Zn); the $LLWR_{0.10\text{-}0.20\ m}$ correlated positively with only calcium (Ca), magnesium (Mg) and copper (Cu) of the grains (Table 2). According to a nutrient's mobility in the soil, its uptake occurs preferentially by mass flux, root interception or diffusion. The ions K^+ and Cu^{2+} are preferentially absorbed by the roots via the diffusion process while the ions Ca^{2+} and Mg^{2+} are preferentially absorbed by mass flux. Therefore, it is not enough for these elements to be present in adequate concentrations in the soil. For good plant nutrition, it is essential for the flow of water in the soil to be sufficient to dissolve these nutrients so they can be carried to the roots (Kerbauy, 2012). Therefore, as broadcast application of lime and fertilizer began to be applied was 10 years, the expansion of the $LLWR_{0.10\text{-}\ 0.20m}$ based on its positive correlation with Ca, Mg and Cu of grains can benefit a greater absorption of these nutrients by plants. Already the proportional ratio of k of grains with the LLWR the evaluated layers can be explained by the probability of k suffer leaching in the soil profile (Raij, 2011).

On the negative correlations with $LLWR_{0\text{-}\ 0.10m}$, in the case of sulfur (S) in the form of the anion SO_4^{2-}, the same is susceptible to leaching under conditions of greater water availability, because, in Oxisols, may predominate negative charges at pH 6 to 6.5. Knowing this, it is important to highlight the positive correlations between grain nutrient levels between P and S (r = 0.29; P < 0.01), P and Zn (r = 0.47; P < 0.0001), and Zn (r = 0.39; P < 0.0001). It is also important to report that, while the $LLWR_{0\text{-}\ 0.10m}$ was negatively correlated with the P of grains, unlike the P was positively correlated with grain yield; while the $LLWR_{0\text{-}\ 0.10m}$ was positively correlated with Mn of grains, unlike the Mn was negatively correlated with grain yield (Table 2).

Furthermore, there was no correlation of boron grains with grain yield and the LLWR, but there was a positive correlation between the levels of B and P in grain (r = 0.21; P <0.05), B and Zn (r = 0.22; P <0.05). As the absorption of phosphorus plant in $H_2PO_4^-$ or $H_2PO_4^{2-}$ and Zn^{2+} depends on the boron level available in the soil solution, there may be an imbalance in this sense (Raij, 2011). In addition, there was a positive correlation of P, S, Zn and B of the grains with the terrain slope, but the reverse with the LLWR (Table 2). Therefore, the negative correlation of P and Zn may be related to deficiency of B, since P and Zn are most adsorbed on the soil (Raij, 2011). Hence, it is important to complement analyses of the plants with soil analyses, to provide more information to plan corrective actions when there are undesirable correlations that can cause declining yield with time, such as the pairwise correlations between the LLWR, land slope and nutrient levels in the soybeans, as phosphorus and manganese levels of the soybeans.

A reasonable portion of the samples had bulk density values above $Bd_{critical}$, namely 50 and 34% at depths of 0-0.10 m ($Bd_{critical}$ = 1.26 Mg m^{-3}) and 0.10-0.20 m ($Bd_{critical}$ = 1.36 Mg m^{-3}), respectively. In light of these aspects, visualization of this variability in space can support decisions to intervene of modify the soil management. Therefore, we fitted the semivariograms of the unitary data from the $LLWR_{0\text{-}0.10\ m}$ and $LLWR_{0.10\text{-}0.20\ m}$ values and obtained the following results: (i) Lower semivariogram range values in the surface layer, indicating less heterogeneity of the 0-0.10 m layer; and (ii) High degree of spatial dependence, that is, the LLWR presented strong spatial continuity with almost no nugget effect, referring to the percentage of unexplained variance (Table 3).

We then interpolated and cross-validated the data. It is important to note that very few studies have been published providing cross-validation results of interpolation by Kriging. Here we obtained satisfactory linearity (r ≈ 0.50), low explanation (R^2 ≈ 0.25), but estimated error acceptable, and the models were significant for both soil layers (P < 0.05 by the F-test) (Table 4).

Therefore, as the linear regressions were significant at

Table 3. Parameters obtained by fitting the semivariogram to the LLWR in the soil layers.

Layer (m)	Parameters [(1)]						R^2	N
	Model	C_o	$C_o + C$	$C/ C_o + C$	*A*	SDD		
0-0.10	Esférico	0.000010	0.003920	0.997	28.00	High	0.51	112
0.10-0.20	Exponencial	0.000001	0.000437	0.998	63.90	High	0.89	113

[(1)] C_O = nugget effect, C = level, A = range (m), SDD = spatial dependence degree, N = number of data points used in the adjustment, with exclusion of biased points from the 0.10-0.20 m layer.

Table 4. Cross-validation of the interpolation of the LLWR in the soil layers.

Layer (m)	Intercept	Coeficient	N [(1)]	r	R^2	P Teste F	EPE	TVC[(2)]
	y0	*a*						
0- 0.10	0.006[ns]	0.344***	108	0.558	0.311	< 0.0001	0.033	0.5030
0.10- 0.20	0.006[ns]	0.244***	113	0.475	0.226	< 0.0001	0.010	0.0509

[(1)] N = number of pairs of data points used to fit the model; [(2)] CVT = constant variance test by Spearman correlation (P > 0.05). *** (P < 0.0001), [ns] = not significant (P > 0.05) by the t-test.

