African Journal of Agricultural Research

Volume 10 Number 5 29 January 2015

ISSN 1991-637X

Academic Journals

ABOUT AJAR

The African Journal of Agricultural Research (AJAR) is published weekly (one volume per year) by Academic Journals.

African Journal of Agricultural Research (AJAR) is an open access journal that publishes high-quality solicited and unsolicited articles, in English, in all areas of agriculture including arid soil research and rehabilitation, agricultural genomics, stored products research, tree fruit production, pesticide science, post harvest biology and technology, seed science research, irrigation, agricultural engineering, water resources management, marine sciences, agronomy, animal science, physiology and morphology, aquaculture, crop science, dairy science, entomology, fish and fisheries, forestry, freshwater science, horticulture, poultry science, soil science, systematic biology, veterinary, virology, viticulture, weed biology, agricultural economics and agribusiness. All articles published in AJAR are peer-reviewed.

Contact Us

Editorial Office: ajar@academicjournals.org

Help Desk: helpdesk@academicjournals.org

Website: http://www.academicjournals.org/journal/AJAR

Submit manuscript online http://ms.academicjournals.me/

Editorial Board

African Journal of Agricultural Research

Table of Contents: Volume 10 Number 5 2 9 January, 2015

ARTICLES

African Journal of Agricultural Research

Table of Contents: Volume 10 Number 5 2 9 January, 2015

ARTICLES

African Journal of Agricultural Research

Table of Contents: Volume 10 Number 5 2 9 January, 2015

academicJournals

Vol. 10(5), pp. 308-316, 29 January, 2015
DOI: 10.5897/AJAR2013.8022
Article Number: 6045EFF49822
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Effect of planting space on plant population at harvest and tuber yield in taro (*Colocasia esculenta* L).

Ogbonna, P. E.[1]*, Orji, K. O.[1], Nweze, N. J.[2] and Opata, P.[2]

[1]Department of Crop Science, University of Nigeria, Nsukka, 410001, Nigeria.
[2]Department of Agricultural Economics, University of Nigeria,Nsukka, 410001,Nigeria.

Received 3 October, 2013; Accepted 22 January, 2015

A two year study was carried out in two locations in south eastern Nigeria in the years 2008 and 2009, to determine the effect of planting space on plant population at harvest, and corm yield in cocoyam cultivars. This was aimed to identify optimum planting space for optimum cocoyam production. Five taro cultivars; Nkpong, Ugwuta, Nworoko, Odogolo and Nadu were used. Three planting space; 50 x 100 cm, 40 x 100 cm and 30 x 100 cm were tested. The result showed that decreasing planting space from 50 x 100 cm to 40 x 100 cm resulted to increase in plant population at harvest. There was a decline in plant population as planting space was further decreased to 30 x 100 cm. The closest planting space of 30 x 100 cm produced the highest tuber yield ha^{-1} among the three planting space in the two locations. The result also showed that the Ugwuta cultivar produced the highest tuber yield among the five cultivars in the Nsukka location while the Odogolo cultivar recorded highest tuber yield in the Umudike location. It was therefore recommended that planting at the spacing of 30 x 100 cm should be adopted as a production practice in these areas for high tuber yield in cocoyam.

Key words: Cocoyam, cultivars, planting space, population, tuber yield.

INTRODUCTION

Cocoyam is the common name for two tuber crops *Colocasia esculenta* and *Xanthosomona sagitifolum*. Cocoyam is an important crop grown for its starchy corms and is a staple food throughout the rural subtropical and tropical regions of the world especially in the Pacific and Caribbean islands and West Africa (Hancock, 2004). Together with yam and cassava, cocoyam forms the major source of carbohydrates in Nigeria. Cocoyam cultivation in Nigeria is concentrated in southwestern and southeastern parts of the country due to favourable ecological conditions in these areas (Shiyam et al., 2007). Cocoyam production, like production of other crops, is still carried out by poor rural farmers with low production technologies. These resource poor farmers account for over 90% of Nigeria's agricultural output through the use of the indigenous farming practices.

Nigeria is presently the world highest producer of cocoyam producing about 1800000 tons per annum, accounting for about 30% of world total and 48% of Africa total production (Onwueme and Sinha, 1991; Eze and Okorji, 2003). Yield is still low in Nigeria as a result of poor production practices. There is therefore the need to

*Corresponding author. E-mail: ogbonnaptr@yahoo.com

enhance the production of cocoyam as this will help to reduce food shortage and also help in alleviating poverty among rural people.

Plant response to spacing varies from species to species and is highly dependent on such environmental conditions as soil characteristics, biotic elements and climatic conditions of the site. Planting with space according to Hailu and Sue (2011) involves the growing of plants on a plot of land with sufficient space between each of the plants so that they can develop their roots and shoots more fully. Cocoyam is a rhizomatous plant and when planted produces a number of suckers which develop into full plants/plantlets. Hence the expected plant population at planting will always be less than the plant population at maturity due to the emergence of these plantlets. Squire (1990) reported that production increases as population increases until a point is reached when further increase only lead to slight increase in production. He attributed the high production to high leaf area index. To maximize production therefore interception of light by chloroplast must be maximized to enhance photosynthesis upon which yield of crops is totally and directly dependent (Barden et al., 1989). Such increases in yield with decrease in plant spacing have been reported in other crops (Ogbonna and Obi, 2000; Ofori and Stern, 1987; Pardales and Belmontes, 1984; Bolton, 1971). Osundare, (2006) however, noted that average cormel weight decreases with increase in plant population. The objectives of this study are to determine the effect planting space on plant population at harvest and tuber yield in cultivars of cocoyam. This was aimed at identify high yielding and stable cocoyam cultivar and optimum planting space for maximum cocoyam production.

MATERIALS AND METHODS

To address the objectives of the study, field practical experiments were conducted in two locations in southeastern Nigeria namely; University of Nigeria, Nsukka in Enugu state (latitude 06°52'N longitude 07°24'E and at altitude 442 m above sea level), National Root Crop Research Institute (NRCRI), Umudike in Abia State (latitude 05°29'N, longitude 07 33'E and at altitude 122 m above sea level. The experiments were carried out in the growing season of two years, Nsukka location (2008) and Umudike (2009).

Material

Three local cultivars of cocoyam (*Colocasia esculenta)*; Odogolo, Nworoko and Nadu were sourced from the study area. Two cocoyam varieties; Ugwuta and Nkpong were also obtained from NRCRI Umudike, bringing the number of cultivars to five. The experiment was a factorial experiment in Randomized Complete Block Design (RCBD). The treatments consist of five cocoyam cultivars and three planting space of 50 x 100 cm, 40 x 100 cm and 30 x 100 cm, respectively. This resulted to 15 treatments combinations and was replicated into four.

The land was ploughed, harrowed and ridged before marking out into blocks and plots according to the experimental design. Planting was done immediately after land preparation at the depth of 10 cm. Two weeding were carried out manually with hoe before maturity. NPK 15:15:15 fertilizer was applied at the rate of 200 kgha^{-1} at eight weeks after planting. At maturity, expert women harvesters were engaged to harvest the cocoyam.

Data collection and analysis

Records were taken on number of plants per plot, number of cormels per stand, weight of cormels per stand, average cormel weight, weight of corm per stand, total tuber yield per stand, cormel yield ha^{-1} and total tuber yield ha^{-1}. These data were subjected to analysis of variance (ANOVA). This was carried out using the method outlined by Steel and Torrie (1980) for factorial experiments. Separation of means for statistical significance was by the F-LSD procedure described by Obi (2001). The F-LSD was calculated at 5% significant level. Meteorological records were obtained from meteorological stations at both institutions.

Soil data

At the time of planting soil samples were taken at different representative locations in each experimental site at the depth of 0 to 20 cm. The samples were thoroughly mixed to obtain a composite sample for each location from which a sub sample was used for laboratory analysis to determine the physical and chemical properties of the soil.

RESULTS

The result of soil analysis for the two locations is shown in Table 1.The result indicated that the soils of Nsukka and Umudike were texturally clay soil and loam soil, respectively. Their acidity levels were not too far apart however, Umudike appeared to be more fertile having higher quantities of organic matter and minerals than Nsukka soil. The weather data from the two location presented in Table 2 also revealed that rainfall started earlier in the year in Umudike. Also, high amount of rainfall and better distributed was recorded in Umudike. Temperature and relative humidity were also higher at Umudike.

The result of the effect of planting space on plant population at harvest shown in Figure 1 indicated significant effect (P=0.05). Decrease in planting space from 50 x 100 cm to 40 x 100 cm caused a significant increase in plant population at harvest. Further decrease in planting space to 30 x 100 cm resulted to a decline in plant population at harvest. The decline was however non significant. This trend was the same in both locations. Similarly, at Nsukka location, yield components such as number of cormels per stand, weight of cormels per stand, weight of corm per stand, average cormel weight and total tuber yield per stand also decreased significantly in capacity with decreased planting space (Table 3). On the contrary cormel yieldha^{-1} and total tuber yield ha^{-1} increased with decrease in planting space, hence planting at 30 x 100 cm planting space produced the highest cormel yieldha^{-1} and tuber yieldha^{-1} and were significantly higher than values obtained at 50 x 100 cm

Table 1. Physical and Chemical Properties of the Soil of the Experimental Sites before Planting.

Physical properties (%)	Nsukka	Umudike
Course sand (%)	10.00	44.00
Fine sand (%)	60.00	40.00
Silt (%)	20.00	9.00
Clay (%)	64.00	7.00
Textural Class	Clay soil	Loam soil
Chemical properties		
pH in Water	5.00	5.20
pH in KCL	4.60	4.10
Organic matter (%)	1.03	1.38
Total Nitrogen (%)	0.05	0.11
Total Carbon (%)	0.60	0.79
Available P (ppm)	2.60	10.30
Exchangeable Na (Meq/100 g)	0.10	1.73
Exchangeable K (Meq/100 g)	0.09	2.72
Exchangeable Ca (Meq/100 g)	1.00	3.80
Exchangeable Mg (Meq/100 g)	0.80	1.80
Exchangeable Al (Meq/100 g)	1.00	Nil
Exchangeable H (Meq/100 g)	0.40	1.40
Cation exchange capacity (Meq/100 g)	6.00	6.00

planting space but statistically the same with planting at 40 x 100 cm planting space. A similar trend was observed at Umudike location (Table 4).

Significant cultivar differences were also identified among the cultivars in plant population at harvest (Figure 2). Nworoko had the highest plant population among the cultivars in the Nsukka location while Nadu was at the top in the Umudike location. However both cultivars did not differed significantly in this attribute at both locations. The lowest plant population at harvest was recorded from Nkpong at both locations. The result presented in Table 5 indicated significant differences among the cultivars grown in the Nsukka location in all the yield components. Odogolo produced the highest number of cormels per stand while Nadu produced the lowest. Ugwuta had the highest weight of cormels per stand and was followed by Odogolo while Nkpong registered the least value. Records on weight of corms per stand showed that Nworoko topped the list followed by Odogolo while Nadu was the last. The highest average cormel weight was recorded in Nadu while Nkpong had the lowest value of average cormel weight. The highest total tuber yield per stand, cormel yieldha^{-1} and total tuber yieldha^{-1} were recorded in Ugwuta and was followed by Odogolo. Nkpong ranked the least in all the yield components except in weight of corm per stand. It was noted that Ugwuta, Odogolo and Nworoko produced statistically the same effect in all the yield components measured.

In the Umudike location, significant effects of cultivars were observed in all the yield components. Odogolo recorded the highest performance in all the yield components measured with the exception of average cormel weight in which Nworoko was the best. Ugwuta however ranked second in all the components with the exception of number of cormels per stand. Nkpong was lowest in weight of corms per stand, average cormel weight and corm yieldha^{-1}, while Nadu was lowest in number of cormels per stand, weight of cormels per stand, total tuber yield per stand and total tuber yieldha^{-1}. It was also observed that Odogolo, Ugwuta and Nworoko registered statistically the same effect in all the yield components with the exception of cormel yieldha^{-1} and total tuber yieldha^{-1} where they differed significantly (Table 6).

The cultivar x planting space interaction effect was significant on plant population at harvest. The result shown in Figure 3 revealed a trend of increase in plant population at harvest in all the cultivars as planting space decreased from 50 x 100 m to 40 x 100 m and declined as planting space was further decreased to 30 x 100 m in the Nsukka location. The same trend was observed in the Umudike location (Figure 4). The highest plant population at harvest was recorded in Nworoko in Nsukka location while at the Umudike location both Nworoko and Nadu produced the highest number.

Cultivar x planting space interaction effect was also significant in all the yield components measured (Table 7). There was a trend of decrease in number of cormels per stand as planting space was decreased in all the cultivars. Odogolo planted at 50 x 100 m spacing produced the highest number of cormels per stand, weight of cormel per stand, weight of corm/stand,

Table 2. Weather records of the areas during the periods of the Experiment.

Location						**NSUKKA**						
Year						**2008**						
Months	**Jan**	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec.**
Rainfall amount (mm)	0	0	61	143	254	186	246	203	326	199	8	
Number of Rain days	0	0	4	11	12	15	14	19	22	11	2	
Maximum Temp (^{0}C)	31.4	34.1	33.8	31.7	31.2	29.8	28.9	27.8	27.6	29.5	31.1	
Minimum Temp (^{o}C)	20.3	22.0	22.9	22.0	20.8	21.4	20.8	20.7	20.8	20.9	22.0	
Relative Humidity (0900)	72.0	73.2	74.1	74.8	75.0	76.9	78.2	79.6	78.7	76.4	74.8	
Relative Humidity (1500)	56.0	56.2	57.0	66.20	70.30	72.7	74.60	75.00	74.50	74.70	61.70	
Location						**UMUDIKE**						
Year						**2009**						
Months	**Jan**	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Rainfall amount (mm)	63	63	48	101	416	237	306	287	204	311	24	0
Number of Rain days	2	4	4	12	15	14	18	19	18	14	7	0
Maximum Temp (^{0}C)	33.0	35.0	34.0	33.0	33.0	31.0	30.0	29.0	30.0	31.0	32.0	34.0
Minimum Temp (^{o}C)	23.0	24.0	24.0	23.0	23.0	23.0	22.0	23.0	22.0	23.0	22.0	23.0
Relative Humidity (0900)	75.0	79.0	78.0	78.0	81.0	83.0	87.0	88.0	86.0	82.0	74.0	78.0
Relative Humidity (1500)	50.0	56.0	57.0	63.0	70.0	72.0	78.0	78.0	72.0	72.0	58.0	43.0

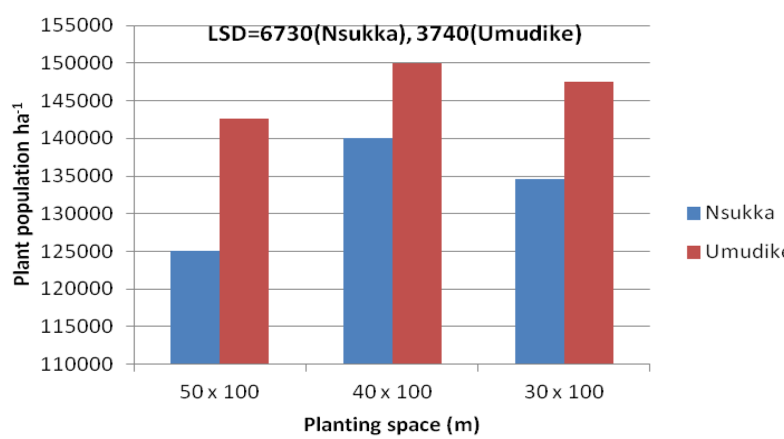

Figure 1. Effect of planting space on plant population at harvest in the Nsukka and Umudike locations.

Table 3. Mean effect of planting space on yield attributes of cocoyam in Nsukka Location in 2008.

Plant population (plants ha^{-1})	No. of cormels per stand	Weight of cormels per stand (kg)	Weight of corms per stand(kg)	Average cormel weight(kg)	Total tuber yield per stand(kg)	Cormel yield (kgha^{-1})	Total tuber yield (kgha^{-1})
20000	17.62	0.93	0.35	0.06	1.28	18560	25547
25000	13.90	0.80	0.32	0.06	1.13	20083	28117
33000	11.82	0.70	0.27	0.05	0.97	22978	32422
LSD (P<0.05)	1.88	0.11	0.06	0.01	0.14	3068	3855

Table 4. Mean effect of planting space on yield attributes of cocoyam in Umudike location in 2009 .

Plant population (plants ha^{-1})	No. of cormels per stand	Weight of cormels per stand(kg)	Weight of corms per stand(kg)	Average cormel weight(kg)	Total tuber yield per stand(kg)	Cormel yield (kgha^{-1})	Total tuber yield(kgha^{-1})
20000	10.46	0.35	0.07	0.24	0.42	9647.00	10827.0
25000	8.65	0.30	0.06	0.15	0.36	10180.00	11265.0
33000	7.32	0.26	0.04	0.13	0.31	11742.00	12926.0
LSD(P<0.05)	1.87	0.08	0.02	0.10	0.07	1678.80	1204.0

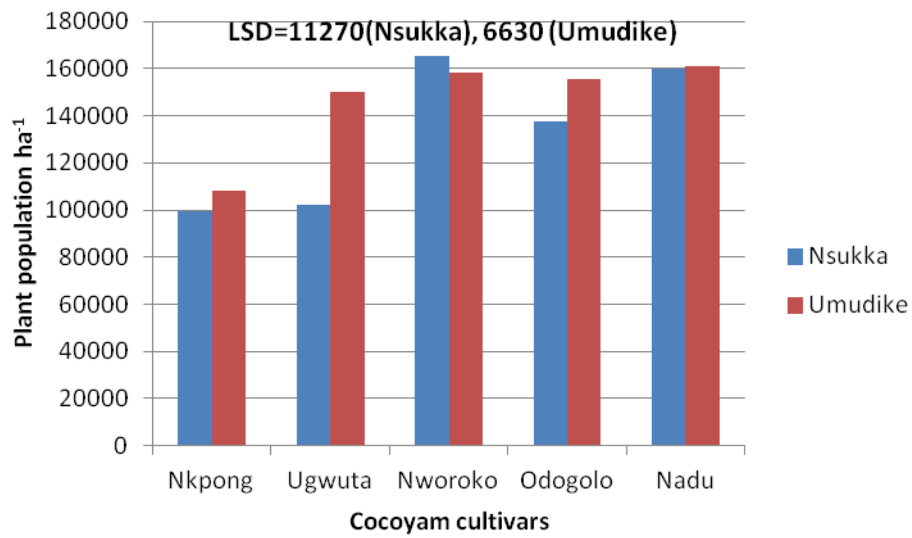

Figure 2. Effect of cultivar on plant population at harvest in the Nsukka and Umudike locations.

Table 5. Mean effect of cultivar on yield attributes of cocoyam in Nsukka location in 2008.

Cultivars	No. of cormels per stand	Weight of cormels per stand(kg)	Weight of corms per stand(kg)	Average cormel weight(kg)	Total tuber yield per stand(kg)	Cormel yield (kgha^{-1})	Total tuber yield(kgha^{-1})
NKPONG	13.11	0.71	0.30	0.05	1.00	17274.00	25557.00
UGWUTA	15.53	0.88	0.31	0.06	1.19	22180.00	30015.00
NWOROKO	14.08	0.79	0.35	0.06	1.15	20204.00	29468.00
ODOGOLO	15.75	0.85	0.32	0.06	1.17	21833.00	29937.00
NADU	13.75	0.83	0.29	0.06	1.12	21211.00	28498.00
LSD(P<0.05)	2.42	0.14	0.07	0.01	0.09	3960.90	4977.30

Table 6. Mean effect of cultivar on yield attributes of cocoyam in Umudike location in 2009.

Cultivars	No. of cormels per stand	Weight of cormels per stand(kg)	Weight of corms per stand(kg)	Average cormel weight(kg)	Total tuber yield per stand(kg)	Cormel yield(kgha^{-1})	Total tuber yield(kgha^{-1})
NKPONG	6.64	0.25	0.04	0.13	0.29	8066.00	9098.00
UGWUTA	9.34	0.32	0.07	0.30	0.40	11832.00	13197.00
NWOROKO	10.11	0.31	0.07	0.24	0.38	10443.00	11869.00
ODOGOLO	11.53	0.42	0.07	0.17	0.48	14080.00	15459.00
NADU	6.42	0.22	0.05	0.14	0.27	8195.00	8740.00
LSD(P<0.05)	2.42	0.10	0.02	0.13	0.08	2167.30	2541.00

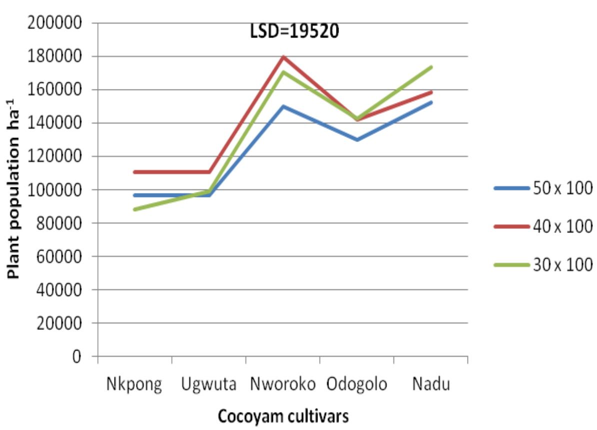

Figure 3. Effect of cultivar x planting space interaction on plant population at harvest in the Nsukka location.