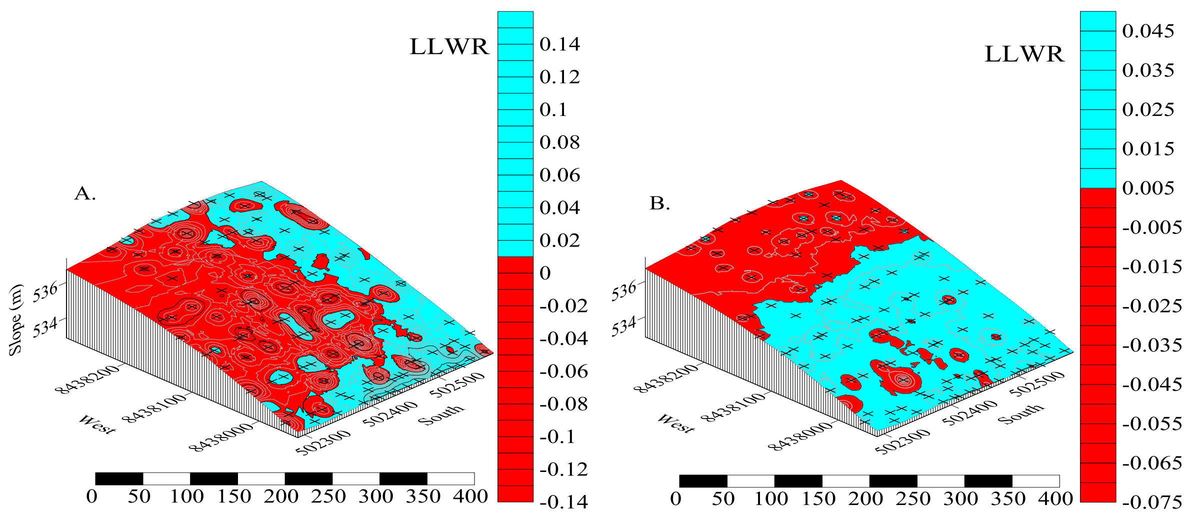

Figure 3. Two-dimensional maps obtained by ordinary kriging, in 2 × 2 m blocks, for the $LLWR_{0-0.10m}$ (A) and $LLWR_{0.10-0.20m}$ (B). note the crosses on the maps indicate the sampling points.

the 5% level of probability by F test, the statistical models were accepted. Then, it was generated maps of the spatial variability of the LLWR for the layers evaluated based on data interpolation by kriging at regular intervals of 0.5 by 0.5 m, considering the separation limit of the bulk density, when the LLWR = 0. Thus, it was found that the spatial correlation analysis was important because it allows to view the area ratio of those values LLWR, wherein Bd > $Bd_{crtical}$, where we observed greater range of LLWR values in topsoil (Figure 3).

The reasons for the appearance of these areas less favorable to plant water availability can be associated with the past traffic or more frequent maneuvering of farm machinery in this region, possibly causing leftover compacted subsurface layers not eliminated with implementation of the no-tillage system. This hypothesis is supported by the positive correlation of the soil bulk density in the 0.10-0.20 cm layer with higher land slope (Table 2). Another possible explanation is the inherent variations of the surface layer, or variations induced by farming practices in past years, such as the pore size or granulometry (Table 5).

We observed that while the $LLWR_{0-0.10m}$ and $LLWR_{0.10-0.20m}$ values were positively correlated with the content of sand and macropores in the soil, the land slope was negatively correlated with these attributes. Furthermore,

Table 5. Pearson correlation coefficients between the variables.

Variable	LLWR_10	LLWR_20	Slope
LLWR_10 ($m^3 m^{-3}$)	1		
LLWR_20 ($m^3 m^{-3}$)	0.22*	1	
Slope (m)	-0.23*	-0.26**	1
Organic matter (g dm^{-3})	-0.06	0.00	0.16
Sand content, 0 to 0.10 m, g kg^{-1})	0.10	0.20*	-0.26**
Clay content, 0 to 0.10 m, g kg^{-1})	-0.07	-0.15	0.24*
Silt content, 0 to 0.10 m (g kg^{-1})	-0.08	-0.11	0.06
Sand content, 0.10 to 0.20 m(g kg^{-1})	0.23*	0.17	-0.31**
Clay content, 0.10 to 0.20 m (g kg^{-1})	-0.15	-0.16	0.30**
Silt content, 0.10 to 0.20 m (g kg^{-1})	-0.13	-0.02	0.04
Macropores, 0 to 0.10 m ($m^3 m^{-3}$)	0.63***	0.07	-0.08
Macropores, 0.10 to 0.20 m ($m^3 m^{-3}$)	0.08	0.70***	-0.37***
Micropores, 0 to 0.10 m ($m^3 m^{-3}$)	-0.32**	0.01	0.21**
Micropores, 0.10 to 0.20 m ($m^3 m^{-3}$)	0.08	-0.42***	0.35**

(1) *** (P < 0.0001), ** (P < 0.01), * (P < 0.05) = significant at 5% probability by the t-test.

while the $LLWR_{0\text{-}0.10m}$ and $LLWR_{0.10\text{-}0.20m}$ values were negatively correlated with the content of clay and micropores in the soil, the land slope was positively correlated with these attributes (Table 5). Therefore, the reason for the increase in the LLWR values inversely with land slope is best explained by the soil porosity and granulometry. Since it is not possible to change the soil texture, corrective actions or changes in the production system should be carried out to balance the macro and micropores in the soil as well as the nutritional equilibrium of the soybeans, especially phosphorus and manganese of grains because both correlated with grain yield (Tabela 2). Therefore, it is possible to use the critical soil bulk density ($Bd_{critical}$) value, when LLWR = 0, as a limit for monitoring soil physical quality.

Conclusions

1. There was greater mechanical penetration resistance of the soil (θPR = 2.0 MPa), and thus a narrower least limiting water range (LLWR), in drier soil. Therefore, in no-till farming the main limiting factor to plant development as soil dries out is resistance to penetration.
2. Although the soybean yield was only correlated with the level of phosphorus and manganese in the grains, the $LLWR_{0\text{-}0.10m}$ and $LLWR_{0.10\text{-}0.20m}$ values were correlated in greater numbers with of the macronutrients and micronutrients analyzed, and also with the land slope. In light of this, nutritional analysis of the grains complemented by physical analysis of the soil can be used to identify imbalances not otherwise spatially apparent and to plan corrective actions in soil and crop management, based on the critical bulk density value ($Bd_{critical}$), when LLWR = 0.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

On farm evaluation of the growth and economic benefit of afar breed rams supplemented with different protein sources: The case of Raya-Alamata District

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On-farm trial was conducted at Raya-Alamata District, Southern Zone of Tigray region, Northern Ethiopia. From the district three representative peasant associations namely Gerjelle, Limate and Harlle was selected based on sheep population and Ziziphus tree availability. The objective of this study was to evaluate the growth performance and economic benefit of Afar breed rams supplemented with different protein sources. Nine farmers were selected per each peasant association. Each farmer had assigned three growing yearly aged Afar breed rams with initial average body weight of 19.33±1.33 kg. The treatments include feeding with traditional practice/free-grazing (T_1), T1+ 277.5 gDM/day/head urea treated teff straw supplementation (T_2), T_1+283.8 gDM/day/head air dried Ziziphus foliages supplementation (T_3) and T_1 + 250 g DM/day/head) concentrate mix of wheat bran and noug cake supplementation (T_4). There was statistically significant difference (P<0.05) in daily live weight gain among the control and supplemented groups, except urea treated straw supplemented group. Rams in the control group and urea treated teff straw had showed 67.60 and 71.87 g of daily body weight gain per head, while the air dried Ziziphus leaf and concentrate mix supplemented group had gained 90.47 and 98.70 g/day/head, respectively. Moreover, the concentrate mix supplemented group (T4) had a higher net benefit of Ethiopian Birr 22.93/head over control group and higher profit margin of Birr 0.5/head, followed by the Ziziphus leaf supplemented group (T3) which had a net benefit of Birr 19.85/head and profit margin of Birr 0.4/head over the control group. Assume one US$ is equals to 20 Ethiopian Birr. The results of this study suggested that supplementation of sheep with 283.8 gDM of dried Ziziphus leaf or 250 g DM concentrate mixture is potentially more profitable to the small scale farmers' sheep fattening practice than the other level of supplements.

Key words: Body weight, concentrate mix, profitability, Ziziphus leaf, free grazing, urea treated teff straw.

INTRODUCTION

Tropical ruminant production is basically depending on fibrous feeds like mature pastures and crop residues. These feeds are mostly deficient in protein, energy, minerals and vitamins. Crop residues are the major

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sources of feed for livestock during dry season, but are low in nitrogen and high in crude fiber and lignin, characteristics that restrict intake and digestibility. With regard their poor CP content they cannot able to meet the rumen microbial requirement when they are feed alone (Van Soest, 1994). Among the nutritional constraints, protein deficiency appears to be the most important. In the face of such scenario, there is a need to integrate trees, crop and livestock production to improve availability of feeds and livestock productivity.

With in Ethiopia in general and Tigray Region in particular, despite the fact that crop residues are the main if not the only feed to livestock, huge amount of crop residues are producing every year. According to the Raya-Alamata district bureau of agricultural and rural development report 452,004 “quintal” teff straws and 473,480 “quintal” stover of sorghum and maize were produced in 2007-2009 years of cropping season. In addition, other possible protein supplements of indigenous browse foliages such as *Ziziphus* tree could be the best alternatives, as they are easily available in the villages and accessible to the smallholder farmers. Browse trees are also among the most feed sources especially in the lowlands of Raya-Alamata District where sheep and goats are important livestock commodities that virtually depend on free grazing and browse foliages throughout the year.

There are two indigenous Ziziphus species (*Ziziphus spina-cristi* and *Ziziphus abyssinica*) growing in many parts of dryland Ethiopia in general and in Tigray region in particular. Out of the two Ziziphus tree species, *Z. spina-cristi* is more dominant in the study area. Ziziphus tree is also drought tolerant and is possible to get good leaf biomass even at times of poor rainfall and dry season; this plant is evergreen, found everywhere, thereby contributing to solving the feed scarcity of small ruminant partially. Traditionally farmers of the study area are observed lop the branches of the trees for the purpose of fence, fire wood and the leaf part is feed to their animals immediate at the field and the remaining leaf are remaining at the ground and decompose or feed by any other browsing animals. Collecting the leaf and stored for the dry season supplementation is not common practice due to lack of awareness of the farmers on browse leaf supplementation for their animals. The nutritional and supplemental values of air dried *Ziziphus* leaf for small ruminant indicated promising results and has crude protein (CP) content of 14.5% (Bruh et al., 2014). Similarly, the Raya-Alamata district has enormous amount of livestock feed resources. However, limited work has been done for maximizing and efficient use of these locally available feed resources. Moreover, for more than 50 years, research work on protein in the nutrition of ruminants has identified urea for treated crop residues due to its ability to increase the nitrogen content of the treated crop residue and due to its readily available in the hand of small scale farmers for the purpose of fertilizer and in this integrated approach multi-purpose trees supplementation, urea treatment and concentrate mix supplementation will have a significant contribution. Hence, utilizing those ample feed resource by identifying the appropriate mix up is quite crucial. Thus, the objective of this study was to evaluate the growth performance and economic benefit of Afar sheep breed supplemented with three different protein sources.

MATERIALS AND METHODS

Study area description

The on-farm experiment was conducted in Raya-Alamata District. It is located at a distance of 600 km North of Addis Ababa and 183 km South of Mekelle. It has an elevation of 1400 to 1600 m above sea level and lies between 39° 35’ East longitude and 12° 15’ North latitude. The area receives a bimodal rainfall distributed from March-May for the short rainy season, and from June - September for the long rainy season with average annual rain fall of 400 to 700 mm. The mean maximum and minimum temperature is 27 and 14.6°C, respectively. Small ruminant production is the main livestock component of the study area followed to cattle production. About 59514 heads of sheep were found in the district (BoARD, 2009; unpublished document).

Peasant association and farmers selection

Three peasant associations (PA) were selected based upon the availability of Ziziphus tree species, teff straw and high population of small ruminant. Farmers who own more than five sheep were selected from each PA in cooperation with agricultural development workers of the area. Twelve participant farmers from each peasant association (PA) were randomly selected from the purposely selected sheep owners, where three farmers were allocated for each feeding regime. Each farmer allocated three growing rams. The growing rams were selected from the herd based on their body weight and allocated to different blocking. Totally the study was participated 36 small scale farmers and 108 Afar breed rams. Farmers and development agents of each PA were given training on project implementation.