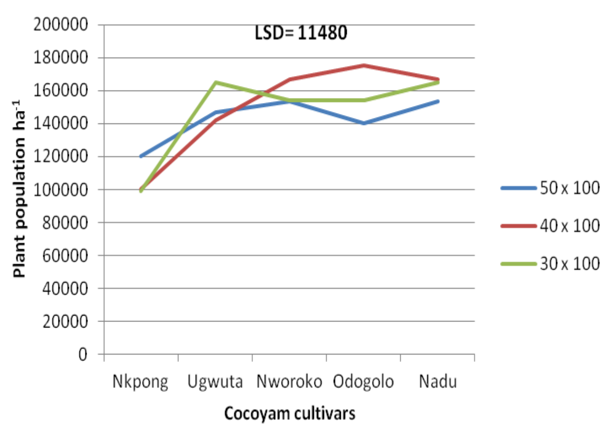

Figure 4. Effect of cultivar x planting space interaction on plant population at harvest in the Umudike location.

average cormel weight and total tuber yield per stand among the cultivar x planting space combinations. On the contrary cormel yieldha^{-1} and total tuber yield/ha increased as planting space was decreased in all the cultivars. Highest cormel yieldha^{-1} and total tuber yieldha^{-1} were recorded in Ugwuta planted at 30 x 100 m spacing. In the Umudike location the trend of the effect of cultivar x planting space interaction was the same with that of Nsukka location (Table 8). However in this location, Odogolo planted at 50 x 100 m spacing produced the highest values in number of cormels per stand, weight of cormels per stand, weight of corms per stand, average cormel weight and total tuber yield per stand among the combinations. It also recorded the

Table 7. Mean effect planting space by cultivar interaction on yield attributes of cocoyam in Nsukka location in 2008.

Cultivar x population	No. of cormels per stand	Weight of cormels per stand(kg)	Weight of corms per stand(kg)	Average cormel weight(kg)	Total tuber yield per stand(kg)	Cormel yield ($kgha^{-1}$)	Total tuber yield ($kgha^{-1}$)
Nkpong x 20000plts ha^{-1}	15.92	0.83	0.33	0.05	1.14	16600.00	22867.00
Nkpong x 25000plts ha^{-1}	13.00	0.69	0.33	0.05	1.02	17333.00	25583.00
Nkpong x 33000plts ha^{-1}	10.42	0.59	0.25	0.05	0.85	17889.00	28222.00
Cocoindia x 20000plts ha^{-1}	18.67	0.93	0.34	0.06	1.28	18667.00	25533.00
Cocoindia x 25000plts ha^{-1}	14.83	0.86	0.33	0.06	1.19	21500.00	29833.00
Cocoindia x 33000plts ha^{-1}	13.75	0.76	0.27	0.05	1.03	25333.00	34444.00
Nworoko x 20000plts ha^{-1}	17.17	0.90	0.36	0.06	1.26	18000.00	25267.00
Nworoko x 25000plts ha^{-1}	13.42	0.79	0.34	0.06	1.17	19833.00	29250.00
Nworoko x 33000plts ha^{-1}	11.67	0.68	0.33	0.05	1.02	22777.00	33888.00
Odogolo x 20000plts ha^{-1}	20.00	1.04	0.38	0.06	1.41	20733.00	28267.00
Odogolo x 25000plts ha^{-1}	15.08	0.86	0.30	0.06	1.16	21583.00	29000.00
Odogolo x 33000plts ha^{-1}	11.50	0.73	0.26	0.05	0.99	24222.00	32778.00
Nadu x 20000plts ha^{-1}	16.33	0.94	0.35	0.06	1.29	18800.00	25800.00
Nadu x 25000plts ha^{-1}	13.17	0.81	0.27	0.06	1.08	20167.00	26917.00
Nadu x 33000plts ha^{-1}	11.75	0.74	0.24	0.06	0.98	24666.00	32777.00
LSD($P<0.05$)	4.20	0.24	0.12	0.01	0.22	6860.50	8629.90

highest cormel yieldha-1 and total tuber yield/ha at the closest planting space of 30 x 100 m.

Table 9 shows the result of the effect of locations on the yield components. The result indicates significant location effects on all the yield attributes. Planting at the Nsukka location produced significantly higher values in all the yield components than planting in Umudike location.

DISCUSSION AND CONCLUSSION

The study has shown that planting space affects plant population at harvest in cocoyam. Plant population at harvest increased with decrease in planting space and peaked at a particular planting space after which further decrease in planting space caused a decline in plant population at harvest. It was also observed that the cocoyam cultivars differed in plant population at harvest irrespective of the planting space. It will be important to note that it may be wrong to make estimate of plant population for some plant species that produce suckers, based on plant spacing at planting as that may entail stating plant populations that are far below the actual plant populations obtained in the field.

The observed decrease in corm and cormel yield per stand at closer planting space was in agreement with the findings of Tumuhimbise et al. (2009), Pardales and Belmonte (1984), Igbokwe and Ogbonnaya (1981) and De la Pena (1977). It has however, been reported that corm yield is a positive function of the number of corms and weight of corms per planting hill (Khan et al., 2003; Kader and Rolle, 2004). Calculated on hectare basis these yield components were found to increase as planting space decreased. In this study highest corm and cormel yieldha^{-1} were realized from the closest planting space of 30 x 100 cm. This has also been reported by Pardales et al. (1982), Villanueva et al (1983) and Talwana et al. (2010). In south eastern Nigeria, like in many other parts of West Africa, sole cropping is a rare practice, so cocoyam is not normally planted sole but in mixture with other crops. In such combination individual plant population is always low and low yields are recorded (Onwueme and Sinha, 1991; Shiyam et al., 2010). This work has shown that growing cocoyam at closer planting space of 30 x 100 cm produced the highest corm and cormel yieldsha^{-1} compared to yields recorded at wider planting spaces of 50 x 100 cm and 40 x 100 cm.

Table 8. Mean effect of planting space by cultivar interaction on yield attributes of cocoyam grown in Umudike location in 2009.

Cultivar x population	No. of cormels per stand	Weight of cormels per stand (kg)	Weight of corms per stand (kg)	Average cormel weight (kg)	Total Tuber yield per stand (kg)	Cormel yield (kgha^{-1})	Total tuber yield (kgha^{-1})
Nkpong x 20000plts ha^{-1}	7.87	0.31	0.05	0.15	0.36	8233.00	9033.00
Nkpong x 25000plts ha^{-1}	6.88	0.22	0.04	0.12	0.26	7675.00	8383.00
Nkpong x 33000plts ha^{-1}	5.18	0.21	0.03	0.10	0.23	8289.00	9878.00
Ugwuta x 20000plts ha^{-1}	11.41	0.37	0.08	0.23	0.45	10733.00	12173.00
Ugwuta x 25000plts ha^{-1}	9.28	0.33	0.06	0.20	0.39	11750.00	13083.00
Ugwuta x 33000plts ha^{-1}	7.34	0.27	0.05	0.16	0.32	13011.00	14333.00
Nworoko x 20000plts ha^{-1}	11.81	0.36	0.08	0.14	0.44	9533.00	10867.00
Nworoko x 25000plts ha^{-1}	9.82	0.32	0.07	0.14	0.38	9983.00	11150.00
Nworoko x 33000plts ha^{-1}	8.71	0.26	0.05	0.13	0.31	11811.00	13589.00
Odogolo x 20000plts ha^{-1}	13.66	0.47	0.08	0.20	0.55	12480.00	13880.00
Odogolo x 25000plts ha^{-1}	11.07	0.41	0.06	0.17	0.47	13383.00	14642.00
Odogolo x 33000plts ha^{-1}	9.85	0.37	0.07	0.17	0.43	16378.00	17856.00
Nadu x 20000plts ha^{-1}	7.55	0.25	0.06	0.16	0.31	7253.00	8180.00
Nadu x 25000plts ha^{-1}	6.20	0.22	0.05	0.14	0.27	8108.00	9067.00
Nadu x 33000plts ha^{-1}	5.52	0.20	0.03	0.11	0.23	9222.00	8972.00
LSD(P<0.05)	4.18	0.13	0.03	0.02	0.12	3753.90	4401.20

Table 9. Mean effect of location on growth and yield of cocoyam.

Locations	No. of cormels per stand	Weight of cormels per stand(kg)	Weight of corms per stand(kg)	Average cormel weight(kg)	Total tuber yield per stand(kg)	Cormel yield(kgha^{-1})	Total tuber yield(kgha^{-1})
Nsukka	14.35	0.84	0.26	0.06	1.10	20657.00	27533.00
Umudike	13.35	0.49	0.14	0.04	0.59	12307.00	15149.00
F-LSD(P<0.05)	1.135	0.07	0.03	0.01	0.07	1644.00	1916.9.00

The variation in yield among the cultivars collaborate with the findings of Khan et al. (2003). The Cocoindia and Odogolo cultivars were observed to produce highest yield at both locations and at the three planting space, among the cultivars. This is an indication that these cultivars possessed inherent genetic qualities that enhanced growth and development than the other cultivars. Such attributes brings about more efficient use of production factors. Breeding genotypes that are adapted to wide geographical areas and that show some degree of stability from year to year is one of the major challenges facing plant breeders. Such stable genotypes will be capable of utilizing the resources available in higher yielding environments and maintain a mean performance that is above average in all environments (Moll and Stuber, 1974). The Nsukka location appeared to have provided conditions most suitable for cocoyam growth and development; hence all the cultivars performed best at that location. It has been reported by other researchers that yield of root crops are affected by changes in environmental conditions between sites and planting dates (Lu et al., 2001; Scheffer et al., 2005; Kumar et al., 2007; Mare and Mode, 2009).

Planting at the closest spacing of 30 x 100 cm which produced the highest tuber yield in all cultivars will be recommended to farmers. It will also be suggested that further studies will be conducted to determine the effect of planting at spacing that are closer than the ones tested in the present study. This will help to determine the optimum planting space. The Ugwuta and Odogolo cultivars which produced high tuber yield ha^{-1} will also be recommended to farmers in these areas. It will however be noted that other parameters may also be considered in making a choice. However, the funding for this research could not cover such other areas.

Conflict of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGMENTS

Author acknowledge the financial and material aids from the CODESRIA – IFS Sustainable Agriculture Initiative, Grant No.T/4434-1 under which this study was carried out and also the support granted by National Root Crop Research Institute (NRCRI), Umudike, Nigeria for granting me the use of their experimental facilities and technical assistance.

REFERENCES

Barden JA, Halfacre RG, Parish DJ (1989). Plant Science. McGraw-Hill. NY. P. 551.

Bolton A (1971). Response of maize vars in Tanzania to different plant populations and fertilizer levels. Expl. Agric. 7:193-203.

De la Pena RS (1977). Yield of upland taro at varying plant density. Field Crop Res. 1:183-190.

Eze CC, Okorji EC (2003). Cocoyam production by women farmers under improved and local technologies in Imo state, Nigeria. Afric. J. Sci. 5(1):113-116.

Hailu A, Sue E (2011). Planting with space. Institute for Sustainable Development. Addis Ababa. www.isd.org.et/publications/Planting with space. Accessed: 21/07/2012.

Hancock JF (2004). Plant evolution and the origin of crop species. CABI Publishing. Wellingford, UK. P. 222.

Igbokwe MC, Ogbonnaya JC (1981). Yield and nitrogen uptake by cocoyam as affected by nitrogen application and spacing. Proceedings of the first Triennial Root Crops Symposium of the International Society for Tropical Root Crops-Africa Branch, 8-12 September, Ibadan, Nigeria pp. 255-257.

Kader AA, Rolle RS (2004). The role of post harvest management in assuring the quality and safety of horticultural produce. FAO Agric. Serv. Bull. P. 152.

Khan IA, Deadman ML, Al-Nabhani HS, Al-Habsi KA (2003). Interactions betweentemperature and yield components in exotic potato cultivars grown in Oman. Acta Hortic. 619:353-359.

Kumar P, Pandey SK, Singh BP, Singh SV, Kumar D (2007). Effect of nitrogen rates on growth, yield, economics and crisps quality of Indian potato processing cultivars. Potato Res. 50(2):143-155

Lu HY, Lu CT, Chan LF, Wei ML (2001). Seasonal variation in linear increase of taro harvest index explain by growing degree days. Agron. J. 93:1136-1141.

Mare R, Modi AT (2009). Influence of planting date and organic fertilization on growth and yield of taro landraces. Afri. Crop Sci. Conf. Proc. 9:179-189.

Moll RH, Stuber CW. (1974). Quantitative genetics-Emperical result relevant to plant breeding. Advanced Agron. 26:277-313.

Obi IU (2001). Introduction to Factorial Experiments for Agricultural, Biological and Social Sciences Research. 2nd ed. Optimal Int. Ltd Nigeria. 45 pp.

Ofori F, Stern WR (1987). Relative sowing time and density of component crops in a maize/cowpea intercrop system. Expl. Agric. 23:41-52.

Ogbonna PE, Obi IU (2000). The influence of poultry manure application and plant density on growth and yield of Egusi melon (Colocynthis citrullus L.) in the Nsukka plains of south eastern Nigeria. Agro-Science 1(1):122-129.

Onwueme IC, Sinha TD (1991). Field Crop Production in Tropical Africa. CTA. Ede, The Netherlands. 552pp.

Osundare B (2006). Effect of fertilizer types and varying population on the performance of cocoyam. Moor J. Agric. Res. 5(1):7-12.

Pardales JR, Belmonte DV (1984). Cultural management studies on upland taro: Effect of population density and planting method on growth and yield. Philipp. J. Crop Sci. 9(1):29-32.

Pardales JR, Villanueva MR, Cotejo FR (1982). Performance of taro under lowland condition as affected by genotype, nutritional status and population density. Ann. Trop. Res. 4:156-167.

Scheffer JJC, Douglas JA, Triggs CM (2005). Factors affecting the production and quality of Japanese taro cormels. Acta Hortic. 670:167-172.

Shiyam JO, Obiefuna JC, Ofoh MC, Oko BFD, Uko AE (2007). Growth and corm yield response of upland cocoyam (*Xanthosoma sagittifolium* L.) to saw dust mulch and NPK 20:10:10 fertilizer rates in the humid forest zone of Nigeria. Continental J. Agron. 1:5-10.

Shiyam JO, Oko BFD, Obiefuna JC, Ofoh MC (2010). Optimizing the productivity of plantain/cocoyam mixture by mulching and fertilizer application. World J. Fungal Plant Biol. 1(2):42-45.

Squire GR (1990). The Physiology of Tropical Crop Production. CABI. UK. 229p.

Steel RGD, Torrie JH (1980). Principles and Procedures of Statiatics: A Biometrical Approach. 2nd ed. McGraw-Hill Book Company Inc. NY. 633p.

Talwana HL, Tumuhimbise R, Osiru DSO (2010). Comparative performance of wetland taro grown in upland production system as influenced by different plant densities and seedbed preparation in Uganda. J. Root Crops. 36(1):65-71.

Tumuhimbise R, Talwana HL, Osiru DSO, Serem AK, Ndabikunze BK, Nandi JOM, Palapala V (2009). Growth and development of wetland grown taro under different plant populations and seedbed types inUganda. Afr. Crop Sci. 17(1):49-60.

Villanueva MR, Pardales JR, Abenoja EA (1983). Performance of taro in the upland as affected by fertilizer application and population density under different production systems. Philipp. J. Crop Sci. 8:17-22.

academicJournals

Vol. 10(5), pp. 317-327, 29 January, 2015
DOI: 10.5897/AJAR2014.8822
Article Number: 6045EFF49822
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Production and bromatological composition of cultivars of *Brachiaria brizantha* and Campo Grande stylo monocropped and intercropped under different planting methods

Juliane Ferreira Morais Moreira[1], Kátia Aparecida de Pinho Costa[2]*, Eduardo da Costa Severiano[2], Gustavo André Simom[1], Patrícia Soares Epifanio[2], Welma Santos Crunivel[2] and José Carlos Bento[1]

[1]University of Rio Verde, Rio Verde, Goiás – Brazil.
[2]Goiano Federal Institute, Rio Verde, Goiás – Brazil.

Received 5 May, 2014; Accepted 22 January, 2015

This study was conducted to assess the production and bromatological composition of cultivars of *Brachiaria brizantha* (cvs. Marandu and Xaraés) and Campo Grande stylo (*Stylosanthes* ssp) monocropped and intercropped under different planting methods for a period of two years. The experimental design used consisted of randomized complete blocks, with four replicates. The treatments consisted of the following forage systems: monocropped Campo Grande stylo; monocropped *Xaraes palisadegrass*; monocropped *Marandu palisadegrass*; *X. palisadegrass* row-intercropped with Campo Grande stylo; *X. palisadegrass* mixed-intercropped with Campo Grande stylo; *M. palisadegrass* row-intercropped with Campo Grande stylo and *M. palisadegrass* mixed-intercropped with Campo Grande stylo. The evaluations were performed for two years, with evaluations for each season of the year (autumn, winter, spring and summer) in the same plots and repeated measures over time. The *X. palisadegrass* and *M. palisadegrass* showed similar results between the intercropping systems, indicating that both may be intercropped with Campo Grande stylo. Intercropping stylo with *B. brizantha* cultivars improves both pasture production and quality. However, the most efficient planting method was row intercropping because it maintains greater legume persistence in the forage system throughout the years assessed while also providing greater production and nutritional value.

Key words: *Marandu palisadegrass*, *Xaraes palisadegrass*, *Stylosanthes* spp.

INTRODUCTION

Nitrogen (N) is a key nutrient for enhancing the productivity of forage grasses. However, its use has been limited by its relatively high cost due to the extension of the areas involved and the need for frequent applications (Costa et al., 2010). Thus, the use of legumes intercropped with tropical grasses may be a more appropriate alternative for supplying N to a system (Barbero et al., 2010). The introduction of legumes adapted to the edaphic and climatic conditions of the region may increase the quantity and quality of the available forage, given the ability of these plants to biologically fix atmospheric N. The contribution is performed indirectly through fixed N transfer to the grass, which enhances the pasture's carrying capacity and prolongs its productive capacity (Barcelos et al., 2008).

There are some difficulties in implementing this system despite all the advantages of grass and legume intercropping. Several factors are implicated in having limited its expansion: the lack of legume persistence in pastures given the choice of species for its formation, deficient establishment and even poor management of the grasslands formed, with a decisive effect on legume persistence in pastures (Rosa et al., 2004).

However, with the emergence of cultivars/varieties of legumes with effective mechanisms of persistence, the system has shown a resurgence in its use in farms that is motivated by the encouraging research results of grasses intercropped with stylo, which show better dry matter production and nutritional values (Moreira et al., 2005; Lopes et al., 2011; Moreira et al., 2013). Accordingly, strategies must be designed to maintain legume persistence in forage systems. Therefore, it should be noted that one of the key issues in managing intercropped pastures is the choice of an appropriate planting system that enables an intercrop botanical composition with a good ratio of legumes. For that purpose, managing practices must be established that increase legume persistence over time. Thus, this study aimed to evaluate the production and bromatological composition of cultivars of *Brachiaria brizantha* (cvs. Marandu and Xaraés) and Campo Grande stylo (*Stylosanthes* ssp) monocropped and intercropped under different planting systems for a period of two years.

MATERIALS AND METHODS

The experiment was conducted at the School of Agronomy Campus, University of Rio Verde (Campus da Faculdade de Agronomia da Universidade de Rio Verde), located at Fontes do Saber farm at a 748 m altitude, 17° 48' latitude south and 50° 55' longitude west. The soil was classified as Haplorthox, and its physical and chemical characteristics at the 0 to 20 cm depth layer are outlined in Table 1. The method used in the soil analysis was reported by Silva (1999).