Experimental design and feeding management

The treatments were: Traditional practice/free grazing (Control/T_1), T1 + 277.5 gDM/day/head urea treated teff straw(T_2), T1 + 283.8 gDM/day/head air dried Ziziphus foliages (T_3) and T1+ 250 g DM/day/head concentrate mix (T_4) supplementation. The concentrate mix was made from equal proportion of wheat bran and noug cake.

The on farm trial was carried for 90 days following the adaptation period of 15 days. The animals were fed based on the farmers practice. The supplement feeds were offered to the animals after the animals returned from the field at the evening. Farmers cut the branches of their Ziziphus tree for fencing purpose and the fresh leaf was collected, air dried and stored before the execution of the on farm trial. The concentrate is purchased from flour factory and private sector in the study area. The animals in all participant farmers were housed in wooden fenced house and follow up by the farmers with regular visits and monitoring by researchers on house cleaning, health and supplementing of the animals. All participant farmers were trained before the experiment was started on the purpose of the research, how to supplement their animal, housing and sanitation of their animals. All farmers had managed their animals in extensive conditions in the day time and the experimental animals were separated and supplemented with their respected feed regime at evening. While the control animals had managed with the local practice. The control group in each PA was compensated by paying/kind payment (that is, providing urea molasses block leak for their cattle) for substitution of the contact time, lose of body weight (if any) to maintain the rams till the project termination.

During the study veterinarian researchers had participated and all animals were drenched with broad-spectrum anti-helminthes and vaccinated against common diseases of the area during the adaptation period. Animals were closely followed for the occurrence of any ill health and disorders during the study period.

Data collected and analysis

The initial weight of animals was taken at the beginning of the experiment and was continued at weekly interval. Animals were weighed at morning following the overnight fasting to avoid gut content variation. Body condition score (BCS) of the animals was also recorded at the beginning and ending of the demonstration trial. BCS was assessed using the 5 point scale (1= very thin to 5=obese) following the procedure of Aumount et al. (1994) and Thompson and Meyer (2002). Animals were visually assessed followed by palpation of the lumbar vertebrae area between the back of the ribs and the front of the pelvic bones. Two experienced animal trader farmers and two researchers carried out the BSC assessment with average scores taken to avoid biasness since the exercise is subjective. Each PA was considered as block and the three PA data were pooled for analysis. Analyses of variance (ANOVA) were done by the General Linear Model Procedure of SAS (1998) for data obtained from the experiment. Least squares means were separated using a t-test. The results reported are based on least squares means. The chemical composition data of the feed ingredients used in this on farm trial was taken from previous on station research works with similar feed sources by different authors in the study area.

Partial budget analysis

Data of such as, supplementary feed cost including the urea treatment inputs, initial and final animal selling cost were taken. The labor cost was assumed to be constant for all the treatments in the farming system. Partial budget analysis was performed to evaluate the economic advantage of the different treatments by using the procedure of Upton (1979) and (CIMMYT, 1988; Shapiro et al., 1994 both cited in Legesse et al., 2005). The partial budget analysis was involved in the calculation of the variable costs and benefits. At the beginning of the study, market price of target animals was estimated by three experienced farmers. Similarly at the end of the experiment, the selling price of each experimental animal was estimated. The selling price difference of target animals in each treatment before and after the experiment was considered as gross/total return (*TR*) in the analysis.

For the calculation of the variable costs, the expenditures incurred on various feedstuffs were taken into consideration. Supplementary feed cost including the urea treatment inputs was also taken. The labor cost was found to be constant for all the treatments in the farming system. The cost of the supplementary feeds was computed by multiplying the actual intake for the whole feeding period with the prevailing prices. At the time of feed purchasing, the prevailing price of the feeds was included the labor and transportation cost incurred to move and process them to the participant farmers. The partial budget method measures profit or losses, which are the net benefits or differences between gains and losses for the proposed change and includes calculating net return (NR), that is, the amount of money left when total variable costs (TVC) are subtracted from the total returns

(TR): NR = TR-TVC

Total variable costs include the costs of all inputs that change due to the change in production technology. The change in net return (ΔNR) were calculated by the difference between the change in total return (Δ TR) and the change in total variable cost (Δ TVC), and this is to be used as a reference criterion for decision on the adoption of a new technology.

$$\Delta NR = \Delta TR - \Delta TVC$$

The marginal rate of return (*MRR*) measures the increase in net income (*Δ NR*) associated with each additional unit of expenditure (*Δ TVC*). This is expressed by percentage.

$$MRR\% = (\Delta NR / \Delta TVC) \times 100$$

RESULTS AND DISCUSSION

Chemical composition of feeds

This on-farm demonstration trial was undertaken with reference to the on station trials on feeding of air dried Ziziphus leaf and concentrate mix supplementation at different period of time. The chemical composition of the ingredients was taken from the result of different previous research works. The DM and CP content of *Z. spina-christi* as reported by different authors was (89.7 and 14.3) in Solomon et al. (2010) and (94.6 and 14.5) in Bruh et al. (2014) respectively. Tesfay and Solomon (2009) report on Afar ram concentrate supplementation also indicated that the DM and CP composition of noug seed cake and wheat bran was (93.5 and 34.5) and (89.2 and 16.8) respectively.

The DM and CP of urea treated teff straw was 92.5 and 8.4 respectively (Awet and Solomon, 2009). The crude protein of untreated teff straw reported in Raya-Alamata District was 5.75 (Tesfay and Solomon, 2009). The dried leaves of Ziziphus tree have higher CP and lower fiber content to wheat bran. Thus, proper and stratategic use of these feed resources as supplementary feed during the dry season can help minimize seasonal fluctuation in animal productivity. The browse tree supplements are expected to play a catalytic role in feed utilization and are needed in small quantities relatively to the basal roughage (Adugna, 2008).

Body weight change and body condition score

Results of effect of feed types on the live weight and body condition score of rams was shown in Table 1. The average initial live weight of ram's in T1, T2, T3 and T4 was 19.75, 19.88, 19.60 and 18.08 kg, respectively. The final live weight of the rams of the supplement group was 26.34, 27.74 and 26.97 kg for T2, T3 and T4, respectively and the control groups had a final live weight of 25.83 kg. There was a significant difference ($P<0.05$) in daily l ive

Table 1. Body weight change of Afar breed rams maintained on different feed regimes in Alamata district.