The experimental design consisted of randomized complete blocks, with four replicates. The treatments consisted of the following forage systems: monocropped Campo Grande stylo; monocropped *Xaraes palisadegrass*; monocropped *Marandu palisadegrass*; *X. palisadegrass* row-intercropped with Campo Grande sytlo; *X. palisadegrass* mixed-intercropped with Campo Grande stylo; *M. palisadegrass* row-intercropped with Campo Grande stylo; and *M. palisadegrass* mixed-intercropped with Campo Grande stylo. The evaluations were performed over two years, with evaluations in each season of the year (autumn, winter, spring and summer) in the same plots and repeated measures over time. Each plot was 4 by 4 m, totaling 16 m^2 of plot and 6 m^2 of floor area. The row-intercropping planting system consisted of eight rows of 4 m each (four rows of grass and four rows of legume) spaced 50 cm from each other. Five and 9 kg of pure viable seeds per hectare of Campo Grande stylo and palisadegrass (Xaraés and Marandu), respectively, were used for the forage planting. The area used was in fallow and the preparation was conducted by eliminating the invasive plants by applying glyphosate at a dose of 1,500 g ha^{-1}. Twenty days after desiccation, 900 kg ha^{-1} dolomitic limestone was applied with 100% LTRN (lime's total relative neutralization); subsequently, disking and leveling were performed. During planting, 100 kg ha^{-1} P_2O_5, 60 kg ha^{-1} K_2O and 20 kg ha^{-1} FTE BR-12 (9.20% Zn; 2.17% B; 0.80% Cu; 3.82% Fe; 3.4% Mn and 0.132% Mo) were applied using the following sources: simple superphosphate, potassium chloride and Fritted Trace Elements (FTE). Maintenance fertilization was performed in the second year using 80 kg ha^{-1} P_2O_5 and 60 kg ha^{-1} K_2O, derived from the simple superphosphate and potassium chloride sources, respectively. Per year, 90 kg ha^{-1} nitrogen was applied to the grasses, divided into three applications of the ammonium sulfate source.

Thinning was conducted following germination, thereby maintaining the same number of grass and legume plants. The ratio of forage system plants was assessed while conducting the experiment in the plot floor area by counting the grass and legume plants in all seasons of the year for a period of two years (Table 1). The evaluation times of dry mass production and nutritional value of forages were conducted in the rainy and dry periods (within each season, autumn, winter, spring and summer). The rainfall and monthly average temperature data were monitored daily during that period (Figure 1).

Two 1 m^2 samples were collected per plot for the evaluations, directing the square for each row of forages in the floor area to sample grass and legume plants. The square was randomly thrown within each plot in the mixed intercropping. Sixteen forage evaluation cuts were performed in two years, corresponding to the following periods: autumn (March 2008/2009 and May 2008/2009); winter (July 2008/2009 and September 2008); spring (October 2008/2009 and December 2008/2009); and summer (January 2009/2010). The cuts in the autumn, spring and summer seasons were performed every 30 days of growth and every 60 days in the winter season, at a height of 20 cm from the soil. A uniformization cut of the entire experimental area was performed after each evaluation at the same cut height of the evaluated plants, clearing the waste from that area. The material collected in the field was stored in plastic bags and sent to the laboratory, where an approximately 500 g sample representative of each plot was collected and placed in a forced-air convection oven for pre-drying, with a temperature of approximately 55°C for 72 h. The samples were subsequently ground in a Willey-type mill with a 1 mm sieve and stored in plastic bags for analysis. Bromatological analyses were performed to assess the dry matter (DM), crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF) according to the method reported by Silva and Queiroz (2002). The total digestible nutrients (TDN) were derived using the equations proposed by Chandler (1990). The data were submitted to an analysis of variance, and the means were compared using the Tukey's test, with a significance level of 5% probability. The analyses were performed using the split-plot model, subdivided in time, upon fitting to Gauss Markov linear models. The software used to perform the analysis of variance and the comparison of means test was the SISVAR (Ferreira, 2000).

*Corresponding author. E-mail: katiazoo@hotmail.com

Table 1. Physical and chemical characteristics of the soil in the forage systems evaluated in the years 2008 and 2009.

Characteristics	2008	2009	Characteristics	2008	2009
pH ($CaCl_2$)	4.4	5.1	V (%)	32.0	46.0
Al^{3+} ($cmol_c\ dm^{-3}$)	0.45	0.1	Cu ($mg\ dm^{-3}$)	3.4	2.7
H+Al ($cmol_c\ dm^{-3}$)	4.8	4.1	Zn ($mg\ dm^{-3}$)	1.5	1.9
Ca^{2+} ($cmol_c\ dm^{-3}$)	1.36	2.19	Fe ($mg\ dm^{-3}$)	43.0	30.0
Mg^{2+} ($cmol_c\ dm^{-3}$)	0.73	0.98	Mn ($mg\ dm^{-3}$)	38.4	41.0
K^{+} ($cmol_c\ dm^{-3}$)	0.17	0.33	O.M. ($g\ dm^{-3}$)	18.6	21.7
CTC ($cmol_c\ dm^{-3}$)	7.05	7.6	Clay ($g\ kg^{-1}$)	600	600
P-Mehlich-1 ($mg\ dm^{-3}$)	2.07	4.3	Silt ($g\ kg^{-1}$)	350	350
SO_4^{-2} ($mg\ dm^{-3}$)	9.6	10.9	Sand ($g\ kg^{-1}$)	50	50

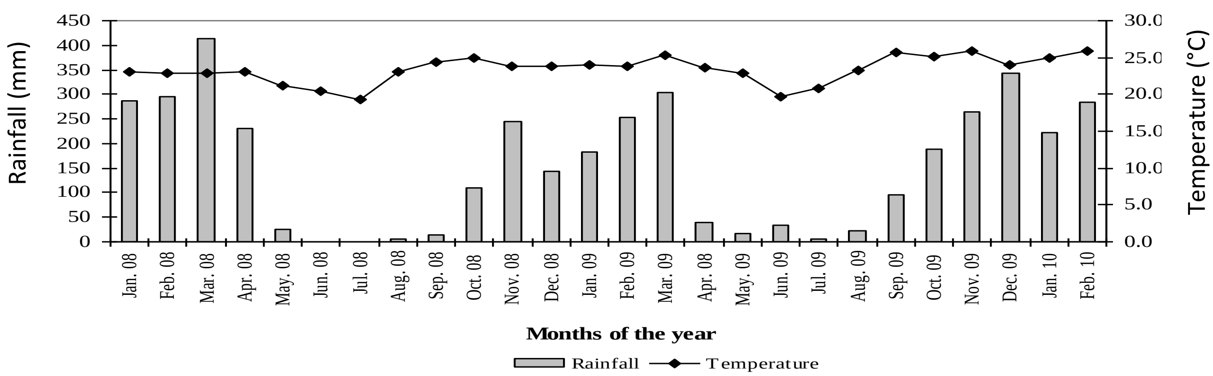

Figure 1. Rainfall (mm) and average temperatures (°C) as monitored during the period from January 2008 to February 2010 in Rio Verde- Goiás (GO), Brazil.

RESULTS AND DISCUSSION

Table 2 shows no significant effect (P<0.05) of the legume ratio on the different forage systems, which remained constant in the autumn and summer seasons of the first year, when assessing the ratio of Campo Grande stylo intercropped with Xaraes and *M. palisadegrasses*. In winter and spring, the greatest ratio of Campo Grande stylo was found in row intercropping with Xaraes palisadegrass. Conversely, no statistically significant difference (P<0.05) in the legume ratio was found in the other systems. However, there was a decrease in the legume ratio, especially in grass-mixed intercropping, given the low resistance of that legume in the dry period. The limitation of Campo Grande stylo in tolerating water stress, unlike several other tropical legumes, which have a greater ratio in the animals feeding during winter, considered the dry season in the Midwest region, must be noted. Natural reseeding of that legume occurs in winter because its plants are predominantly annual or biannual (Embrapa, 2000). The comparison of seasons within each forage system in the first year shows that the legume ratio for Campo Grande stylo row intercropping with *X. palisadegrass* was similar in autumn, winter and spring, differing only in the summer, which showed the lowest ratio. Conversely, in the other systems, a statistically significant effect (P<0.05) occurred only in the autumn, recording the highest legume ratio Table 2 shows that the highest ratio of Campo Grande stylo in the autumn, winter and spring occurred with row intercropping *X. palisadegrass* when assessing the forage systems for each season of the second year. Conversely, there was a decline in the legume ratio in the other planting systems, especially for mixed intercropping of the legume with the grasses. Similar results were found by Aroeira et al. (2005), who noted that the dry mass availability of Mineirão stylo forage linearly decreased throughout the experimental period, when assessing *Brachiaria decumbens* intercropped with Mineirão stylo and that of *B. decumbens* varied with the climatic conditions. No statistically significant effect (P>0.05) of the legume ratio was found for the row intercropping systems among the seasons of the year when assessing the seasons of the year within each forage system. However, a decrease in the legume percentage occurred with mixed intercropping, especially in the summer, with a ratio of only 10% legumes. This decrease in the legume percentage in the intercrop system may be explained by

Table 2. Ratio of Campo Grande stylo (%) as a function of intercropping with Xaraes and Marandu palisadegrasses in the different forage systems and seasons of the year for a period of two years.

Forage systems	Proportion of the legume (%)			
	Autumn	Winter	Spring	Summer
	First year (2008/2009)			
Row *Xaraes palisadegrass* x Campo Grande	50 Aa	60 Aa	60 Aa	40 Ab
Mixed *Xaraes palisadegrass* x Campo Grande	50 Aa	35 Bb	35 Bb	40 Ab
Row *Marandu palisadegrass* x Campo Grande	50 Aa	40 Bb	40 Bb	40 Ab
Mixed *Marandu palisadegrass* x Campo Grande	50 Aa	35 Bb	35 Bb	40 Ab
CV (%)	.... 7.48 ………..…………………			
	Second year (2009/2010)			
Row *Xaraes palisadegrass* x Campo Grande	60 Aa	60 Aa	60 Aa	30 Ab
Mixed *Xaraes palisadegrass* x Campo Grande	30 BCa	30 Ba	20 Cb	10 Bc
Row *Marandu palisadegrass* x Campo Grande	40 Ba	35 Ba	35 Ba	35 Aa
Mixed *Marandu palisadegrass* x Campo Grande	35 Ba	30 Ba	20 Cb	10 Bc
CV (%)	……………….………… 12.46 ………………………..			

Means followed by different uppercase letters in columns (forage systems) and lowercase letters in rows (season of the year) differ from each other according to Tukey's test (P <0.05).

competition for water, light and nutrients, as *B. brizantha* plants have a lower photosynthetic efficacy (C4 cycle) in tropical conditions, outperforming the legume, which is a C3 cycle plant (Aroeira et al., 2005). Figure 2 shows that the highest ratios of Campo Grande stylo in the different systems were found in the first year of the evaluation, when comparing the forage system within the years evaluated. There was a significant reduction in legume ratio from the second year, especially when performing the mixed intercropping, reaching only 10% in the second year, compared to 35% in the first year. This shows that the best intercropping method in the experimental conditions for favoring legume persistence is row intercropping because it maintains the most balanced ratio of grasses and legume in the stem.

Table 3 shows that only row-intercropped *X. palisadegrass* differed from the other systems in autumn and winter, with greater production of dry mass, when evaluating the production of dry mass of the forage systems within each season. This finding results from the better rate of resprouting and, consequently, a greater accumulation of this grass forage in periods of low rainfall, enabling the satisfactory production of forage even in the dry period of the year. Flores et al. (2008) report that *X. palisadegrass* has advantages over other cultivars of *Brachiaria,* including a higher rate of resprouting and greater forage production, which ensures a greater yield per area.

In spring, the greatest production occurred in the row and mixed intercropping systems, which differed from the other forage systems (Table 3). This greater production in the intercropped systems is associated with the presence of legume, which significantly contributed to increasing the production given the soil nitrogen supply (Lopes et al., 2011). The ratio of Campo Grande stylo is also important to maintain the balanced supply of forage because it offsets the natural decline in the production of monocropped grasses. A better production of dry matter was also found in intercropped systems by Schunke and Silva (2003), who noted that the largest production was found in *B. decumbens* intercropped with Campo Grande stylo, showing that introducing the legume into pasture systems significantly contributes to an increase the dry matter availability of pastures. Barcellos et al. (2008) explain that nitrogen transfers will occur below and above the soil surface, directly or indirectly to the nearest plant, whether by N excretion from the legume rhizosphere, decomposition of roots and nodules, connection through root mycorrhizae of the grass with those of the legume or even by the action of the soil fauna on the roots and nodules of the legume. In the summer, the greatest production was found in the row intercropping systems, which showed an increase in production of 16.0 and 6.54% when compared to mixed intercropping with Xaraes and *M. palisadegrasses*, respectively. This increase in production in row intercropping results from the greater presence of Campo Grande stylo following the natural resprouting, which occurred in the dry period (winter), and the greater availability of water, light and temperature in the summer, enabling the development of new plants, increasing the production and maintaining the greater persistence of the legume. Furthermore, the legume presence in the system increased the soil nitrogen contribution and favored the greater grass growth, which explains the greater production of dry mass in these systems.

Pinheiro (2011) found lower dry mass production values than those found in the present study, with a production of 4.678, 6.276 and 4.004 kg ha^{-1} in the seasons of spring, summer and autumn, respectively, when studying Campo

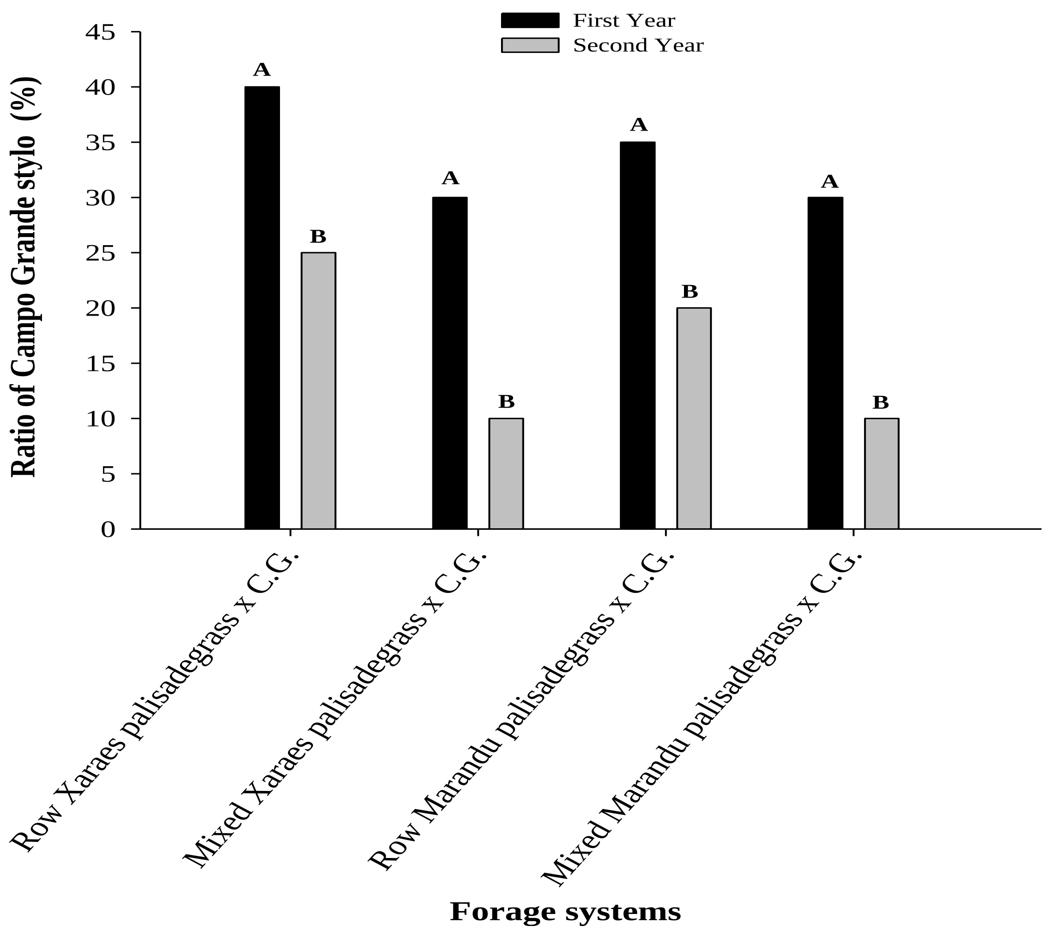

Figure 2. Ratio of Campo Grande stylo depending upon intercropping with *X. palisadegrasses* and *M. palisadegrasses* in the different forage systems evaluated in the first and second years. Means followed by different letters differed from each other according to Tukey's test (P< 0.05).

Table 3. Mean production of dry matter (kg ha^{-1}) for the forage systems evaluated at different seasons of the year.

Forage systems	Seasons			
	Autumn	Winter	Spring	Summer
Campo Grande	8.770 ^{Bb}	5.270 ^{Bc}	10.130 ^{Ba}	10.150 ^{Ca}
Xaraes palisadegrass	9.120 ^{Bb}	4.040 ^{Bc}	11.720 ^{Ba}	11.470 ^{Ca}
Marandu palisadegrass	8.900 ^{Bb}	5.150 ^{Bc}	10.800 ^{Ba}	11.290 ^{Ca}
Row *Xaraes palisadegrass* x Campo Grande	11.140 ^{Ab}	5.800 ^{Ac}	14.850 ^{Aa}	15.440 ^{Aa}
Mixed *Xaraes palisadegrass* x Campo Grande	9.150 ^{Bb}	4.840 ^{Bc}	13.250 ^{Aa}	13.300 ^{Ba}
Row *Marandu palisadegrass* x Campo Grande	8.940 ^{Bb}	4.600 ^{Bc}	13.950 ^{Aa}	14.670 ^{Aa}
Mixed *Marandu palisadegrass* x Campo Grande	8.430 ^{Bb}	4.540 ^{Bc}	12.670^{ABa}	13.770 ^{Ba}
CV (%)	....8.53..			

Means followed by different uppercase letters in columns (forage systems) and lowercase letters in rows (season of the year) differ from each other according to Tukey's test (P <0.05).

Grande stylo intercropped with Tanzania grass. An interesting factor observed in the study is the similar production between monocropped Campo Grande stylo and grasses. The high production of that legume resulted from the natural bank of seeds it produces in the dry season. A better development of that legume occurs with favorable conditions of soil fertility, temperature and rainfall, with a high production of dry matter. Those results

Table 4. Crude protein and total digestible nutrients of the forage systems evaluated in different seasons of the year.

Forage systems	Seasons			
	Autumn	Winter	Spring	Summer
	Contents of CP (g kg^{-1} de MS)			
Campo Grande	192.0 Aa	149.3 Ab	192.5 Aa	177.5 Aa
Xaraes palisadegrass	134.3 Da	96.5 Bc	102.3 Db	108.3 Db
Marandu palisadegrass	140.2Da	93.0 Bc	109.5 Db	103.8 Db
Row Xaraes palisadegrass x Campo Grande	161.6 Ba	121.4 Ac	166.0 Ba	141.0 Bb
Mixed Xaraes palisadegrass x Campo Grande	157.5 BCa	114.3 Ac	140.2 Cb	124.1 BCb
Row Marandu palisadegrass x Campo Grande	161.9 Ba	124.8 Ac	156.4 BCa	130.4 Bb
Mixed Marandu palisadegrass x Campo Grande	157.3 BCa	113.5 Ac	134.0 Cb	124.8 BCb
CV (%)	....8.27			
	Contents of TDN (g kg^{-1} de MS)			
Campo Grande	626.6 Aa	635.5 Aa	632.1 Aa	630.1 Aa
Xaraes palisadegrass	587.5 BCa	544.1 Bb	537.6 Cb	564.1 Ca
Marandu palisadegrass	562.3 Ca	535.1 Bb	542.5 Cb	568.2 Ca
Row Xaraes palisadegrass x Campo Grande	594.33 Bb	599.8 Bb	597.0 Bb	634.8 Aa
Mixed Xaraes palisadegrass x Campo Grande	595.1 Ba	555.1 Bb	565.8 Cb	586.3 Ba
Row Marandu palisadegrass x Campo Grande	616.8 Ba	555.0 Bb	620.1 Aa	617.3 Ba
Mixed Marandu palisadegrass x Campo Grande	615.5 Ba	546.5 Bb	591.1 Ba	594.6 Ba
CV (%)	.... 2.78			

Means followed by different capital letters in the columns (forage systems) and lowercase in the rows (seasons) are significantly different by Tukey's test (P <0.05).

indicate that Campo Grande stylo is recommended for intercropping with grasses and that this legume shows great potential for use as protein bank during the growth season. The comparison of the seasons of the year within each forage system shows that the production in winter was different from all other seasons, in all systems (Table 3). This fact was expected because the temperature and rainfall conditions (Figure 1) were limiting factors for development, hampering the growth and formation of new tillers; the reduction in the number of hours of light per day disfavors the process of photosynthesis. Figure 3 shows that the greatest productions of dry mass of Campo Grande stylo monocropped and row-intercropped with palisadegrasses were found in the second year. This shows that legume persistence increases in the system when forage plants are row-intercropped because the legume is not fully competing with palisadegrasses, given the spacing between forages; thus, the production of dry matter is favored throughout the year because the legume has the ability to fix atmospheric nitrogen to the soil-plant system (Barcellos et al., 2008). However, there was a decline in the production of the mixed-intercropping system, as demonstrated by the lower legume ratio in this system.

Table 4 shows that the monocropped Campo Grande stylo reached the highest CP levels in the autumn, followed by row and mixed intercropping with grasses, when evaluating the CP levels in the forage systems within each season of the year. In the winter, only monocropped grasses differed from the other systems, with lower CP levels. Conversely, all of the forage systems were affected in the spring, with the highest CP levels found in monocropped Campo Grande stylo, followed by row-intercropped Xaraes palisadegrass. That finding results from the greater ratio of stylo in the row intercropping system, following natural reseeding. However, in the summer, the intercropped systems showed similar CP levels for methods ways of planting.

The CP levels varied with the seasons of the year (Table 4). Campo Grande stylo differed in the winter from the other seasons, with lower CP levels. This finding results from the low resistance of that legume in the dry period of the year, when natural reseeding occurs. The highest CP levels of *X. palisadegrasses* and *M. palisadegrasses* monocropped and mixed-intercropped with Campo Grande stylo were found in the autumn, followed by spring and summer, and similar levels were found among the seasons. Conversely, the CP levels of row-intercropped *X. palisadegrasses* and *M. palisadegrasses* were similar in the autumn and spring, differing only from the summer and winter. The mean CP levels (129.7 g kg^{-1}) in the systems of palisadegrasses intercropped with Campo Grande stylo in the summer were higher than those found by Aroeira et al. (2005), who reported a mean level of 105.0 g kg^{-1} when *B. decumbens* was intercropped with *Stylosanthes guianensis* in the summer (December).The highest levels of CP in all of the forage systems were found in the autumn, and the lowest

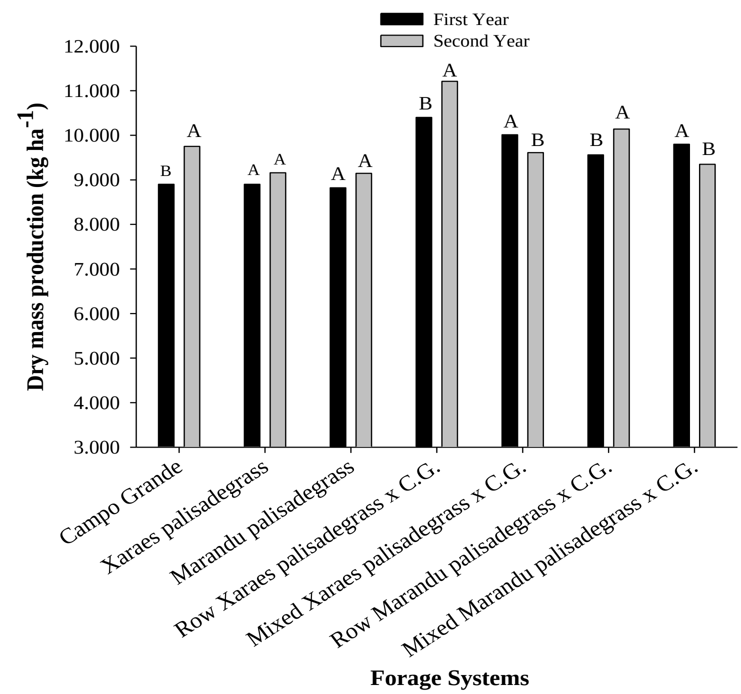

Figure 3. Dry mass production of the forage systems evaluated in the first and second years. Means followed by different letters differ from each other according to Tukey's test (P< 0.05).

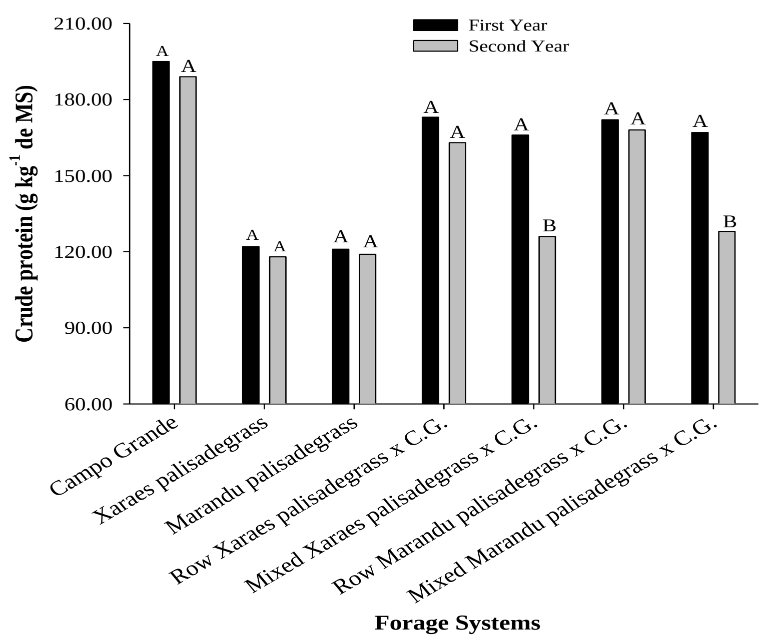

Figure 4. Crude protein levels of forage systems evaluated in the first and second years. Means followed by different letters differ from each other according to Tukey's test (P <0.05).

were found in the winter because the climatic conditions, including temperature and rainfall (Figure 1), were limiting for the development of forage. Another factor influencing this difference could be related to pasture maturation, as the cut was performed at a longer growth cycle (60 days) than in the other seasons (30 days) in response to the

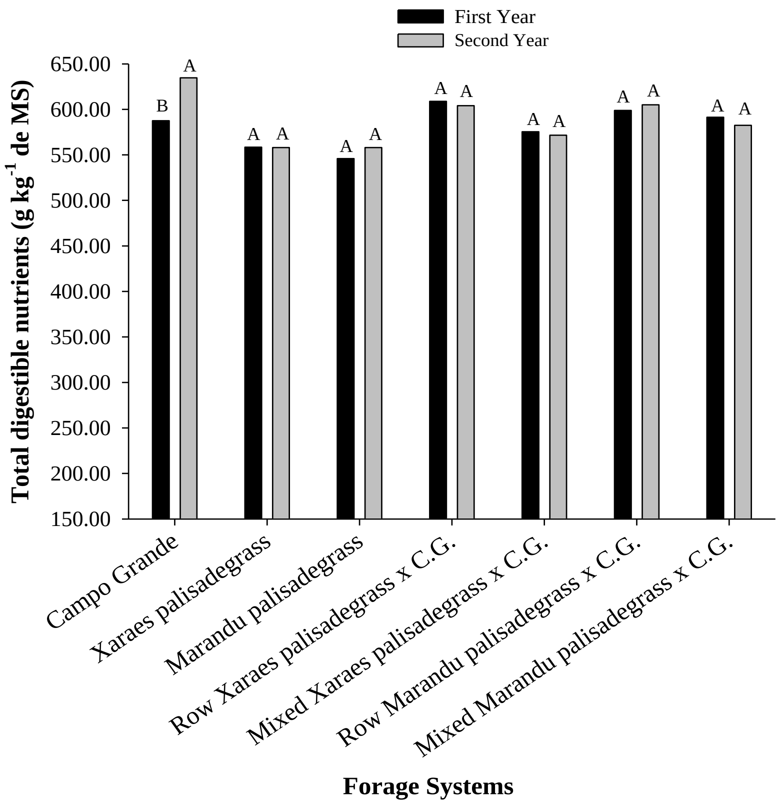

Figure 5. Total digestible nutrients levels of forage systems evaluated in the first and second years. Means followed by different letters differ from each other according to Tukey's test (P <0.05).

seasonality of forage production, thereby decreasing its nutritional value.

Almeida et al. (2002) noted lower CP levels than those found in the present study while studying the effect of the season of the year on the nutritional values of *M. palisadegrass*, with levels of 97.0 g kg^{-1} in the rainy season and 89.0 g kg^{-1} in the dry season. The levels of CP found in Campo Grande stylo monocropped and intercropped with palisadegrasses, regardless of the evaluation period, are well above the level needed to not restrict bovine pasture consumption. This fact results from the advantages that intercropping the palisadegrasses and the legume brings to the improvement in forage nutritional quality (Moreira et al., 2013). The levels of CP were not affected (P>0.05) when comparing the monocropped and row-intercropped systems in the first and second years of the evaluation (Figure 4). However, there was a decrease in the levels of CP in the mixed intercropping systems with *X. palisadegrasses* and *M. palisadegrasses* of 31.7 and 30.4% in the second year, respectively. This result is important for managing the implementation of intercropping with Campo Grande stylo and *B. brizantha* cultivars. This is because mixed intercropping shows lower legume persistence in surviving next to polisadegrasses, with a ratio percentage of only 10% (Table 2) in the second year of system implementation. Conversely, legume persistence and its likelihood of remaining in the system increase when intercropping is conducted in rows because the spacing between plants is 50 cm, favoring legume development as it does not compete with the palisadegrass, which is more aggressive in its uptake of water and nutrients. This occurs because *B. brizantha* is one of the most aggressive palisadegrasses, complicating the stability and persistence in pastures intercropped with hearbaceous or low-size legumes (Barcellos et al., 2008).

Table 4 shows that the highest levels of TDN in the autumn were found in monocropped Campo Grande stylo, followed by intercropped palisadegrasses, when analyzing the levels of TDN in forage systems within each season of the year. In winter, only stylo differed from the other forage systems with higher levels of TDN. In spring, the lowest levels were found in monocropped palisadegrasses, which differed from the other systems. In summer, Campo Grande stylo monocropped and row-intercropped with palisadegrasses showed the highest levels of TDN, followed by the mixed-intercropping systems and monocropped palisadegrasses. It is noteworthy that the levels of TDN were estimated based on the levels of NDF; therefore, the lower levels of TDN are necessarily recorded in the monocropped palisadegrass systems, wherein they

Table 5. Neutral detergent fiber and acid detergent fiber levels of forage systems evaluated in different seasons of the year.

Forage systems	Seasons			
	Autumn	Winter	Spring	Summer
	Contents of NDF (g kg^{-1} de MS)			
Campo Grande	548.3 Aa	560.0 Aa	543.5 Aa	549.1 Aa
Xaraes palisadegrass	683.5 Ca	766.4 Cc	756.3 D^{c}	717.0 ^{C}D^{b}
Marandu palisadegrass	720.4 Cab	760.5 Cc	741.7 D^{ac}	711.5 ^{C}D^{a}
Row *Xaraes palisadegrass* x Campo Grande	671.0 BCb	695.3 Bc	669.5 Bb	613.8 Ba
Mixed *Xaraes palisadegrass* x Campo Grande	673.5 BCa	730.7 Cc	714.3 ^{C}D^{bc}	685.9 Ca
Row *Marandu palisadegrass* x Campo Grande	641.6 Ba	690.5 Bb	635.4 Ba	639.2 Ba
Mixed *Marandu palisadegrass* x Campo Grande	640.3 Ba	743.1 Cb	697.2 Ca	682.0 Ca
CV (%)	.... 3.60			
	Contents of ADF (g kg^{-1} de MS)			
Campo Grande	319.1 Aa	310.0 Aa	299.3 Aa	299.1 Aa
Xaraes palisadegrass	400.8 Cb	421.6 Cc	396.1 Ca	374.1 Ca
Marandu palisadegrass	400.3 Cb	431.6 Cc	403.5 Cb	376.3 Ca
Row *Xaraes palisadegrass* x Campo Grande	353.3 Bb	361.8 Bc	342.5 Bab	313.5 Ba
Mixed *Xaraes palisadegrass* x Campo Grande	375.0 Bb	386.6 Bc	362.5 Bab	344.8 Ba
Row Marandu palisadegrass x Campo Grande	359.1 Ba	366.6 Bb	343.3 Ba	342.8 Ba
Mixed Marandu palisadegrass x Campo Grande	350.8 Ba	388.3 Bb	359.3 BCa	350.0 Ba
CV (%)	.... 5.36			

Means followed by different uppercase letters in columns (forage systems) and lowercase letters in rows (season of the year) differ from each other according to Tukey's test (P <0.05). CV: Coefficient of variance; NDF: neutral detergent fiber; DM: Dry Matter; ADF: acid detergent fiber.

showed the highest values of NDF. The levels of TDN of the forage systems varied with the seasons of the year for the period evaluated (Table 4). The levels in Campo Grande stylo were similar between the seasons studied. The monocropped palisadegrass levels of TDN in the autumn and summer were similar, differing from the winter and spring. Conversely, row-intercropped Xaraes palisadegrass only differed from the other seasons in the summer. The lowest level of TDN of row and mixed-intercropped *M. palisadegrass* was found in the winter. The mixed-intercropped *X. palisadegrass* levels of TDN in the winter and spring were similar, differing from the autumn and summer. Van Soest (1994) explains that numerous factors, including plant species, temperature, light intensity, water availability, latitude, maturity, type of crop and forage intercropping, affect the chemical composition of the plants and, consequently, the availability of energy from food. Therefore, higher levels of TDN are noticeably reached when the legume is intercropped with the palisadegrasses. Comparing the levels of TDN between the years of evaluation (Figure 5), only monocropped Campo Grande stylo differed from the other systems, and the highest level was found in the second year. However, the levels of TDN in the other forage systems were similar between the years evaluated. The levels of NDF (Table 5), of the forage systems within each season of the year were affected (P<0.05). In autumn, Campo Grande stylo showed the lowest levels, followed by row- and mixed-intercropped systems, which showed similar levels. In winter, the levels of NDF of palisadegrasses monocropped and mixed-intercropped with Campo Grande stylo did not differ from each other, showing similar levels. The high levels of NDF found in winter result from the longer growth cycle (60 days), promoting pasture maturation. Therefore, there was a reduction in growth rate and consequently an increase of stems compared to leaves, leading to lower levels of CP and higher levels of fiber. Similar results were found by Moura et al. (2011), who noted that the NDF levels of Campo Grande stylo decreased with the resprouting age (50 days), albeit without great losses in forage quality. Conversely, the NDF levels in the spring and summer were affected by the planting method, showing that the levels in mixed intercropping were similar to the monocropped grasses, with the highest levels of NDF. However, lower levels of NDF were found in the row intercropping system, given the greater legume presence in this system, which shows lower fiber levels than palisadegrasses (Van Soest, 1994).

Table 5 shows that the Campo Grande stylo levels of NDF were similar when comparing the seasons of the year. However, the lowest values of NDF for the monocropped palisadegrasses were found in the autumn and summer, given the better climatic conditions (Figure 1) for the development of forage. Moreover, the intercropped systems only differed from the other seasons in the winter, with higher levels of NDF. This increase results from the increase in cell wall components, which

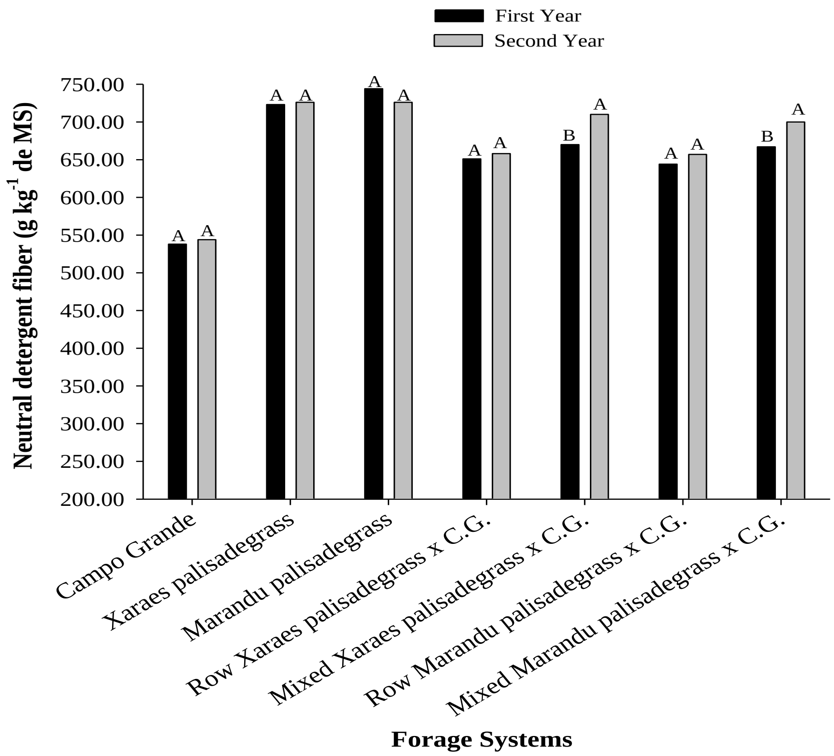

Figure 6. Neutral detergent fiber levels of forage systems evaluated in the first and second years. Means followed by different letters differ from each other according to Tukey's test (P <0.05).

occurs as the plant ages, most likely resulting from the reduced percentage of blades and increased ratio of rods, raising the fibrous components (Costa et al., 2007). Van Soest (1994) reports that the NDF level is the most limiting factor of roughage intake, and the levels of cell wall components are higher than 550 g kg^{-1} and correlate negatively with forage intake. Comparing the levels of NDF between the years evaluated (Figure 6), a statistically significant effect ($P<0.05$) was only found in the mixed intercropping systems, with the highest NDF levels in the second year. This finding results from the lower ratio of Campo Grande stylo plants when performing mixed intercropping, providing higher fiber levels, given the lower percentage of legume in the second year, which show lower levels of NDF than palisadegrasses because they have a C3 cycle. However, the levels of NDF were similar between the years evaluated in the monocropped and row-intercropped systems.

Table 5 shows that Campo Grande stylo had the lowest ADF levels, followed by the row- and mixed-intercropping systems and finally the monocropped palisadegrasses, which had the highest levels of ADF. This pattern was true in all seasons of the year given the higher ratio of lignin found when analyzing the ADF levels for the different forage systems in different seasons. These results show the importance of the legume presence in the intercropping with palisadegrasses because it benefits the quality of pastures, thereby improving the forage digestibility. In that same study, Moreira et al. (2013) found digestibility levels of 767.8 g kg^{-1} for monocropped Campo Grande stylo and 704.4 and 689.3 g kg^{-1} upon row- and mixed-intercropping stylo with *X. palisadegrasses* and *M. palisadegrasses*, respectively. Low fiber levels are desirable because the decrease of fiber in the forage enables an improvement in intake, digestibility and animal performance, according to Van Soest (1994). The ADF levels of Campo Grande stylo were similar for all seasons of the year (Table 5). However, the highest ADF levels for monocropped and row- and mixed-intercropped palisadegrasses were found in the winter. This finding results from the higher ratios of stems, which were accumulated with plant aging and the unfavorable climatic conditions of this season also (Figure 1), which hampered the development of new tillers. The mean levels of ADF in the winter were 375.82 g kg^{-1} for intercropped palisadegrasses and 426.60 g kg^{-1} for monocropped palisadegrasses. According to Noller et al. (1996), forages with ADF levels of approximately 300 g kg^{-1} or less will be consumed at high levels, whereas those with levels above 400 g kg^{-1} will be consumed at low levels. Figure 7 shows that the highest ADF values of Campo Grande stylo monocropped and mixed intercropped with palisadegrasses were found in the second year, when comparing the levels of ADF between the years evaluated. However, the ADF levels of monocropped and row-intercropped palisadegrasses were similar between the years evaluated, showing the advantage of this form of planting because it maintains the levels of fiber unstable throughout the year, given the legume presence.

Conclusion

The *X. palisadegrasses* and *M. palisadegrasses* showed similar results between the intercropping systems, indicating that both may be intercropped with Campo Grande stylo. The intercropping of stylo with the cultivars of *B. brizantha* improves pasture production and quality. However, the most efficient planting method was row intercropping because it maintained greater legume persistence in the forage system throughout the years evaluated and provided greater production and nutritional value. Campo Grande stylo is indicated for intercropping with grasses and has a great potential for use as a protein bank given the high production of dry mass during the growth season.

Conflict of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGMENT

Authors would like to acknowledge the State of Goiás Research Foundation (Fundação de Amparo a Pesquisa do Estado de Goiás, FAPEG) for funding the project.

REFERENCES

Almeida RG, Nascimento Jr D, Euclides VPB, Macedo MGM, Regazzil AJ, Brânciol PA, Fonseca DM, Oliveira, MP (2002). Produção animal em pastos consorciados sob três taxas de lotação, no cerrado. Rev. Bras. Zootec. 31(2):852-857. http://dx.doi.org/10.1590/S1516-35982002000400007

Aroeira LJM, Paciullo DSC, Lopes FCF, Morenz MJF, Saliba ES, Silva JJ, Ducatti C (2005). Disponibilidade, composição bromatológica e consumo de matéria seca em pastagem consorciada de *Brachiaria decumbens* com *Stylosanthes guianensis.* Pesq. Agropec. Bras. 40(4):413-418. http://dx.doi.org/10.1590/S0100-204X2005000400014

Barbero LM, Cecato U, Lugão SMB, Gomes JAN, Limão VA, Abrahão JJS, Roma CFC (2010). Produção animal e valor nutritivo da forragem de pastagem de coastcross consorciada com amendoim forrageiro. Arq. Bras. Med. Vet. Zootec. 62(3):645-653. http://dx.doi.org/10.1590/S0102-09352010000300021

Barcellos AO, Ramos AKB, Vilela L, Martha Jr GB (2008). Sustentabilidade da produção animal baseada em pastagens consorciadas e no emprego de leguminosas exclusivas, na forma de banco de proteína, nos trópicos brasileiros. Rev. Bras. Zootec. 37:51-67. http://dx.doi.org/10.1590/S1516-35982008001300008

Chandler P (1990). Energy prediction of feeds by forage testing explorer. Feedstuffs 62(36):12.