Parameter	Treatments				SEM	SL
	Control (T_1)	Urea treated teff straw (T_2)	Dried Zizipus leaf foliages (T_3)	Concentrate mix supplementation (T_4)		
Live Body weight change (LBWC)						
Initial LBW	19.75	19.88	19.60	18.08	1.33	NS
Final LBW	25.83	26.34	27.74	26.97	0.97	NS
ADBWG	67.60^b	71.87^b	90.47^a	98.70^a	5.09	*
Body score condition (BSC)						
Initial BSC	2.17	2.15	2.25	2.32	0.14	NS
Final BSC	2.56	2.81	3.16	3.16	0.19	NS
Difference of BSC	0.39^b	0.65^b	0.84^a	0.91^a	0.12	*

$^{a,\ b}$= means within a row not bearing a common superscript letter significantly differ. *= P<0.05; NS = not significant; SEM= standard error of Mean; SL= significant level; BSC= body score condition, ADBWG= average daily body weight gain.

weight gain among the control and supplemented ones, except the group fed on urea treated straw. Rams in the control group and urea treated teff straw supplemented group gained 67.6 and 71.9 g/day of live weight, while the Ziziphus leaf and concentrate mix supplemented group gained 90.5 and 98.7 g/day/head, respectively. Macit et al. (2002) reported higher body weight gain of 148, 155 and 172 g/day for Awassi, Morkaram and Tushin lambs grazed on pasture and supported with concentrate respectively. The daily body weight gain of Ziziphus supplemented animals reported in this study was higher than the report of Bruh et al. (2014) (23.8 g/day) on Abergelle goat and Axum ARC progress report (2012) (30.3 g/day) on Tigray highland sheep supplemented with Ziziphus dried leaf respectively. Similarly, Kaitho et al. (1998) also reported that lower daily body weight gain of 6.5 to 65.2 g/day of sheep supplemented with different level of fodder trees. On the other hand, Tesfay and Solomon (2009) reported that lower daily body weight gain of 43.33 to 67.11 g/day for Afar lambs supplemented with graded level of concentrate supplementation under on-station condition. In this study the concentrate mix supplemented group showed the highest daily body weight gain, while the control group showed the lowest daily body weight gain.

The body score condition (BSC) assessed by taking average estimation of two researchers and two experience animal trader farmers of the study area. The initial body condition score of the treatments were 2.17, 2.15, 2.25 and 2.32 for control (T1), urea treated teff straw (T2), dried Ziziphus leaf (T3) and concentrate mix supplementated groups (T4), respectively (Table 1). There was statistically significance difference at (P<0.05) in total body score condition between control and supplemented groups. The total body score condition difference of T1, T2, T3 and T4 was 0.39, 0.65, 0.84 and 0.91, respectively (Table 1). The highest body score condition was found in the concentrate mix supplemented group followed by dried ziziphus leaf supplemented group.

Partial budget analysis

The partial budget analysis for the feeding trial was reported in Table 2, which involved the evaluation of overall profitability. The result of the partial budget analysis for Afar rams fed on different feed regimes indicated that the concentrate mix supplemented group (T4) returned a higher net benefit of Birr 22.93/head over control group and higher profit margin of Birr 0.5/head, followed by the Ziziphus leaf supplemented group (T3), which recorded net benefit of Birr 19.85/head and profit margin of Birr 0.4/head over the control group. Legesse et al. (2005) reported lower net return of 10.6 ETB per grazed goat supplemented with concentrate as compare to goats managed extensively. The urea treated teff straw supplemented group (T2) were recorded lower net benefit and profit margin. The net return from the supplemented rams was 117.38, 139.29 and 142.37 ETB/head with marginal rate of return (MRR) of 28.7, 42.4, and 49.3 for T2, T3, and T4, respectively. This means each additional unit of 1 birr per lamb cost increment resulted in 1 Birr and additional of 0.4 and 0.5 ETB benefit for T3 and T4, while loss of -0.3 ETB for T2.

The net return of T4 and T3 was higher than the net return of T2 and T1. The difference in the net return per treatment was due to the difference in live weight change of the animals in each treatment. The higher net return and MRR in T4 and T3 was due to the optimum protein source of the supplemented feeds, which resulted in higher body weight gain of (98.70 and 90.47 g/day) in T4 and T3 respectively, as compared to the other treatments that had relative body weight gain of 67.60 and 71.87

Table 2. Partial budget analysis of Afar breed rams feed different feed regimes in Raya-Alamata District.

Specific Items and their cost	Treatments			
	T1	T2	T3	T4
Initial price of sheep	233.33	226.39	228.15	200.00
Urea consumed (kg/head)	0	0.50	0	0
Plastic sheet used (M2/head)	0	1.00	0	0
Total Concentrate mix consumed (kg/head)	0	0	0	27.00
Zeziphus leaf consumed (kg/head)	0	0	27.00	0
Urea cost (ETH Birr/head)	0	3.15	0	0
Plastic sheet cost (ETH Birr/M2/head)	0	11.00	0	0
Zeziphus Leaf collection cost (ETH Birr/head)	0	0	52.00	
Concentrate mix cost (ETH Birr/head)	0	0	0	79.85
Total feed cost (ETH Birr/head)	0.00	14.15	52.00	79.85
Total Cost (ETH Birr/head)	233.33	240.54	280.15	279.85
Gross Return(ETH Birr/head)	352.78	357.92	419.44	422.22
∆GR		5.14	66.67	69.45
Net Return (ETH Birr/Head)	119.44	117.38	139.29	142.37
∆NR/NROC		-2.07	19.85	22.93
∆TVC		7.21	46.82	46.52
MRR (Ratio)		-0.3	0.4	0.5
MRR (%)		28.7	42.4	49.3

∆NR = change in net return; ∆TVC = change in total variable cost; MRR = marginal rate of revenue, Assume that the conversion rate is 1 US dollar is equals to 20 Ethiopian Birr.

g/day/sheep for T1 and T2 respectively. This indicates that lambs fed with better quality feed performed well and had higher body weight gain and sale at maximum price and earned better net return. Legesse et al. (2005) reported that combining grazing with concentrate supplementation seems potentially more profitable than grazing without supplementation. Lambs fed on Ziziphus leaf supplemented group (T3), had almost similar body weight gain and MRR with the concentrate mix supplemented group (T4), suggesting that Zizphus leaf could be used by local farmers as a good protein source supplement small ruminant.

Even though lambs in T4 showed better performance in live weight gain and MRR as compare to T3, it was not found to be economically feasible as compared to the dried Ziziphus leaf supplemented group. The sheep fed on urea treated tef straw (T2) and control (T1) diet showed lower body weight gain relative to the concentrate and Ziziphus supplemented groups. The supplemented feed item cost taking in this on farm study was 6.3, 2.7, 3.2, 2 and 2.9 Birr/kg for urea, wheat bran, noug cake; dried Ziziphus leaf and concentrate mix respectively.

There was a field day involving researchers, experts, DAs, farmers, woreda and PA administration members. The participant farmers had noticed that the benefit of different supplemental feed was not visible immediately after an adaptation period. Later farmers were very much impressed with the technology being demonstrated. They said that the income generated from the supplemented sheep was higher than that of control group and urea treated groups. Using the strategic supplementation during the dry season farmers could recondition their sheep to an attractive marketing body weight to fetch better price especially during the holidays. Therefore, the study indicated that farmers would readily adopt the technology and disseminate it to other neighboring farmers. However, as farmers had expressed their worries which is less availability of concentrate is the major limitation to the dissemination and wider use of the technology.

Conclusion

The results of this study suggested that supplementation of small ruminant with 283.8 g DM of dried Ziziphus leaf or 250 g DM concentrate mixture consisting of noug seed cake, and wheat bran is potentially more profitable and economically beneficial to the small scale farmers than the other level of supplements. Moreover, the dried Ziziphus leaf feeding technology does not require farm land and can grow in farm boarder waste land and hillsides. The only resource required to utilize it is the labour during harvest/collect and process the leaf until feeding to animals. Nevertheless, it would be important to check whether the Ziziphus leaf harvesting time could not coincide with a seasonal labour peak. In Raya-Alamata

District, Ziziphus leaf harvesting should occur when demand for labor is less.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

Physiological quality and genetic parameters of maize landraces seeds in southwestern Bahia

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The environmental adaptation of maize germpasm is mainly controlled by certain genes, such as ZmCCT. This factor is influenced by both the genotype and the environment itself, being the gene able to express itself in the germination and seedling vigor under the conditions that is offered. The objective of this study was to estimate genetic parameters for traits related to physiological quality in maize landraces seeds. Hundred seeds of six strains were used: Catingueiro, Colombianoroxo, Colombianopreto, Cabeça de negro, Colombiano Vermelho and Estrada de ferro, arranged in polystyrene trays, each tray with 25 seeds, maintained at a temperature of 19 to 23°C, moistened with 15 ml of deionized water daily. The experimental design was completely randomized, with four repetitions. We evaluated the percentage of seeds germinated in the presence of coleoptile (%); assessment of the total weight of adventitial and primary roots (g); assessment of the total weight of the coleoptile (g); assessment of the length of the longest coleoptile (mm) and the length of the largest adventitial root (mm); length ratio of shoots with roots using direct division between heritability and genetic gain variables. Data were submitted to ANOVA. Percentage data were transformed by the formula arcsin [(x +0.5) / 100] 1/2 before being submitted to ANOVA. For comparison of means, we adopted the Tukey test at 5% probability of error. The results indicated genetic variability for the different characteristics of the studied physiological quality, especially for Catingueiro variety with high heritability and possible genetic gain with the potential to be used in breeding programs.

Key words: Variety, genetic gain, heritability, vigor, *Zea mays* L.

INTRODUCTION

Maize (*Zea mays*. L) is one of the most important cerealsin Brazil, being produced in different regions of the country (Costa et al., 2013). Bahia is highlighted as a major producer of the Northeast region, with a production of 1.7 million tons (IBGE, 2013). More vigorous, with higher germination speed, good adaptation and

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productive seeds are characteristics desired by producers, and higher production can be attributed to the evolution of grain yield, which has a joint relationship with breeding techniques, adoption of supplies and different ways of managing and cultivation acquired by various cultures to which maize can be included (Mundstock and Silva, 2005).

Among the characteristics that offer good quality to seeds, genetic deserves close attention, because improvement in culture conferred an increase in yields of 78 kg $ha^{-1}.year^{-1}$ between the 30 and 70 s, going to 4,316 $Kg.ha^{-1}$ in 2010, giving improved corn plants a good gene expression (Martin et al., 2007; CONAB, 2011). Seeds of local varieties are considered components of agro biodiversity as they are of inestimable value for traditional populations (CATÃO et al., 2010). The environmental adaptation of maize germpasm is mainly controlled by certain genes, such as ZmCCT (Hung et al., 202). This factor is influenced by both the genotype and the environment itself (Gondim et al., 2006) and the genes may express on germination and seedling vigor under the offered conditions.

Gene expression is a result of the genetic dominance, additive and/or epistatic effect that may influence the hum of expression quantitative character in a population (Bespalhok filho et al., 2005). The genotype can be seen through evaluations on the phenotype of culture and its performance represents the genotypic value in occupied environment (Cargin et al., 2006). The phenotypic variance can be divided into: environmental produced variation, variation due to the different characteristics of heredity and variation acquired by the sum of the effects caused by environment and heredity. Vencovsky (1987) states that the variation can be calculated due to genetic differences between treatment and/or progeny, which is one of the favorable components to improvement, because it confers genetic gains. Genetic variability can be quantified by the coefficient of genetic variation, which expresses the genetic variation compared to the average evaluated character (Resende, 1991).

Heritability is the result on the quotient between phenotypic and genotypic variances, which assesses the efficiency of selection in the application of genetic variability (Carvalho et al., 2012). This heritability is divided into wide or narrow, and may vary according to the kind, character, environmental conditions, and phenological stages. The objective of this study was to estimate the genetic parameters of physiological related characters ofmaize landraces seeds, so as to provide practical directions for their application in breeding programs.