Costa KAP, Faquin V, Oliveira IP (2010). Doses e fontes de nitrogênio na recuperação de pastagens do capim-marandu. Arq. Bras. Med. Vet. Zootec. 62(1):192-199. http://dx.doi.org/10.1590/S0102-09352010000100026

Costa KAP, Oliveira IP, Faquin V, Neves BP, Rodrigues C, Sampaio FMT (2007). Intervalo de corte na produção de massa seca e composição químico-bromatológica da *Brachiaria brizantha* cv. MG-5. Cienc. Agrotec. 31(4):1197-1202. http://dx.doi.org/10.1590/S1413-70542007000400037

Embrapa (2000). Estilosantes Campo Grande: estabelecimento, manejo e produção animal. Campo Grande, MS: Embrapa Gado de Corte, 2000.. (Embrapa Gado de Corte. Comunicado Técnico 61). 8 p.

Ferreira DF (2011). Sisvar: A computer statistical analysis system. Cienc. Agrotec. 35(6):1039-1042. http://dx.doi.org/10.1590/S1413-70542011000600001

Flores RS, Euclides VPB, Abrão MPC, Galbeiro S, Difante GS, Barbosa RA (2008). Desempenho animal, produção de forragem e características estruturais dos capins marandu e xaraés submetidos a intensidades de pastejo. Rev. Bras. Zootec. 37(8):1355-1365. http://dx.doi.org/10.1590/S1516-35982008000800004

Lopes J, Evangelista AR, Pinto JC, Queiroz DS, Muniz JA (2011). Doses de fósforo no estabelecimento de capim-xaraés e estilosantes Mineirão em consórcio. Rev. Bras. Zootec. 40(12):2658-2665. http://dx.doi.org/10.1590/S1516-35982011001200007

Moreira JFM, Costa KAP, Severiano EC, Epifanio PS, Crunivel WS, Guimarães KC (2013). Protein fraction and digestibility of marandu, xaraes and campo grande grasses in monocropping and intercropping systems under different sowing methods. Acta Sci. Anim. Sci. 35(1):63-71. http://dx.doi.org/10.4025/actascianimsci.v35i1.15134

Moreira LM, Fonseca DM, Vítor CMT, Assis AJ, Nascimento Jr D, Ribeiro Jr JI, Obeid JA (2005). Renovação de pastagem degradada de capim-gordura com a introdução de forrageiras tropicais adubadas com nitrogênio ou em consórcios. Rev. Bras. Zootec. 34(2):442-453. http://dx.doi.org/10.1590/S1516-35982005000200011

Moura RL, Nascimento MPSCB, Rodrigues MM, Oliveira ME, Lopes JB (2011). Razão folha/haste e composição bromatológica da rebrota de estilosantes Campo Grande em cinco idades de corte. Acta Sci. Anim. Sci. 33(3):249-254. http://dx.doi.org/10.4025/actascianimsci.v33i3.10981

Noller CH, Nascimento Jr D, Queiroz DS (1996). Exigências nutricionais de animais em pastejo. In: SIMPÓSIO SOBRE O MANEJO DAS PASTAGENS. Produção de bovinos a pasto. 130, 1996, Piracicaba. Anais... Piracicaba: FEALQ. pp. 319-352.

Pinheiro AA (2011). Produtividade animal e características morfológicas do capim-tanzânia adubado com nitrogênio ou consorciado com estilosantes. 68p. Dissertação (Mestrado) – Universidade Estadual de Maringá, Maringá-PR.

Rosa SRA, Castro TAP, Oliveira IP (2004). Análise de crescimento em Braquiária nos sistemas de plantio solteiro e consórcio com leguminosas. Cienc. Animal Bras. 5(1):9-17.

Schunke RM, Silva JM (2003). Estilosantes Campo Grande stylo consorciado com *Braquiária* contribui para a sustentabilidade da pastagem. Comunicado Técnico 83, Campo Grande, MS. pp. 1-5.

Silva DJ, Queiroz AC (2002). Análise de Alimentos (métodos químicos e biológicos). Imprensa Universitária da UFV. Viçosa 3:235.

Silva FC (1999). Manual de análises químicas de solos, plantas e fertilizantes. Brasília, Embrapa, Informação Tecnológica P. 370.

Van Soest PJ (1994). Nutritional ecology of the ruminant. 2 ed. Ithaca: Cornell P. 476.

academicJournals

Vol. 10(5), pp. 328-333, 29 January, 2015
DOI: 10.5897/AJAR2013.6946
Article Number: FCD102949891
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Study on prevalence of poultry coccidiosis in Nekemte town, East Wollega, Ethiopia

Asamenew Tesfaye*, Addisalem Hunde and Hussein Balcha

School of Veterinary Medicine, Wollega University, P. O. Box, 395, Nekemte, Ethiopia.

Received 22 February, 2013; Accepted 18 November, 2014

A cross sectional study was conducted between November, 2013 and June, 2014 to determine the prevalence of chicken coccidiosis, identify *Eimeria* species and assess different risk factors in free ranging and intensively managed chickens. Test tube flotation technique was used for qualitative study of coccidian oocysts. Of 384 chickens examined, an overall prevalence of 19.5% (75) was found. The prevalence of coccidiosis was accounted 17.7% (95%CI = 13.2 - 23.0), 44.8% (95%CI = 33.2 - 56.8) and 4.7% (95%CI = 1.3 - 11.6) in Chelaleki, Burka-jato and Bake-jama, respectively. The prevalence was significantly different between breed (χ^2 = 5.1, p = 0.021), management (χ^2 = 15.9, p = 0.000) and age (χ^2 = 7.1, p = 0.008). However, no statistically significant difference (χ^2 = 0.03, p = 0.865) was found in the prevalence of coccidiosis between sex. Among different species of *Eimeria* isolated *Eimeria tenella* and *Eimeria acervulina* were identified to be the major cause of the disease and each accounted 29(38.7%) of the total isolate of infected birds followed by 13.33% *Eimeria necatrix* and 9.33% *Eimeria maxima*. In conclusion, the present study showed that coccidiosis was an important disease of poultry in the study area and therefore, poultries infected with this parasite should be treated, chicken house should be periodically cleaned and disinfected as well as effective biosecurity measures should be in place.

Key words: Coccidiosis, *Eimeria*, flotation, prevalence, oocyst.

INTRODUCTION

Poultry are kept in backyards or commercial production systems in most areas of the world and a recent survey made by Food and Agricultural Organization of the United Nations (FAO) put the whole poultry population in the world at approximately 22 billion, with about 75% in the developing countries (FAOSTAT, 2013). Over the years, there has been an increasing demand for poultry products both for nutritional supply and for poverty alleviation in the village communities. Compared to a number of other livestock species, fewer social and religious taboos are related to the production, marketing, and consumption of poultry products. For these reasons, poultry products have become one of the most important protein sources for people throughout the world. FAO has estimated the world poultry population accounted to be 14,718 million, of which 1,125 million distributed throughout the African, 1,520 million in South America, 6,752 million in Asia, 93 million in Oceania, 3,384 million in North America and 1,844 million in Europe (Anders and Jorgen, 1998).

The total poultry population in Ethiopia was estimated to about 44.89 million. Poultry includes cocks, cockerels, pullets, laying hens, non-laying hens and chickens. Consequently, most of the poultry are chicken (40.11%),

*Corresponding author. E-mail: asefiker@yahoo.com, Tel: 251913154099. Fax: +251576617980.

followed by laying hens (33%). Pullets, cocks and cockerels were estimated to about 4.12, 4.3 and 2.2 million, respectively. Others that were non-laying hens make up about 3.1% (1.39 million) of the total poultry population in the country. With regards to breed, 96.46, 0.57 and 2.97% of the total poultry were reported to be indigenous, hybrid and exotic, respectively (CSA, 2012).

Coccidiosis is an important parasitic disease in poultry industry all over the world (Nematollahi et al., 2009). In domestic chickens, at least nine species of *Eimeria* have been recognized to cause the disease (Gari et al., 2008; Bowman, 2009). The infection occurs through ingestion of feed or water contaminated with sporulated oocysts (Allen and Fetterer, 2002). It is a widely distributed disease among growing chickens around the world and can seriously restrict the development of poultry production. Due to higher stocking densities and intensive husbandry practices, the incidence of coccidiosis has been increasing in poultry population (Conway and Mckenzie, 2007).

Coccidiosis is endemic in most of the tropical and sub-tropical regions where ecological and management conditions favor an all year round development and propagation of the causal agent (Obasi et al., 2006). It remains one of the major disease problems of poultry in spite of advances made in prevention and control through chemotherapy, management and nutrition (Gari et al., 2008). Quantitative losses due to coccidiosis in Ethiopia were not well documented, but the study conducted by Kinung'hi et al. (2004) showed that coccidiosis contributes to 8.4 and 11.86% losses in profit in large and small-scale farms, respectively. Losses due to mortality following a severe outbreak may be devastating and incidence rates as high as 80% were observed in the country (Gari et al., 2008).

The aim of the study was to determine the prevalence of *Eimeria* species and associated risk factors in different poultry production systems in Nekemte town.

MATERIALS AND METHODS

Study area

The study was conducted in Nekemte town, East Wollega zone, Oromia regional state, Ethiopia, which lies at latitude of 90°5' N and longitude of 36° 33' E at an elevation of 2,088 m above sea level. Nekemte is located at a distance of 331 km west of the capital city Addis Ababa. The climatic condition alternates with long summer rainfall (June to September), short rain season (March to April) and winter dry seasons (December to February). The minimum and maximum annual rainfall and daily temperature ranges from 1450 to 2150 mm and 15 to 27°C, respectively. The total land coverage of the region is about 769,725 ha of which 336,220 ha is used for crop production, 184,412 ha for animal grazing, 256,901 ha covered with forest and 20,492 ha for other activities (EWARDO, 2007).

Study population

The study populations were Bovans brown and local chicken breed, kept under traditional (free ranging) and intensive farming system. Since the prevalence of chicken coccidiosis in Nekemte town has not been reported, sample size was determined based on the assumption that 50% expected prevalence rate, 95% confidence interval and 5% desired absolute precision (Thrusfield, 2005). Therefore, 384 local and Bovans brown was considered in the study.

Study design

A cross sectional study was conducted between November 2013 and June 2014 in three sub-cities of Nekemte, namely Chelaleki, Burqa-Jato and Bake-Jama to determine the prevalence of coccidiosis in local and Bovans brown breeds. Questionnaire survey was used to collect information from farmers and farm owners on the management systems used in poultry production; at the same time feacal samples were collected aseptically to conduct fecal examination in order to identify the species of *Eimeira*.

Sample collection

Freshly deposited 10 g feacal samples collected from chickens of different ages, breed, and sex kept under intensive and free-range system; samples were examined thoroughly. Samples were collected with a spatula, which was washed and cleaned after each collection in order to avoid contamination. Each feacal sample was placed in a pre-labeled bottle indicating the age, breed and sex of the chicken. The presence of feacal oocysts was determined using the concentration by flotation method. The principle allowed the eggs to float to the surface of the solution of higher specific gravity (S.G), which concentrates at the top and leaves debris lower down. The higher the S.G of the solution, the more the eggs of various types will float, and S.G of eggs various types will float. One gram of faecal sample was weighed using a top loader balance. Put into a beaker and mixed with saturated salt solution of NaCl(40%w/v), it was thoroughly mixed and strained using 90 mesh sieves into another beaker. The filtrate was poured into test-tube of respective faecal sample number and these were placed in test-tube stands. Each test tube was then filled to the brim with salt solution of NaCl. Cover-slip was placed on test tube surface and was left to stand for 15 min after which they are gently lifted (without brushing against the tubes). They were then placed on microscope slides sideways in one quick movement to avoid bubbles on the glass-slide and viewed under the microscope. Examinations of slides were carried out using x40 objective lens (Conway and McKenzie, 2007).

Data management and analysis

The raw data was entered and managed using Microsoft Excel worksheet and summarized with descriptive statistics. SPSS statistical software version 20 was used to determine the prevalence of the disease and the association between prevalence and risk factor was assessed by using Pearson's Chi-square and odd ratio. A statistically significant association between variables was considered to exist if the computed p-value is less than 0.05.

RESULTS

The overall prevalence of chicken coccidiosis in the study area was 19.5%. The prevalence of coccidiosis in Chelaleki, Burka-Iato and Bake Jama district was accounted for 17.7, 44.8 and 4.7%, respectively (Table 1)

Table 1. Prevalence of chicken coccidiosis in the selected study area.

Sub-cities	No. examined	No. negative	No. positive	Prevalence (%)	95%CI
Chelaleki	232	191	41	17.7	13.2 - 23.0
Burka Jato	67	37	30	44.8	33.2 - 56.8
Bake Jama	85	81	4	4.7	1.3 - 11.6
Total	384	309	75	19.5	15.8 - 23.7

Table 2. Association between prevalence and risk factors.

Risk factors	No. examined	No. negative	No. positive	Prevalence (%)	χ^2 value	OR (95%CI)	p-value
Breed							
Local	147	127	205	13.6	5.3	0.52 (0.3 - 0.9)	0.021
Bovans	37	32		23.2			
Age							
2 - 8 weeks	263	202	61	23.2	7.1	2.3 (1.2 - 4.3)	0.008
>8 weeks	121	104	14	11.6			
Management							
Backyard	192	139	53	27.6	15.9	2.9 (1.7 - 5.1)	0.000
Intensive	192	170	22	11.5			
Sex							
Male	135	108	27	20.0	0.03	1.05 (0.6 - 1.8)	0.865
Female	249	291	48	19.3			

The overall prevalence of coccidiosis in Bovans brown and local breeds were 23.21 and 13.61%, respectively. There was statistically significant difference (χ^2 = 5.322; p = 0.021) in coccidial infection between Bovans brown and local breeds (Table 2).

Among examined chickens, higher infection (23.2%) rate was observed in chicken under the age category of 2 to 8 weeks (young) than in chickens greater than 8 weeks (11.6%). There was statistical significance difference (χ^2 = 7.12; p = 0.008) between the two age group. Higher infection rate was detected in back yard birds 27.6% as compared to birds under intensive management system 11.45%. There was statistical significance difference (χ^2 = 15.9, p = 0.000) between the two management system. The prevalence rate of 20 and 19.27% were also recorded in males and females, respectively. Male birds showed higher infection rate than females; however, there was no statistically significant difference (χ^2 = 0.03, p = 0.865) in between the two sexes (Table 2).

Based on morphological identification of oocytes, five species in poultry were of major interest. These included *Eimeira acervulina, E Eimeira tenella, E Eimeira maxima, E Eimeira necatrix, E Eimeira burneti* and *E Eimeira mitis*. However, detection was made for the first four species of oocysts. From 75 infected birds, *E. tenella* and *E. acervulina* accounted 29(38.7%) and 29(38.7%), respectively. Therefore, *E. tenella* and *E. acervulina* are considered as the predominant species responsible for infection of chickens residing in the study area. The remaining 10(13.33%) and 7(9.33%) were found to be infected by *E. necatrix* and *E. maxima,* respectively. Among 75 infected birds, 69(92%) were infected by single infection and 6(8%) of them were found with mixed infection (Table 3).

DISCUSSION

Coccidiosis is classified as an intestinal disease affecting the small intestine and caecal portion of the large intestine. The overall prevalence of chicken coccidiosis in the study area was 19.5%. The result agreed with the finding of Diriba et al. (2012) and Gari et al. (2008) who reported prevalence 20.57% in poultry farms in and around Ambo town, Western Ethiopia and 22.58% in litter system of exotic breed (Rhode Island Red) in Tiyo districts, Arsi zone, Ethiopia, respectively. The finding of this research was also close to the finding of Ashenafi et al. (2004). However, the present result was inconsistent with the findings of Netsanet (2003), who reported a

Table 3. Prevalence of morphologically identified Emeria species.

Species	No. examined	No. negative	No. positive	Prevalence	95%CI
Eimeria acervulina	75	46	29	38.7	28.2 - 50.02
Eimeria tenella	75	46	29	38.7	28.2 - 50.02
Eimeria maxima	75	65	10	13.3	7.0 - 23.2
Eimeria necatrix	75	68	7	9.3	4.2 - 17.6
Eimeria burneti	75	65	10	13.3	7.0 - 23.2
Eimeria mitis	75	68	7	9.3	4.2 - 17.6

prevalence of 38.5 and 41.43% in Kombolcha, Ethiopia. This variation in prevalence of the disease may be due to epidemiology of coccidian infection and differences in management systems of the farms.

The prevalence rate of disease was higher in Bovans brown (23.21%) than local breeds (13.61%). The finding was statistically significant difference (p = 0.021) between Bovans and local breeds. This agreed with the findings of Gari et al. (2008) and Diriba et al. (2012) who reported higher prevalence in exotic breeds. The findings also agreed with the findings of Jatau et al. (2012) who reported higher prevalence of the coccidian infection in exotic chickens as compared to that seen in the free ranging local chickens in Zaria (Nigeria). In the present study, higher rate of infection might be due to breed difference. It was also documented that some indigenous breed of chicken could produce immunity earlier than other breeds (Rehman, 1971). In addition, Calnek et al. (1991) have reported the existence of genetic variation in resistance to coccidiosis among breeds and strains.

The current study also revealed that all ages of poultry are susceptible to coccidiosis but younger birds (23.2%) are more susceptible to infection than older birds (11.6%). This also agreed with the report of Julie (1999) who stated that all ages of poultry are susceptible to infection. These upshots are in accordance with the conclusions of Omer et al. (2011) and Bachaya et al. (2012), who has also observed the same pattern of infection in the Farasan gazelles infected with the single species of *Eimeria* and susceptibility of younger chickens than older chickens in layers in Muzafargarh district, respectively. The result is in concurrence with the report of Muazu et al. (2008) which stated that the predominance of coccidial infection among adult chickens were 36.7% and among the younger chickens were 52.9%. The prevalence rate of the disease was significantly different (p = 0.008) between young and adult birds. This was because most coccidian infections occur at the age of 3 to 4 weeks but clinical diseases develop one or more weeks later. The disease appears to reach climax at 5 to 7 weeks of age and as age exceeded 7 weeks, most birds will develop immunity and increase resistance to the disease (Taylor et al., 2007; Bowman, 2009).

Upon the finding, the prevalence rate of coccidiosis in free ranging chickens (back yard) 27.6% was greater than those chickens managed under intensive management 11.45%. This finding is in line with Sharma et al. (2013) who stated high infection rate of backyard (un-organized) chickens with *Eimeria* species in Jammu region. However, the current finding was inconsistent with reports that coccidiosis was the most common problems to chickens kept under intensive management especially those on deep litter due to relative higher oocyst accumulation in deep litter (Methusela et al., 2002; Taylor et al., 2007). In fact, Adhikari et al. (2008) reported that coccidiosis was a disease of poor management. In the present study, statistically significant difference (p = 0.000) was found between backyard and intensive farms, and percentage prevalence of infection in backyard chickens may be high due to poor management practices, malnutrition, indiscriminate scavenging behavior of free ranging chickens and non-use of coccidiostats as preventive measures.

The present study also indicated that the prevalence of coccidiosis was relatively higher in male (20%) than female (19.27%) chickens; however, there was not statistically significant difference among sex (p = 0.865). This result is in consistent with the previous studies of Nematollahi et al. (2009) and Alemayehu et al. (2012). Absence of statistically significant difference between male and female might be due to equal chance of exposure for the parasite infection.

The biological characteristics of coccidia of chickens are well known and are variable which is used in the identification of different species of *Emeria* (McDougald, 2003). Some species are easily identified based on occyst size *(E. maxima*), whereas others produce unmistakable lesions (*E. tenella* and *E. necatrix*). In the current study, high prevalence of four important species of *Emeria* such as *E. tenella, E. acervulina, E. necatrix* and *E. maxima* were identified. This finding was in agreement with reports from Iran (Hadipour et al., 2013), Ethiopia (Ashenafi et al., 2004), Jordan (Al-Natour et al., 2002), France (Williams et al., 1996), and Argentina (McDougald et al., 1997) suggesting that those species of *Eimeria* were widespread in most countries. On the other hand, Hadipour et al. (2011) reported that at least four species of *Eimeria* (*E. tenella, E. acervulina, E. necatrix* and *E. maxima*) were found in the litter of flock, while the

E. tenella was the most rampant species (24%) followed by *E. acervulina* (18%), *E. necatrix* (12%) and *E. maxima* (10%). The high prevalence of the infection of studied chickens in the current study indicates the maintenance of oocysts in the farm and in the environment of free ranging birds.