MATERIALS AND METHODS

The experiment was conducted in the Bio factory of *Universidade Estadual do Sudoeste da Bahia* (UESB). Seeds of sSeeds six maize landraces varietiesvarieties, harvested ined in 2012, were selected: Catingueiro, Colombiano roxo, Colombiano preto, Cabeça de negro, Colombiano vermelho and Estrada de ferro. All varieties come from plantations made by Diretoria de Campo da UESB (DICAP). These varieties are widely cultivated in the Southwestern region of Bahia - Brazil. The experimental design was completely randomized with six treatments and four repetitions for each treament. Each repetition was represented by a tray containing 25 seeds.

The seeds were selected and arranged in polystyrene trays, covered with moistened cotton in 60 ml of deionized water. Each repetition was daily rehydrated with 15 ml of deionized water. The average temperature during the experiment ranged from 19°C to 23°C. The occurrence of seed germination was daily observed by coleoptile emission; they were counted and identified for variables analysis:

(i) Germination speed, in days, was determined by Edmond and Drapala equation (Oliveira et al., 2009).

$$TM = \frac{G1T1 + G2T2 + ... + GiTi}{G1 + G2 + ... + Gi} \quad (1)$$

Where: TM - number of days to coleoptile emission; G1 to Gi - number of germinated seedlings occurring every day; T1 to Ti - number of days of growth.

(ii) Percentage of germination in 1st and final count, calculated by the percentage of germinated seeds every day;

(iii) Count of the number of roots;

(iv) Percentage of seeds germinated with the presence of coleoptile;

(v) Evaluation of total weight of adventitious and primary roots (g), by weighing with a precision balance using three decimals;

(vi) Evaluation of the total weight of coleoptile (g), by weighing with a precision balance using three decimals;

(vii) Evaluation of the length of the longest coleoptile (mm), using a precision graduated ruler;

(viii) Evaluation of the length of the longest adventitial roots (mm), using a precision graduated ruler;

(ix) Relation of the shoot length with the roots, using direct division between the variables.

Data were subjected to analysis of variance and Tukey test at 5% probability using SAEG program.

Genetic parameters estimates were determined using the methodology presented by Oyiga and Uguru (2010) and Sunday et al. (2007):

(1) Genotypic, phenotypic and environmental variability were calculated *via* the following formulas:

$$Vg = \frac{MSg - MSe}{r} \quad (2)$$

$$Vp = \frac{MSg}{r} \quad (3)$$

$$Ve = MSe \quad (4)$$

Where Vg, Vp and Ve are genotypic, phenotypic and environmental variances, respectively, and MSg, MSe and r are the mean square of genotypes, mean square error, and the number of repetitions, respectively.

(2) Coefficient of genotypic, phenotypic and environmental variation were calculated *via* the following equations:

Table 1. Medios values for different variables evaluated in maize varieties, UESB, Vitória da Conquista - BA, 2013.

Varieties	TG (%)	VG (%)	SC (%)	CMC (mm)	PTC (g)	NMR	CMR (mm)	PR (g)
Catingueiro	97± 3.83 [a]*	2.735 ± 0.27 [b]	95± 5.03 [a]	41.733± 22.50 [a]	1.450± 1.08 [a]	108± 16.05 [a]	50.675± 24.28 [a]	2.141± 1.47 [a]
Colombiano roxo	90 ± 9.52 [ab]	2. 995± 0.18 [b]	69± 22.24 [ab]	23.380± 5.94 [a]	0.725± 0.38 [ab]	101± 36.74 [a]	58.105± 14.48 [a]	1.339± 0.76 [ab]
Colombiano preto	76 ± 9.80 [ab]	3.153± 0.15 [ab]	34± 9.52 [c]	20.390± 7.61 [a]	0.254± 0.09 [b]	39± 6.18 [b]	36.220± 8.16 [a]	0.503± 0.24 [b]
Cabeça de negro	79 ± 11.49 [ab]	3.625± 0.32 [a]	44± 25.09 [bc]	17.280± 7.80 [a]	0.320± 0.24 [b]	46± 20.43 [b]	32.893± 12.63 [a]	0.461± 0.28 [b]
Colombiano vermelho	92 ± 3.27 [ab]	3.133± 0.13 [ab]	64± 0.00 [abc]	35.745± 3.02 [a]	0.915± 0.20 [ab]	95± 9.98 [a]	64.228± 20.02 [a]	1.518± 0.24 [ab]
Estrada de ferro	72 ± 9.80 [b]	2.848± 0.39 [b]	57± 8.25 [bc]	28.798± 6.74 [a]	0.589± 0.19 [ab]	79± 4.43 [ab]	57.755± 4.71 [a]	1.028± 0.27 [ab]

* Different letters in the same column differ significantly by Tukey test at 5% probability.

$$GCV = \frac{\sqrt{Vg}}{\overline{X}} X100 \quad (5)$$

$$PCV = \frac{\sqrt{Vp}}{\overline{X}} X100 \quad (6)$$

$$ECV = \frac{\sqrt{Ve}}{\overline{X}} X100 \quad (7)$$

Where GVC, PCV and ECV correspondingly refer to phenotypic, genotypic and environmental variation coefficients, respectively, and $\overline{X}$ to the overall mean ofeach treatment.

(1) Heritability

$$h^2 = \frac{Vg}{Vp} \quad (8)$$

Where Vg and and V presents thepresent genotypic and phenotypic variability, respectively.

(2) Genetic gain

$$\Delta G = i\Delta ph^2 \quad (9)$$

Where i referrefers to a constant (equivalent to 2.06 when the intensity selection is 5%), Δp to the standard deviation of the phenotypic variance and h^2 to heritability.

Data in percentages were transformed to ArcSin square root ((x +0.5)/ 100), by SISVAR program, version 5.3 before being submitted to ANOVA, and those in other forms were submittedto ANOVA directly (FERREIRA, 2010). For means comparison, we adopted the Tukey test at 5% probability of error using SISVAR program, version 5.3 (Ferreira, 2010).