The present study also indicated the presence of mixed *Eimeria* infection (8%). This was attributed to mixed infections that were observed in the fecal matter of both local and exotic chicken. Adhikari et al. (2008), who identified mixed *Eimeria* infection in chickens, reported similar finding. Furthermore, Getachew et al. (2008) reported 55.6% of oocysts being due to mixed infections.

Coccidiosis is the most important constraint for poultry production in both free ranging and intensive poultry management systems. Heavy infection of coccidia cause serious disease and cause higher mortality and morbidity rate in poultry production. The finding of the current study indicated that the existence of *E. tenella, E. acervulina, E. necatrics* and *E. maxima* were responsible for chicken coccidiosis in the study area. The occurrence of coccidiosis was associated with breed, age and the type of poultry management. Coccidiosisis is still the most important parasitic disease of poultry in the study area. This higher prevalence might be due to poor poultry production management systems. Therefore, good poultry management systems such as treating diseased poultry, maintaining cleanness of the environment and applying strict biosecurity measures play a significant role to minimize the infection among different poultry production systems.

Conflict of Interest

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

ACKNOWLEDGEMENT

We are grateful to Wollega University and National Animal Health Diagnostic and Investigation Center for supporting us to accomplish this research on time.

REFERENCES

Adhikari B, Gupt R, Pant GR (2008). Prevalence and identification of coccidian parasite (Eimeria species) in layer chicken of Ratnanagar municipality, Chitwan District, Nepal. J. Nat. Historie Mus. 23:45-50.

Alemayehu T, Tekeselassie A, Kassa SA (2012). Prevalence study of poultry coccidosis in small andlarge scale farms in Adis Ababa, Ethiopia. Sci. J. Crop Sci. 1:26-31.

Al-Natour MQ, Suleiman MM, Abo-Shehadab MN (2002). Flock-level prevalence of Eimeria species among broiler chicks in northern Jordan. Prev. Vet. Med. 53:305-310.

Allen PC, Fetterer RH (2002). Recent advances in biology and immunology of *Eimeria* species and in diagnosis and control of infection with coccidian parasites of poultry. Cl. Microbiol. 15:58-65.

Anders P, Jorgen W (1998). Epidemiology diagnosis and control of poultry parasites. 1st Ed., FAO animal health manual, 4:1020-5187 Rome, Italy.

Ashenafi H, Tadesse S, Medhin G, Tibbo M (2004). Study on coccidiosis of scavenging indigenous chickens in central Ethiopia. Trop. Anim. Health Prod. 36:693-701.

Bachaya HA, Raza MA, Khan MN, Iqbal Z, Abbas RZ, Murtaza S, Badar N (2012). Predominance and Detection of Different Eimeria Species Causing Coccidiosis in Layer Chickens. J. An. Plant Sci. 22(3):1018-7081.

Bowman D (2009). George's parasitology for veterinarians. 9thed. India: Saunders Elsevier. 2-94.

Calnek BN, Barnes HJ, Beard CW, Reid WM, Yoder HW (1991). Disease of poultry 9thedn, (Iowa University Press, Ames, IA) pp. 723-778.

Conway DP, McKenzie ME (2007). Poultry Coccidiosis: Diagnostic and Testing Conway, D.P. and M.E. McKenzie, 1991. Poultry Coccidiosis. Diagnostic and Testing Procedures, 2nd Edn. Pfezer Inc., The Netherland, pp: 7-14, 37-40.Procedures. 3rd ed. Blackwell Publishing. Ames, IA, USA. pp. 134-165.

Diriba O, Achenef M, Basaznew B (2012). Prevalence and Risk Factors of Coccidiosis in Poultry Farms in and Around Ambo Town, Western Ethiopia. Am. Eur. J. Sci. Res. 7(4):146-149.

East Wollega Agricultural and Rural Development office, 2007: EWARDO Annual report.

Edgar SA (1992). Field diagnosis of coccidiosis in chickens. Agri-Bio Corporation.

Ethiopia Central Statistical Agency (CSA) (2012). Report on Livestock and Livestock Characteristics (private peasant holdings). Agric. Sample Survey 2:23-24.

FAOSTA (2013). Food and Agricultural Organization of the United Nations. FAO Statistical Databases. FAO, Rome, Italy.

Gari G, Tilahun G, Dorchies P (2008). Study on poultry coccidiosis in Tiyo district, Arsi

Hadipour MM, Olyaie A, Naderi M, Azad F, Nekouie O (2011). Prevalence of Eimeria species in scavenging native chickens of Shiraz, Iran. Afr. J. Micro. Res. 5:3296-3299.

Hadipour MM, Olyaie A, Naderi M, Azad F, Nekouie O (2013). Prevalence of Eimeria species in scavenging native chickens of Shiraz, Iran. Afr. J. Poult. Farm. 1(2):034-036.

Jatau ID, Sulaiman NH, Musa IW, Lawal AI, Okubanjo OO, Isah I, Magaji Y (2012). Prevalence of Coccidia Infection and Preponderance Eimeria Species in Free Range Indigenous and Intensively Managed Exotic Chickens during Hot-wet Season, in Zaria, Nigeria. Asian J. Poult. Sci. 6:79-88.

Julie DH (1999). Coccidiosis in poultry Livestock. Poultry Health Programs, Clemson, Columbia, February. 17:191-199.

Kinung'hi SM, Getachew T, Hafez MH, Moges W, Moses K, Mathias G, Maximillian PO (2004). Assessment of economic impact caused by poultry coccidiosis in small and large poultry farms in DebreZeit, Ethiopia. Int. J. Poult. Sci. 3:715-718.

McDougald LF, Mattiello RA (1997). Survey of coccidia on 43 poultry farms in Argentina. J. Avian Dis. 41:923-929.

McDougald LR (2003). Coccidiosis. In: Y.M. Saif, H.J. Barnes, J.R. Glisson, A.M. Fadly, L.R. McDougald and D.E. Swayne (Eds.), Diseases of Poultry. 11th ed. Ames, Iowa, USA: Iowa state press pp. 974-991.

Methusela SK, Tilahun G, Hafez HM, Woldemeskel M (2002). Studies on poultry coccidiosis in different production systems in Debrezeit and surrounding areas. Ethiopia. Bull. Anim. Health. Prod. Afr. 50: 41-52.

Muazu A, Masdooq AA, Ngbede J, Salihu AE, Haruna G, Habu AK, Sati MN, Jamilu H (2008). Prevalence and Identification of Species of Eimeria Causing Coccidiosis in Poultry With in Vom, Plateau State, Nigeria. Int. J. Poult. Sci. 7: 917-918.

Nematollahi A, Moghaddam G and Pourabad RF (2009). Prevalence of Eimeria species among broiler chicks in Tabriz (Northwest of Iran). Mun. Ent. Zool. 4(1):53-58.

Netsanet W (2003). Poultry coccidiosis: its prevalence and distribution of Eimeria species in Kombolcha, South Wollo, Ethiopia. DVM thesis Faculty of Veterinary Medicine, Addis Ababa University, Debreziet, Ethiopia.

Obasi OL, Ifut OJ, Offiong EA (2006). An outbreak of caecalcoccidiosis in a broiler flock post Newcastle disease vaccination. J. An. Veter.

Adv. 5(12):1239-1241.
Omer S, Apio AA, Wronski T, Mohammad OB (2011). A new coccidian parasite (Eimeriafarasanii n. sp.). Indicates parasite-host specificity in endemic Farasan gazelle. Int. J. Zool. Res. 7:85-92.
Rehman B (1971). Comparative Studies on the Immune Response in Desi and Foreign Breeds of Chicken against Emeriatenella. Park. J. Sci. 23:201-04.
Sharma S, Iqbal A, Azmi S, Shah HA (2013). Study of poultry coccidiosis in organized and backyard farms of Jammu region, Vet World 6(8):467-469.
Taylor MA, Coop RL, Wall RL (2007). Veterinary parasitology. 3rd Ed. UK. Black well Science, pp. 475-484.
Thrusfield M (2005). Veterinary Epidemiology, 3rd ed., Blackwell publishing, incorporated, AmesIOWA, USA, pp. 122-123.
Williams RB, Bushll AC, Reperant JM, Doy TG, Morgan JH, Shirley MW, Yvore P, Carr MM, Fremont Y (1996). A survey of Eimeria species in commercially reared chickens in France during 1994. Avian Pathol. 25:113-130.

academicJournals

Vol. 10(5), pp. 334-344, 29 January, 2015
DOI: 10.5897/AJAR2013.8364
Article Number: 5FC08DB49849
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Evaluation of agro-morphological diversity of groundnut (*Arachis hypogaea* L.) in Niger

Nana Mariama IDI GARBA[1], Yacoubou BAKASSO[1], Mainassara ZAMAN-ALLAH[2], Sanoussi ATTA[3*], Maârouhi Inoussa MAMANE[1], Moutari ADAMOU[4], Falalou HAMIDOU[5], Saïdou Sani IDI[1], Ali MAHAMANE[1] and Mahamane SAADOU[1]

[1]Laboratoire Garba Mounkaila, Département de Biologie, Faculté des Sciences et Techniques, Université Abdou Moumouni, BP 10662 Niamey, Niger.
[2]Université de Maradi, BP 465 Maradi, Niger.
[3]Centre Régional AGRHYMET, BP 11011 Niamey, Niger.
[4]Institut National de la Recherche Agronomique du Niger, BP 429 Niamey, Niger.
[5]International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), BP 12404 Niamey, Niger.

Received 10 December, 2013; Accepted 9 January, 2015

This work evaluated a collection of hundred groundnut (*Arachis hypogaea* L.) varieties from different origin using twenty four (24) agro-morphological traits that can help to enhance selection efficiency in crop improvement. The experiment was carried out at the experimental station of INRAN-Tarna, in the region of Maradi (Niger) during the rainy season of 2010. Analysis of variance showed a large variability among varieties for the agro-morphological traits. Principal Component Analysis (PCA), Agglomerative Hierarchical Clustering (AHC) and Fisher Discriminant Analysis (FDA) revealed that this variability is structured into four distinct groups. Groups I and II consisted of early varieties that have a high emergence rate and high pods and seed weight. These groups included mainly local varieties and those introduced in Niger through seed dissemination. Groups III and IV are composed of late varieties with large pods while group III had mostly varieties with long leaflets. Understanding the genetic control of the most discriminating among the studied traits would bring significant contribution to the genetic improvement of this important crop.

Key words: *Arachis hypogaea* L, groundnut, agro-morphological traits, genetic variability, Niger.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important grain legume that grows in wet conditions in semi-arid regions of the world (Rao, 1980). As major crop in most of the tropical and subtropical regions, groundnut ranks 12th in the world crop production. It is grown in all continents with a total area of 24.6 million hectares, and a production of 41.3 million tons in 2012 (FAO, 2013). Africa, with 11.7 million hectares of land used for groundnut production and 10.9 million tons of annual production in 2012 is second only to the American

*Corresponding author. E-mail: S.Atta@agrhymet.ne.

continent (FAO, 2013). Despite this second position in terms of groundnut production, Africa has the lowest average yield per hectare (1 ton ha^{-1}) compared to Asia (1.8 tons ha^{-1}) and America (3 tons ha^{-1}). These low yields are related not only to the rainfed production systems combined with very low input but also to the use of traditional varieties that despite their genetic diversity are low yielding.

Several studies have shown that there is a large agro-morphological diversity in groundnut. This large diversity has led to the distinction of two sub-species: *A. hypogaea* subsp. *hypogaea* and *A. hypogaea* subsp. *fastigiata*. These subspecies are distinguished primarily by their port, usually crawling in *hypogaea* and erected in *fastigiata*, the absence of flowers on the main axis in *hypogaea* and the difference in leaf color: Dark green in *hypogaea* and light green in *fastigiata* (Fonceka, 2010). Both subspecies were themselves divided into several botanical groups including several commercial types.

Groundnut plays a key role in African farming systems, including savanna zone, in rotation or in combination with staple crops. In Niger, groundnut is widely cultivated in the southern belt of the country where its production provides both food for humans and feed for livestock. In addition, it is used as fuel and also contributes to protect the environment through nitrogen fixation. It also provides an additional source of income as a cash crop (NARP, 1993). Globally in 2007, groundnut production volume representing 10% of the production of oilseeds, accounted for a turnover of about $ 17 billion (Foncéka, 2010).

Evaluation of genetic resources is a key step towards efficiency in utilization of these resources through introduction of new genes as well as for their maintenance. In addition, the evaluation and characterization of the collection on the basis of morphological and agronomic traits are the starting point of any breeding program (Fundora, 1998; Simpson et al., 1986). There are several reports on breeding for varieties adapted to abiotic and biotic stresses to alleviate the major constraints in groundnut production (Ntare and Waliyar, 2000). However, in Niger, research activities on this topic are still not well articulated (Maria, 2009) although a number of groundnut varieties were released (Ndjeunga et al., 2003). The present study aimed to (i) study the variability of a collection of groundnut varieties collected in Niger through the evaluation of morphological and agronomic traits and (ii) analyze how the diversity of these traits is structured.

MATERIALS AND METHODS

Plant materiel

This study was conducted using a collection of 100 varieties of groundnut (*A. hypogaea* L.) from various origins and cultivated in Niger (Table 1). This collection, kindly provided by Dr Adamou Moutari from Institut National de la Recherche Agronomique du Niger (INRAN) was evaluated during the rainy season of 2010.

Experimental site

The trial was carried out at the experimental station of INRAN Tarna, in the region of Maradi which is located in the Sahel sedentary agro-climatic zone (Saadou, 1990), 657 km east of Niamey (13° 27 N and 7° 06 E) and 353 m above sea level (Figure 1). The characteristics of the soil and climate are presented in Table 2. The total rainfall recorded in 2010 was 592.4 mm distributed over 47 days.

Experimental design

The experimental design was a randomized complete block design with three (3) replications each, separated by 1.5 m. In each block a variety is represented by two rows of 3 m long and separated by an alley of 0.5 m. On each row, the seed were sown in 20 holes separated from each other by 0.15 m. Sowing was done on July 18^{th}, 2010 at the rate of three seeds per hole. Prior to sowing, the seeds were treated with fungicide (Thioral). Two weeks after emergence, the plants were thinned to one plant per hole.

Traits measured

All the agronomic and morphological traits studied were selected from descriptors in the peanut IBPGR / ICRISAT Manual (1992). The parameters were measured on five plants per variety and per block. Two categories of traits have been studied namely quantitative traits (Table 3) and qualitative traits (Table 4).

Data analysis

Frequency table was used for qualitative data while a comparison of means by the analysis of variance (ANOVA) was performed for quantitative data. Analysis of the variability structure was done with multivariate analysis (MANOVA). Principal component analysis (PCA) defines the main components to account for the largest fraction of the total variance. Hierarchical clustering (AHC) using the unit Euclidean distance was performed to test for linkage between varieties and the resulting clusters were characterized through Fisher discriminant analysis (FDA) on the basis of the most discriminating traits.

RESULTS

For each qualitative trait, the frequency of the different morphological types is presented in Figure 2. From all the studied traits, seed color (CGR), leaf color (CFE) and to some extent pod reticulation (RGO) were the least variable as for each of them, there was one predominant morphological type. Grain color was rose for 85% of the varieties, while 62% had light green leaves (CFE) and 67% reticulated pods (RGO). Unlike these three characters which showed a trend towards the predominance of one morphological type, there were two major morphological types for the plant port (PPL) with 47% of varieties belonging to the erected and 45% to the semi-erect type. The traits showing the highest variability

Table 1. Origins of the groundnut varieties.

N°	Varieties	Origins	N°	Varieties	Origins	N°	Varieties	Origins
1	T 4 - 83	Niger	35	T 1 -2005	Niger	69	ICGV 93305	ICRISAT
2	T 5 - 83	Niger	36	T 2 - 2006	Niger	70	ICGV 10973	ICRISAT
3	T 6 - 83	Niger	37	T 3 - 2006	Niger	71	ICGV- IS-96606	ICRISAT
4	T 18 - 83	Niger	38	T 4 - 2006	Niger	72	ICGV -IS -96806	ICRISAT
5	T 19- 83	Niger	39	T 1 - 2007	Niger	73	ICGV- SM-99506	ICRISAT
6	T 49 - 83	Niger	40	T 2 - 2007	Niger	74	ICGV-SM-99513	ICRISAT
7	T 79 - 83	Niger	41	Zanzaro Maradi	Niger	75	ICG S - 31	ICRISAT
8	T 92 - 83	Niger	42	T M - H - 94	Niger	76	TA 94092	America
9	T 95 - 83	Niger	43	KH -241 -D	Burkina Faso	77	Tx AG - 1	America
10	T 108 - 83	Niger	44	Chico	Spain	78	Tx 798739	America
11	T 133 - 83	Niger	45	UGA - 7	Nigeria	79	Tx 804472	America
12	T 134 - 83	Niger	46	RRB	Nigeria	80	Tx 855157	America
13	T 145 - 83	Niger	47	796	Russia	81	Tx 872561	America
14	T 152 - 83	Niger	48	55 - 33	ICRISAT	82	Tx 872616	America
15	T 163 - 83	Niger	49	FDRF 5 - 277	ICRISAT	83	Tx 872621	America
16	T 169 - 83	Niger	50	SRV I - 3	ICRISAT	84	Tx 883623	America
17	T 177 - 83	Niger	51	CG - 8 - 35	ICRISAT	85	Tx 903020	America
18	T 183 - 83	Niger	52	ICG 3736	ICRISAT	86	Tx 903644	America
19	T 45 - 87	Niger	53	ICG 3968	ICRISAT	87	Tx 903654	America
20	T 46 - 87	Niger	54	ICG 6121	ICRISAT	88	Tx 903714	America
21	T 42 - 88	Niger	55	ICG 6760	ICRISAT	89	Tx 903796	America
22	T 44 - 88	Niger	56	ICG 7433	ICRISAT	90	Tx 903838	America
23	T 1 - 89	Niger	57	ICG 9199	ICRISAT	91	Tx 903839	America
24	T 4 - 89	Niger	58	ICG 11183	ICRISAT	92	72 - 112	America
25	T 13 - 89	Niger	59	ICGV 86024	ICRISAT	93	73 - 30	America
26	T 14 - 89	Niger	60	ICGV 86072	ICRISAT	94	55 - 437	America
27	T 16 - 89	Niger	61	ICGV 86124	ICRISAT	95	O - 20	America
28	T 20 - 89	Niger	62	ICGV 86529	ICRISAT	96	EC - 5	America
29	T 35 - 89	Niger	63	ICGV 87003	ICRISAT	97	Nelson spanish	America
30	T39 - 89	Niger	64	ICGV 87281	ICRISAT	98	JL - 24	India
31	T 2 - 93	Niger	65	ICGV 91284	ICRISAT	99	Fleur 11	India
32	T 1 - 95	Niger	66	ICGV 91317	ICRISAT	100	Tainan 9	India
33	T 2 - 96	Niger	67	ICGV 91341	ICRISAT			

were (i) pod spout (BGO) with 3 to 4 morphological types: Moderate spout (31%), light spout (30%), without spout (25%) and to a lesser extent the prominent spout (12%); and (ii) pod throttle (EGO): thin throttle type (44%), moderate throttle (34%) and without throttle (17%).

ANOVA exhibited highly significant differences ($p < 0.001$) for all traits except for the length of leaflets as indicated by F values (Table 5) and the extent of variation was quite large. For example, the pod weight varied from 32 g (ICGV91317) to 113.5 g (T13-89) and the number of days to flowering varied from 23 (T42-88, T134-83, T5-83, ICGV 93305 and ICGV 91341 23) to 29 days (Q2 96 ICG6760, T4-83 and ICGV IS 96806). Similarly, the 100-seed weight ranged from simple (22.3 g for ICGV IS 96806) to more than double (51 g for ICG3938). Besides, the block effect was highly significant for all traits except for the number of branches, the seed width and threshing index. For the interaction between varieties and blocks, the difference was not significant for all traits except for leaf length.

Principal component analysis (PCA) revealed that the first four axes account for 51.4% of the variation of the traits measured in the 100 varieties. To define the relationship between the agro morphological traits, the eigenvectors and the correlations between 21 traits out of 24 were analyzed along with the main components. Only characters that are highly correlated with one of the first three components were presented in Table 6. The projection of these characters on the first two principal components (Figure 3) showed that:

1. Axis 1 explains 20.6% of total variation. It combines

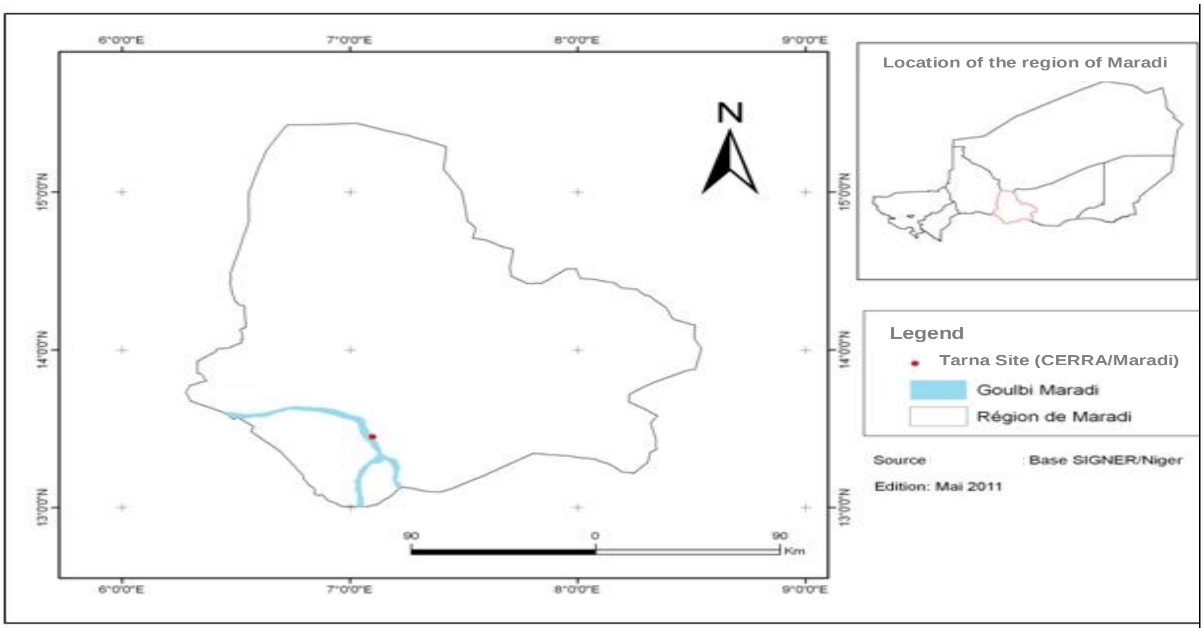

Figure 1. Experiment site location.

Table 2. Soil and weather conditions of the experiment site (INRAN Tarna).

Soil	
Type	Sandy loam
Acidity	pH = 6.49
Total Nitrogen	0.07%
Organic Carbon	0.24%
Phosphorus	16.12 ppm
CEC	1.94 meq/100g
Organic matter	0.41%
Climate	
Rainfall (mm)	400 mm≤ PI<600 mm
RH (%)	18%<HR<77%
Temperature (**°C)**	18.6**°C** <T<37.1**°C**
Average rainfall (2000-2009)	491.01 mm

high values of pod length and width of pods, seed length and days to flowering as opposed to the lowest values of main stem height, harvest index and number of plants after emergence.

2. Axis 2, with 12.6% of the variation is defined by the following characters: Seed width, 100-seed weight, pod weight and seed weight. Varieties at the positive side of axis 2 have small values and those at the negative side of this axis have high values for these traits.

These results suggest that late genotypes had larger pods, longer seeds and smaller harvest index. In addition, genotypes with low pod weight, shorter seeds and small 100-seed weight were identified from component 2.

The dendrogram resulting from hierarchical clustering (CAH) with 0.8 units of truncation threshold of Euclidean distance exhibited four distinct groups (Figure 4). The number of varieties in the different groups was 22, 66, 3, and 9 for groups I, II, III, and IV, respectively (Table 7). The distribution of varieties in different groups showed that diversity was not structured based on origin.

Fisher discriminant analysis (FDA) performed using the data of the four identified groups provided distances

Table 3. Description of the studied quantitative traits.

Parameters	Abbreviations	Descriptions
No of plants	NPL	No of plants per plot 4 weeks after sowing
Days to flowering	DFL	Number of days from sowing to flowering
Main stem height	HTP	Height in cm from ground level to the terminal bud (average of 5 plants)
Haulm dry weight	PFS	Dry weight (g) of 5 plants excluding pods
No of branches/plant	NBR	Number of cotyledonary lateral branches (average of 5 plants)
Plant throttling	EPL	Length of branches (cm) 2 months after planting (average of 5 plants).
Harvest index	IR	% Ratio of seed weight to total dry biomass.
Leaflet length	LOF	Length (cm) of the apical leaflet of the third leaf of the main stem along the limbus (5 leaflets / plant and average of 5 plants).
Leaflet width	LAF	Width (mm) of the apical leaflet of the third leaf of the main stem. Measurements were taken between the tops of the leaflet. (Five leaflets per plant and average of 5 plants).
No Harvested plants	NPR	Number of plants just before harvest
Pod weight	PGO	Weight (g) of pods (average of 5 plants)
Pod length	LOG	Length (mm) of mature pod (5 pods / plant and average of 5 plants)
Pod width	LAG	Width (mm) of mature pod (5 pods / plant and average of 5 plants)
Threshing index	IB	% Ratio of seed weight to pod weight (seed weight / pod weight * 100)
Seed weight	PGR	Grain weight (g) (average of 5 plants).
100-Seed weight	PCG	100-seed weight (average of 5 plants).
Seed length	LGR	Seed length (mm)
Seed width	WGR	Mid-seed width (mm)

Table 4. Description of the studied qualitative traits.

Trait	Abbreviation	Description
Plant port	PPL	Plant port at pod development stage : 1 = erect, 3 = semi erect, 5 = crawling
Leaf color	CFE	1 yellow green, 2 = light green, 3 = green, 4 = dark green, 5 = blue green;
Pod beak	BGO	0 = without beak, 3 = thin, 5 = moderate, 7 = marked, 9 = very pronounced
Pod throttling	EGO	0 = no throttling, 3 = mild, 5 = moderate, 7 = strong, 9 = very deep
Pod reticulation	RGO	0 = without reticulation, 3 = mild, 5 = moderate, 7 = prominent, 9 = very prominent
Seed color	CGR	1 = pink, 3 = red, 5 = purple, 7=black, 9 = motley

between groups and their significance as defined by Mahalanobis (Table 8). The difference between the four groups on the basis of all the characters, except for PPL, PGO, PGR, PCG, WGR, GERD was highly significant ($p < 0.001$) (Table 9). In other words, apart from these traits, all the remaining ones have contributed to discriminate between the four groups. These results were confirmed by the Wilks' Lambda test ($P < 0.0001$).

Moreover, LOF, LAG, LOG, HTP, DFL LGR and NPL were the most discriminating traits with highly significant F and R^2 values ($p < 0.0001$) (Table 9). The eigen values of the canonical axes showed that the first two axes ($P < 0.0001$) accounted for 88.33% of the variation (Table 10).

The projection of the four groups on the canonical system of axes 1 and 2 indicated that the first axis discriminates between groups the best (Figure 5). It divides groups III and IV which were composed of varieties with long leaflets and those IV with short leaflets. Group being positioned on the positive side of axis 2, is characterized by late varieties, with low emergence rate, large pods and long seed as opposed to varieties belonging to group II which are early and have high emergence rate and relatively small pods. Varieties of group III have long leaflets unlike those of group IV. Groups I and II which were located in the center of the plan presented average values for these traits.

DISCUSSION

The results of this study on agro-morphological traits in

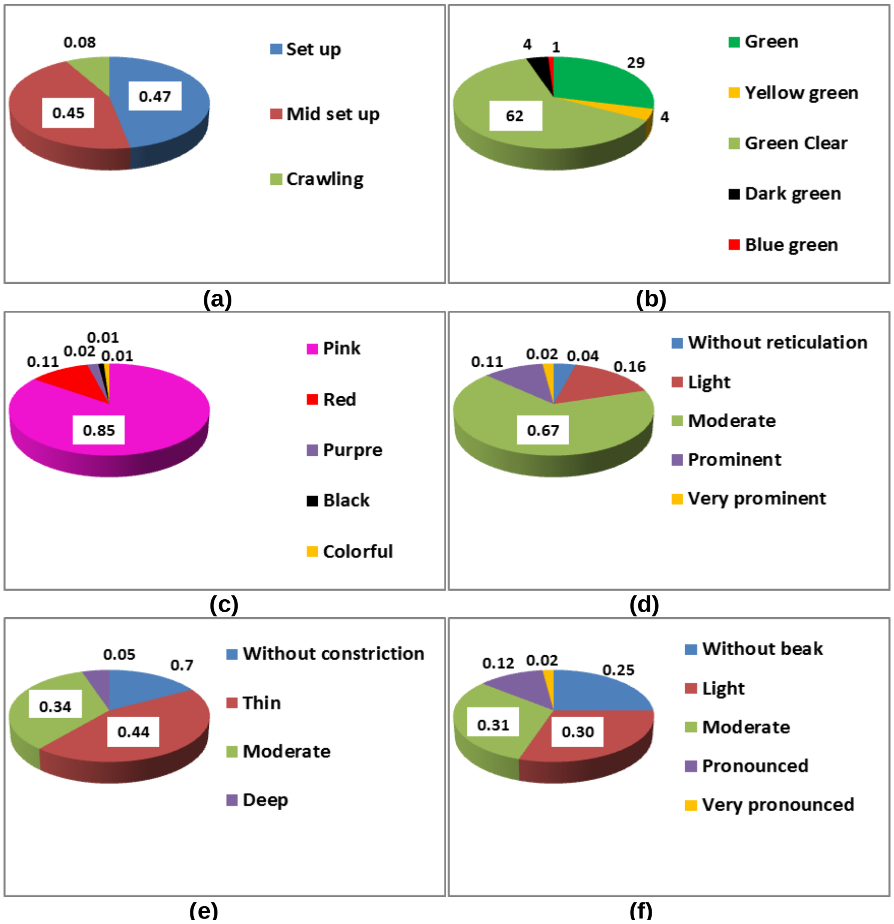

Figure 2. Morphological types for the different qualitative characters. (a) Plant port; (b) leaf color; (c) grain color; (d) pod reticulation; (e) pod throttling; (f) pod beak.

100 groundnut varieties (*A. hypogaea* L.) showed large genetic variation which might be related to the origin of the varieties. In fact, these varieties were developed in different growing areas, with a possible maintenance of some level of variability. Each variety has evolved in isolation from others, which accentuated the differences. This is favored by the mode of reproduction of the crop that is mostly autogamous with a low level of cross pollination (0.2 to 6.6%). Several authors (Clegg et al., 1992; Hamrick and Godt, 1990) reported that highly autogamous mode of reproduction promotes inter-population heterogeneity and allows good adaptation to the environment, in addition to plant-to-plant heterogeneity in the population. These results are in agreement with those of Balma (1994) who assessed the quantitative traits of 140 varieties in a groundnut collection from the center of Burkina Faso and those of Clavel (2004) on drought adaptation of groundnut in Senegal.

This varietal aspect may also explain the highly significant block effect observed for most of the studied traits except seed width, number of branches and threshing index. Because varieties are usually developed on the basis of traits that allow them to adapt to their environment, these traits are closely related to the ecological conditions in the production areas. The observed variation for the traits measured in this work is partly due to environmental factors in addition to genotypic differences, although it is often difficult to measure their relative share.

Genetic improvement is largely related to the types of correlation between traits (Bakasso, 2010). In this work, results showed that there was a significant correlation between pod length and seed length, in agreement with the findings of Godoy (1982), Soomro and Larik (1981) and Varisai and Ramachandra (1975). Moreover, the size of the pods and seeds were positively and significantly correlated, so any restriction of pod growth may result in smaller seeds. These results corroborated those reported by Zaman et al. (2011). In addition, Manggoel et al. (2012) reported that 100-seed weight is a key yield trait affecting grain yield in legumes like cowpea.

The 100 groundnut varieties tested in this study

Table 5. Analysis of variance and average performance of the varieties.

Source of variation	DDI	NPL F	DFL F	HTP F	NBR F	EPL F	LOF F	LAF F	PFS F	PGO F	LAG F	LOG F	PGR F	PCG F	LGR F	WGR F	IB F	IR F	CGO F
Blocs	2	7***	5.7***	3.1***	1.8^{ns}	67***	9.1***	2.1***	29.8***	9.5***	3.6***	7.3***	11.2***	2.1***	3.8***	1.1^{ns}	1.2^{ns}	47.7***	9.1***
varieties	99	8.3***	2.7***	2.9***	2.4***	1.4***	1.2^{ns}	14.3***	1.3***	1.8***	6.5***	8.2***	1.8***	3.5***	5.5***	2.2***	1.8***	1.5***	7.5***
Blocs * genotypes	198	0.2^{ns}	0.4^{ns}	0.6^{ns}	0.8^{ns}	0.5^{ns}	2.3***	0.6^{ns}	0.6^{ns}	1.1^{ns}	0.3^{ns}	0.3^{ns}	1.0^{ns}	0.6^{ns}	0.3^{ns}	0.5^{ns}	1.3^{ns}	0.5^{ns}	0.3^{ns}
Min		8	23	17.5	4	33.3	4	2.2	245.3	32	9..1	15.7	16.1	22.3	8.9	6.2	44.7	3.2	0
Max		36	29	43	10	64.3	8.9	3	857.9	113.5	15.2	33	74.9	51	15.7	7.9	79.3	19.3	9
Mean		20.2	25.1	30.3	5.5	49.7	5.2	2.6	402.5	66.5	11.3	23.7	43.1	33.2	11.1	7	64.6	10.7	3.4
ET		7.5	1.7	6.3	1.4	10	1.1	0.2	167.8	27.5	1.1	3.5	18.9	6.3	1.3	0.5	8.9	6.1	2

Min, minimum; Max, maximum; ET, standard deviation; cv, coefficient of variation; F, F- test (Fischer), ***, highly significant (5%), ns : non-significant; Legend: NPL, Number of seedlings at emergence, DFL, Days to flowering; NBR, Number of branches; HTP, Height of main stem; LOF, Length of the leaflet; LAF, width of the leaflet; PFS, haulms dry weight; PGO, pods weight; LOG, pod length; LAG, pod width; PGR, seed weight; PCG, 100-seed weight; LGR, seed length; WGR, seed width; IB, threshing index; IR, harvest index; PPL, plant port; CFE, leaf color; RGO, pod reticulation; CGR, seed color; EPL, plant throttling.

Table 6. Eigen values and proportion of information on the four axes of PCA.

Axes	Eigen values	Proportions	Cumulative %	HTP	LOG	LAG	LGR	IR	NPL	WGR	PCG	PGO	PGR	DFL
1	4.328	20.6	20.6	-0.323	0.341	0.329	-0.324	-0.324	-0.314	0.016	0.081	-0.155	-0.226	0.287
2	2.648	12.6	33.2	-0.021	-0.25	-0.174	-0.359	-0.227	-0.07	-0.417	-0.501	-0.3	-0.301	0.123
3	2.223	10.6	43.8	-0.231	-0.11	-0.105	-0.06	0.288	-0.29	-0.221	-0.11	0.45	0.44	0.326
4	1.585	0.075	51.4											

NPL, Number of seedlings at emergence; DFL, Days to flowering NBR, Number of branches; HTP, Height of main stem; PGO, pods weight; LOG, pod length; LAG, pod width; PGR, seed weight; PCG, 100-seed weight; LGR; seed length; WGR seed width; IR, harvest index;

were clustered into four different groups. Varieties of groups I and II, with medium performance, like 55-437, T169-83, T 177-83, JL 24, ICGV 87003, ICGV 87281, RRB, O-20,

Tx 872,561 are the most disseminated in Niger. For a better exploitation of the species in Niger, varieties of these groups, especially those of group II, which are from erect or semi-erect type, early and have high emergence rate, high seed and pod weight, would be more appropriate for the country. Varieties of Group III as well as those from group IV, which were found to be late with large pods, should be grown in areas where the rainy season is longer. Their low performance in this work may be related to environmental conditions, particularly the duration of the rainy season which was quite short. However, these varieties can be used for haulm production as feed for livestock.

The structure was proved to be not origin based as each group is a mixture of varieties from several origins. All the traits measured have contributed to discriminate between the groups except those primarily related to grain yield and plant port. In a study of peanut collection of 86 accessions from Cuba, Fundora et al. (2004) showed that the traits pod length, number of seeds per pod, pod/seed weight and pod width were predominant among the 14 traits measured. This implies that these varieties were developed for high grain yield in relation to plant port type. Indeed, in this study, the analysis of qualitative traits showed that all varieties were divided mainly

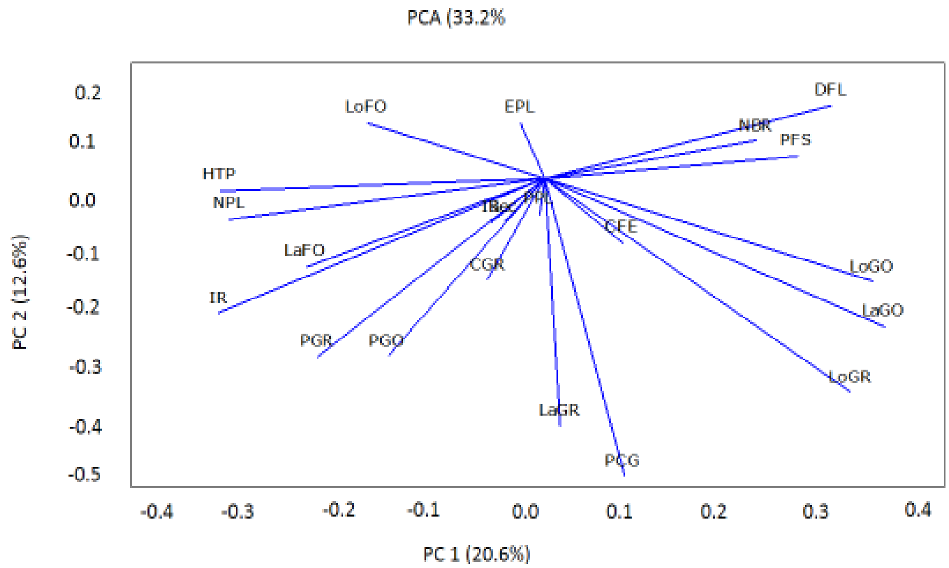

Figure 3. Graphical representation of the first two axes.

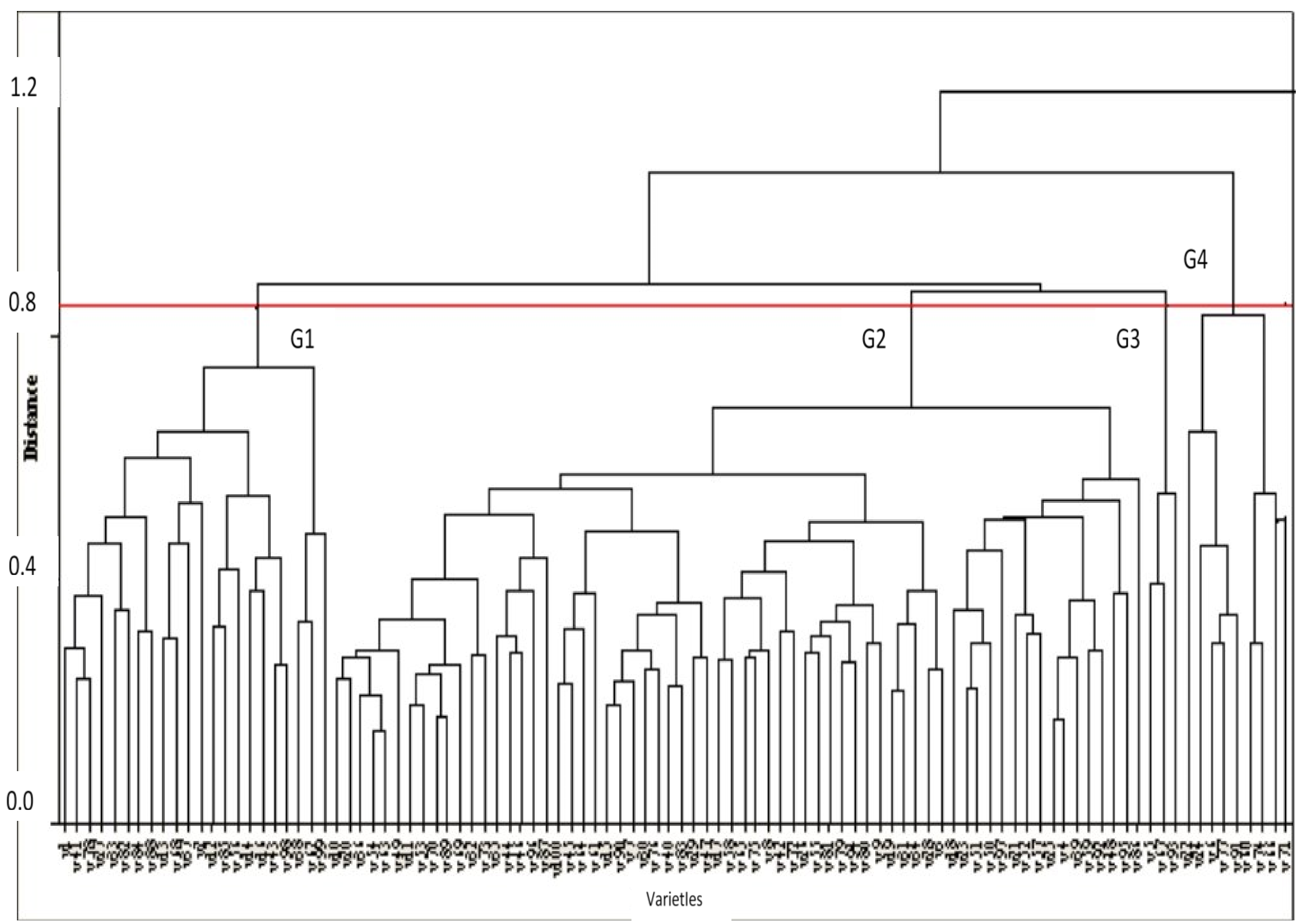

Figure 4. Dendrogram obtained by hierarchical clustering of groundnut varieties (*Arachis hypogaea* L.).