RESULTS AND DISCUSSION

Germination for the different maize landraces strains presented significant difference between Catingueiro and Estrada de ferro varieties (Table 1). Germination rate percentage parameter (TG), germination speed (VG), seeds with coleoptiles (SC), length of the longest coleoptile (CMC), total weight of coleoptile (PTC), average number of roots (NMR), longest root length (CMR), weight of roots (PR).

Costa et al. (2013) reported that reportedgermination index in maize landraces ranged from 47 to 75%. For germination speed, Cabeça de negro Black Head showed greater speed, without, however, differ from Colombiano preto and Colombiano vermelho which did not differ from the others (Table 1). Lower germination was observed in cultivars of Catingueiro and Cabeça de negro (Costa et al., 2013). The highest percentage of seeds with presence of normal seedlings (95%) was shown in Catingueiro strain; relative to the length of coleoptiles and roots, the strains showed no significant differences. For the weight of the seedlings and roots, Catingueiro showed the highest values, without differ from Colombiano preto, Colombiano vermelho, Estrada de ferro variet, for both evaluated characteristics. The Catingueiro, Colombiano preto and Colombiano vermelho strains showed higher number of roots, however, the Estrada de ferro did not differ from those and another's (Table 1). Results corroborate Cato et al. (2010) for Catingueiro strain in germination rate and germination speed variables. In general, the Catingueiro strain showed the best characteristics for almost all studied variables, except for the speed of germination, but not harming the development of seed for other variables evaluated.

Statistically the Catingueiro variety obtained higher performance than the other varieties not relevant mathematically evaluate the data.

As can be seen in Table 2, there was high heritability (h^2) and low genetic gain (GA) for the variables: root weight, shoot weight, presence of

Table 2. Estimation of the mean square; average; phenotypic variance (Vp); genotypic variance (Vg) and environmental variance (Ve); phenotypic variation coefficients (PCV); genotypic variation coefficients (GCV) and environmental variation coefficients (ECV); heritability (h^2) and genetic gain (GA) for the variables of six cultivars of maize landraces seeds, UESB, Vitória da Conquista - BA, 2013.

Variables	Mean squares	Mean	Vp	Vg	Ve	PCV	GCV	ECV	(%)	GA
PR (g)	1,647	1,165	0,412	0,305	0,425	55,084	47,442	55,983	74,177	0,981
NR	3351,967	77,667	837,992	751,011	347,922	37,272	35,285	24,016	89,620	53,443
CR (mm)	649,009	49,979	162,252	106,296	223,823	25,486	20,629	29,934	65,513	17,191
PPA (g)	0,772	0,709	0,193	0,138	0,221	61,997	52,370	66,364	71,355	0,646
CPA (mm)	354,641	27,888	88,660	57,359	125,206	33,764	27,158	40,124	64,695	12,549
Shoot presence	113,075	15,125	28,269	24,922	13,386	35,153	33,006	24,190	88,162	9,656
Root +shoot weight (g)	4,644	1,874	1,161	0,850	1,243	57,509	49,218	59,494	73,244	1,626
Ratio CPA/root(mm)	0,066	0,566	0,016	0,008	0,034	22,686	15,808	32,541	48,558	0,128
VG (%)	0,388	3,081	0,097	0,080	0,067	10,112	9,194	8,419	82,668	0,531
TG (%)	25,067	21,083	6,267	4,906	5,444	11,874	10,505	11,067	78,280	4,037

PR - root weight; NR - Numbers of root; CR - root length; PPA - shoot weight; CPA - shoot lenght; VG - germination speed; TG - germination rate.

shoot, root plus shoots weight, germination speed and germination rate, on the other hand, there was high heritability and moderate genetic gain for root length and shoot length; high heritability and high genetic gain for number of roots and moderate heritability and low genetic gain for the ratio of shoot length with root, considering the intervals determined by Johnson et al. (1955). Similar results were found by Sunday et al. (2007) in work with rice seeds.

The highest estimates of genotypic variability coefficients (GCV) were observed among the parameters including PPA(weight of shoots), root + shoot weight, CR (root weight), NR (number of roots), presence of shoots, CPA (shoot length), and CR (root length), showing high genetic variability for traits evaluated, with the possibility of obtaining greater genetic gain for the desired characters, as they showed a percentage above 20%, according to the methods of Oyiga and Uguru (2010) and Sunday et al. (2007).

The lower environmental variation coefficient (ECV) was 8.419% for VG (germination speed) and the greatest was 66.364% for PPA (shoot weight). For the other parameters a high ECV was observed, which implies greater difficulty in selection of these traits. In this case say that there is environmental influences in the formation of character, however, it is worth noting that the genetic influence is considerable, which is given by the heritability as can be seen in Table 2 for all variables (Oyiga and Uguru, 2010).

Differences of PCV and GCV for germination rate, root number, presence of shoots, germination speed, indicated that such characteristics are ruled primarily by genetic factors and minimal environmental influence on phenotypic expression of the characters, so the selection of these characteristics based on phenotypic seems to be effective.

On the other hand, major differences were found in root weight, root length, shoot weight, shoot length, root plus shoot weight, ratio of shoot/root characteristics, indicating a greater environmental influence, reducing response to possible phenotypic selection. The high heritability (h^2h^2) presented in most variables suggests that the phenotype reflects the genotype showing ease in the selection of studied varieties. The high heritability also points the presence of sufficient genetic variation to obtain additional gains by selecting on these varieties. According to Rodrigues et al. (2011), the GCV for maize, in Brazilian conditions, over 7%, indicates a good germplasm genetic potential to be used in breeding.

According to results, it was found that both the genetic variance (Vg) and genetic gain (GA) had different values within the same population for a given characteristic, showing that even having presented a high heritability; the environment may have influenced the variables in low to moderate genetic gains.

Conclusion

The Catingueiro variety, in general, presents better physiological quality among the others, which indicates that there is genetic variability with high heritability and possible genetic gain, and therefore is important their conservation, collection and subsequent evaluation in plant breeding programs in the Southwest Region of Bahia.

Conflict of Interest

The author(s) have not declared any conflict of Interest.

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