Table 7. Groups composition from hierarchical clustering analysis.

N Group	Number	Composition
I	22	V54. V57. V25. V74. V36. V50. V39. V90. V40. V22. V6. V13. V45. V11. V71. V52. V69. V65. V98. V66. V41. V73.
II	66	V92. V83. V14. V84. V3. V2. V97. V81. V5. V91. V48. V87. V84. V94. V47. V26. V32. V59. V88. V10. V38. V53. V20. V30. V18. V35. V100. V51. V79. V1. V63. V64. V99. V97. V28. V46. V82. V23. V17. V43. V60. V34. V19. V15. V21. V76. V9. V12. V31. V95. V78. V29. V4. V77. V93. V82. V96. V27. V85. V8. V75. V89. V61. V56. V49. V24.
III	3	V80. V44. V67.
IV	9	V33. V55. V70. V58. V37. V89. V72. V62. V16.

Table 8. Discrimination test using Mahalanobis distance.

Group	Grp I	Grp II	Grp III	Grp IV
I	0	-	-	-
II	5.0***	0	-	-
III	12.5***	14.6***	0	-
IV	8.2***	12.6***	14.9***	0

Table 9. Univariate and multivariate analysis of variance.

Variables	R^2	F(3)*	Prob
NPL	0.8	11.36	< 0.0001
DFL	0.58	15.27	< 0.0001
NBR	0.56	7.2	0.001
HTP	0.6	8.1	< 0.0001
LOF	0.97	90.15	< 0.0001
LAF	0.54	5.18	< 0.0001
EPL	0.57	2.72	0.048
CFE	0.72	6.13	0.001
PPL	0.7	0.8	0.496
PFS	0.49	5.16	0.002
PGO	0.49	1.8	0.151
LOG	0.8	22.29	< 0.0001
LAG	0.76	19.46	< 0.0001
PGR	0.5	2.39	0.073
PCG	0.64	2.51	0.063
LGR	0.74	9.34	< 0.0001
WGR	0.53	1.88	0.137
IB	0.47	4.08	0.009
IR	0.55	5.02	0.003
RGO	0.53	3.19	0.027
CGR	0.4	4.39	0.006
Wilks' Lambda test		0.021 (ddl= 96)	<0.0001

(3)*, ddl = 3; NPL, Number of seedlings at emergence; DFL, Days to flowering NBR, Number of branches; HTP, Height of main stem; LOF, Length of the leaflet; LAF, width of the leaflet; PFS, haulms dry weight ; PGO, pods weight; LOG, pod length; LAG, pod width; PGR, seed weight; PCG, 100-seed weight; LGR; seed length; WGR seed width; IB, threshing index; IR, harvest index; PPL, plant port; CFE, leaf color; RGO, pod reticulation; CGR, seed color; EPL, plant throttling.

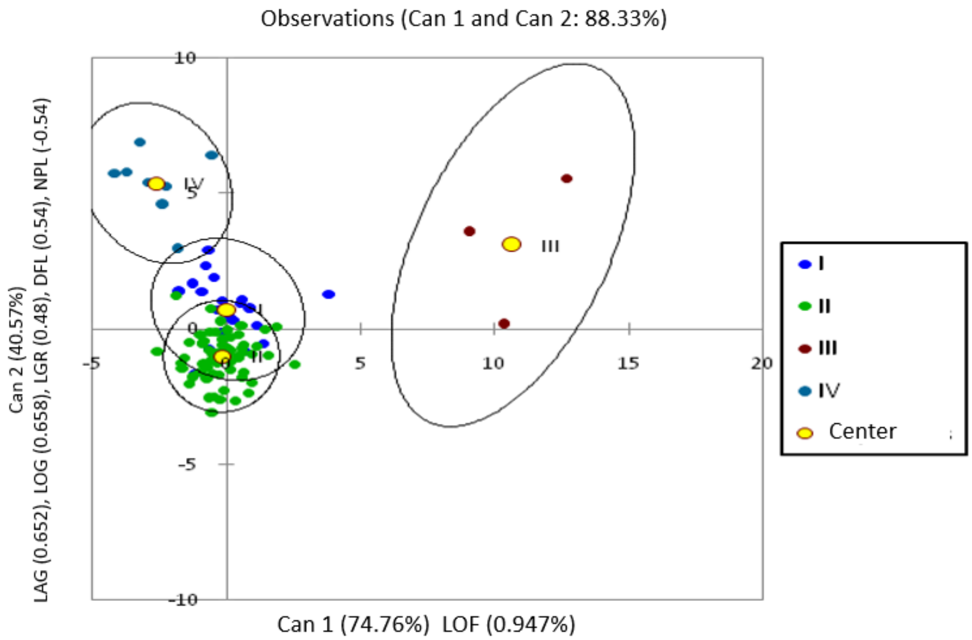

Figure 5. Projection of the four groups on the plane defined by the two first axes of canonical discrimination.

Table 10. Proportions of information from canonical axes (Correlations and significance of canonical axes).

Axes	Proportions	Cumulative proportions	Prob
1	0.48	0.48	<0.0001
2	0.40	0.88	<0.0001
3	0.12	1.00	0.710

Into erected and semi-erected types.

Conclusion

The results of this study have revealed a large genetic diversity in the groundnut collection of Niger. It also helped to understand that even if the varieties are geographically distant, some of them have agro-morphological and genetic traits that are close to each other. However, cultivated varieties, even if they are not genetically variable have strong potential for ecotypic differentiation related to abiotic and biotic stresses they were exposed to. The genetic variation observed in this work demonstrates the possibility of genetic improvement of groundnut to meet the agronomic and morphological requirements for increased productivity and adaptation to local conditions. The four groups defined by the CAH based on agro-morphological traits may represent the required variability for a basic collection. In order to establish an efficient improvement program, it is indispensable to understand the nature of the genetic control of these different traits, especially the most discriminating.

Conflict of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGMENT

The authors are grateful to the Tropical Legumes II project for financial support and INRAN for providing facility to carry out this study.

REFERENCES

Bakasso Y (2010). Ressources génétiques des roselles (Hibiscus sabdariffa L.) du Niger: Evaluations agromorphologique et génétique. Thèse de Doctorat d'Etat, Université de Niamey, P. 109.

Balma D (1994). Ressources phylogénétiques de l'arachide (Arachis hypogaea L.). Evaluation des caractères quantitatifs de la collection du centre du Burkina Faso.- Ouagadougou : CNRST. Pp. 134-147.

Clavel D (2004). Amélioration variétale de l'arachide (*Arachis hypogaea* L.) pour l'adaptation à la sécheresse. Proposition d'une approche intégrée pour la sélection. Thèse de Doctorat, Université de Paris-Val-de-Marne, P. 155.

FAO (2013). FAO Data Base. http://www.faostat.fao.org/ 4 July.

Fonceka D (2010). Elargissement de la base génétique de l'arachide cultivée (Arachis hypogaea): Applications pour la construction de populations, l'identification de QTL et l'amélioration de l'espèce cultivée. Thèse de doctorat de Montpellier SupAgro. P.162.

Fundora MZ (1998). La convention et l'utilisation des ressources phylogénétiques: Résumé de la troisième réunion latino-américaine sur la biotechnologie végétale, REDBIO'98. Palais des conventions de la Havana, Cuba. pp. 199-200.

Fundora MJ, Hernadez M, Lopez R, Ferandez L, Sanchez A, Lopez J, Ravelo I (2004). Analyse de la variabilité des accessions d'arachide collectes (*Arachis hypogaea* L.) pour la création de la collection de base. Bulletin des ressources phylogénétiques n° 137, Cuba pp. 9-13.

Clegg MT, Epperson BK, Brown AHD (1992). Genetic diversity and reproductive system, pp. 323-331 In: Y. Dattée, C. Dumas, A. Gallais, eds., Reproductive biology and plant breeding, Berlin: Springer-Verlag. http://dx.doi.org/10.1007/978-3-642-76998-6_30

Godoy IJ (1982). Genetics and interrelationships of fruit seed size in *Arachis hypogaea* L. Dissertation Abstracts International B. 42(9):3527B

Hamrick JL, Godt NJ (1990). Allozyme diversity in plant species. In: Plant population genetics, breeding and genetic resources (AHD Brown, MT Clegg, AL Kahler, BS Weir, eds).Sinauer Associates, Sunderland, MA, pp. 43-63.

IBPGR/ICRISAT (1992). Descriptors for groundnut. P.125.

Manggoel W, Uguru MI, Ndam ON, Dasbak MA (2012). Genetic variability, correlation, and path coefficient analysis of some components of 10 cowpea [*Vigna unguiculata* (L.)Walp] accessions. J. Plant Breed. Crop Sci. 4(5):80-86. http://dx.doi.org/10.5897/JPBCS12.007http://dx.doi.org/10.5897/JPBCS12.007

Maria ABS (2009). Caractérisation agromorphologique et moléculaire d'une collection de landraces péruviennes de pigeonpea (Cajanus cajan L. Millsp.) pour l'analyse de sa diversité. These de Doctorat, FUNDP, URBV- Namur- Belgique, P. 224.

NARP (1993). National Agricultural Research Project Report, Grain Legumes, Accra Ghana: NARP.

Ndjeunga J, Ntare BR, Schilling R (2003). Perspectives globales et régionales du marché de l'arachide : compétitivité des producteurs africains. In : Ntare Bonny R, Mayeux Alain, Waliyar Farid (Eds). Conservation, évaluation et diffusion du matériel arachide et production et diffusion de semences de base en Afrique de l'ouest : comptes rendus de l'atelier de restitution du projet Germplasm arachide, 22-24 avril 2002, Bamako, Mali. Patancheru : ICRISAT, p. 55-75. Atelier de restitution du projet Germplasm arachide, 2002-04-22/2002-04-25, Bamako, Mali.

Ntare BR, Waliyar F (2000). Progrès faits dans l'amélioration de l'arachide en Afrique de l'ouest et du centre. In : compte rendus de la sixième réunion régionale de l'ICRISAT sur l'arachide en Afrique occidentale et centrale, 5 au 8 octobre 1998, Bamako, Mali. Waliyar F, Ntare BR (eds). ISBN 92-9066-421-5.

Rao VR (1980). Groundnut genetic resources at ICRISAT. In proceedings of the International workshop on Groundnuts, pp. 65-71, ICRISAT, India.

Saadou M (1990). La végétation des milieux drainés nigériens à l'est du fleuve Niger. Thèse présentée à la Faculté des sciences de l'Université de Niamey pour obtenir le grade de Docteur Es-Sciences Naturelles, P. 395.

Soomro B, Larik AS (1981). Inheritance and correlation of pod and seed caractères in peanuts. Genetica Agragria 35(3-4):263- 264.

Varisai M, Ramachandra M (1975). Variation in pod weight of *Arachis hypogaea* L. Plant Breeding Abstract 45(6):378.

Zaman MA, Tuhina-Khatun M, Ullah MZ, Moniruzzamn M, Alam KH (2011). Genetic Variability and Path Analysis of Groundnut (*Arachis hypogaea* L.). Agriculture 9(1-2):29-36.

academicJournals

Vol. 10(5), pp. 345-350, 29 January, 2015
DOI: 10.5897/AJAR2014.8688
Article Number: 60411C949854
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Impact of nutrient management technologies in transplanted rice under irrigated domains of Central India

A. K. Singh[1]*, U. S. Gautam[2], J.Singh[3], A. Singh[4] and P. Shrivastava[5]

[1]Department of Soil Science, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Krishi Vigyan Kendra, Katni-483 442, Madhya Pradesh, India.
[2]Zonal Project Directorate, Zone-VII, ICAR, JNKVV Campus, Adhartal, Jabalpur-482004 (MP), India.
[3]Department of Plant Protection, Jawaharlal Nehru Krishi Vishwa Vidyalaya, KrishiVigyan Kendra, Sidhi-486661 (MP), India.
[4]Department of Home Science, Jawaharlal Nehru Krishi Vishwa Vidyalaya, KrishiVigyan Kendra, Chhattarpur-471201 (MP), India.
[5]Department of Agricultural Engineering, Jawaharlal Nehru Krishi Vishwa Vidyalaya, KrishiVigyan Kendra, Narsinghpur-487001 (MP), India.

Received 14 March, 2014; Accepted 9 January, 2015

An experiment on impact of different approaches of nutrient management in transplanted rice was conducted in participatory mode on mixed red to shallow black soils under irrigated domains in Kymore Plateau and Satpura Hills zone of central India. The study was carried out for three consecutive years since *kharif* 2008. The results revealed that the application of organic inoculants *viz.* blue green algae (BGA) and phosphate solubilizing bacteria (PSB) with NPK nutrients on soil test crop response (STCR) basis recorded higher grain yield (4.025 tonne ha^{-1}) and straw yield (6.68 tonne ha^{-1}) of rice. Further higher gross returns, net returns, yield response (kg) kg^{-1} nutrients use and net return (Rs) Re^{-1} spent on nutrients were observed when compared to the other treatments. The targeted yield in rice was achieved with integrated nutrient supply through organic and inorganic sources using STCR approach, however, ±5% deviation was observed using inorganic fertilizers alone through STCR technology. It was inferred from the study that the STCR technology may be the appropriate approach for optimum nutrient supply which improves the soil properties especially the soil health and productivity in a long run in comparison to other nutrient management technologies.

Key words: General recommended dose (GRD), soil test crop response (STCR), yield response, net return.

INTRODUCTION

Rice is life for almost half of the global population and majority (60%) of the Indian populace, who are also highly vulnerable to inflationary pressure due to high rice price. The living and livelihood of majority of the Indian

*Corresponding author. Email: singhak123@rediffmail.com

farming population also depends on growing rice. Rice production increased almost three-fold over the last five decades and contributes handsomely to the nutritional security of the country. In India, the annual compounded growth rate (ACGR) of rice production has declined from 3.55% during 1981-1990 to 1.74% during 1991-2000. Although an all-time high production of 99.50 million tons of rice with a productivity of 2.20 tons per hectare was achieved during the year 2008-2009, India needs to produce 120 million tons by 2030 to feed its one and a half billion plus population by then. A real-time analysis of this scenario provides sufficient justification for strengthening, intensifying and introducing cutting edge science and technology for increasing rice productivity in India (Adhya, 2011).

Rice is grown in almost all the states of the country. West Bengal, Uttar Pradesh, Madhya Pradesh, Bihar, Orissa, Andhra Pradesh, Assam, Tamilnadu, Punjab, Maharashtra and Karnataka are major rice growing states and contribute to a total 92% of area and production. India is still amongst the countries with the lowest rice yields. Seventy percent of the 414 rice-growing districts report yields lower than the national average, clearly indicating that well after the advent of high yield technology, a sizable area is categorized as low producing. Sixty percent of the low productivity rice areas are in Bihar, Orissa, Assam, West Bengal, and Uttar Pradesh. Surprisingly, 32% of the irrigated rice areas produce low yields (Tiwari, 2012). Rice based cropping systems are the major production systems contributing to food production. Current crop production systems are characterized by inadequate and imbalanced uses of fertilizers e.g. blanket fertilizer recommendations over large domains with least regard to the variability in soil fertility and productivity. Future gains in productivity and input use efficiency require soil and crop management technologies that are tailored to specific characteristics of individual farms or fields. Farm research demonstrated existence of large field variability in terms of soil nutrient supply, nutrient use efficiency, crop responses etc. Management of this variability is a principal challenge for further increasing crop productivity of intensive rice crop systems (Rao, 2011).

Madhya Pradesh contributes approximately two per cent of the total National rice production with about 4% of the total area. According to Agricultural Statistics 2009-2010, area under rice is about 14.457 lakh ha, production - 12.606 lakh tons and productivity - 872 kg/ha in MP which is far below the average national productivity, that is, 2125 kg/ha (Anonymous, 2011). Rice is cultivated in more than one lakh hectare with the average productivity of 1035 kg/ha in Katni district which falls in Kymore Plateau and Satpura Hills zone (Anonymous, 2011a). Low production of rice is mainly attributed to very less and inadequate nutrient use (47 kg NPK/ha) in the State. The nutrient consumption in the study area is 48.45 kg NPK/ha. The fertilizer nutrients use and removal by different crops in various agro-climatic zones of MP have shown that there is a negative balance of about 1.09 million tonnes of NPK and 0.05 million tonnes of sulphur in the State. The balance of NPK and sulphur is negative in all the agro-climatic zones except the Nimar Valley Zone of the State. Acute deficiencies of other nutrients in future are expected if remedial measures are not taken to reduce the nutrient gap. To meet the demand of National food grain requirement and nutritional security, there is need to increase production of rice by balanced use and site specific management of nutrients through organic and inorganic sources together with introducing high yielding varieties. Considering these aspects, the present study was therefore carried out in Kymore Plateau and Satpura Hills zones of central India during 2008-2009 to 2010-2011 with the objective to assess the impact of nutrient management through various technologies on growth and yield of transplanted rice.

MATERIALS AND METHODS

Experiments were conducted in participatory mode in Kymore Plateau and Satpura Hills zone of Madhya Pradesh (Central India) in *kharif* season since 2008 for three years. The crop was transplanted during IInd fortnight of July 2008, 2009 and 2010 respectively on mixed red to shallow black soils, nearly neutral in reaction with low soluble salts (0.22 dSm^{-1}), low in organic carbon (0.27%) and available nitrogen (115.35 kg ha^{-1}), medium in available phosphorus (18.8 kg ha^{-1}) and high in available potassium (255.8 kg ha^{-1}). The crop variety IR 36 was used with the seed rate of 15 kg ha^{-1} as the said variety is recurrently used for paddy cultivation by most of the farmers of the area. The soil was puddled at desirable field condition and followed by planking. Nitrogen (N), Phosphorus (P) and Potassium (K) were applied in the form of urea, single super phosphate (SSP) and muriate of potash (MOP) respectively. Whole P, K and one third of the N were side dressed at the time of transplanting, while the remaining N was top dressed in two splits at tillers initiation and pre-flowering stages respectively. Zinc (Zn) was well above the critical limit in the study soils at all the locations, hence, not applied in the respective treatments. Biofertilizers, that is, phosphate solubilising bacteria (PSB) was applied as basal @ 1.5 kg ha^{-1} before transplanting and blue green algae (BGA) used @ 12 kg ha^{-1} one week after transplanting in the selected treatments. Irrigations were applied as per crop need especially during dry spells. All other agronomic practices were done uniformly in all treatments except farmers' practice. The crop was harvested manually during Ist to IInd week of November, 2008, 2009 and 2010 respectively. The trial was laid out in Randomized Complete Block Design (RCBD) with five treatments at farmers' field (0.2 ha each) at five locations during the study period. The treatments were

T_1: Farmer's practice as control - NPK @ 41:57:0 kg/ha,
T_2: Blanket dose (BD) of NPK @80:40:30 kg ha^{-1} without soil test,
T_3: General recommended dose (GRD) @ 80:40:30 kg NPK ha^{-1} on soil test basis,
T_4: NPK application based on soil test crop response (STCR) equation and Zn @ 5 kg ha^{-1},
T_5: NPK application based on soil test crop response (STCR) equation, BGA @ 12 kg, PSB @ 1.5 kg and Zn @ 5 kg ha^{-1}.

The fertilizer adjustment equation given by All India Co-ordinated Research Project on soil test crop response (STCR), Jawaharlal

Table 1. Growth and yield parameters of transplanted rice as influenced by different approaches of nutrient management.

Treatments		Plant height (cm)	No. of tillers hill^{-1}	Panicles plant^{-1}	Grains panicle^{-1}	Grain yield (tonne ha^{-1})	Straw yield (tonne ha^{-1})	Per cent deviation in grain yield from the target	Per cent increase in grain yield over control
T_1 ($N_{41}P_{57}K_0$ kg ha^{-1})		91.0	17.2	15.8	158.6	2.458	4.135	-	-
T_2 ($N_{80}P_{40}K_{30}$ kg ha^{-1} without soil test)		96.4	29.7	27.5	208.3	3.140	4.960	-	27.75
T_3 ($N_{80}P_{40}K_{30}$ kg ha^{-1} on soil test basis)		101.2	32.9	30.8	223.1	3.485	5.853	-	41.78
T_4 (NPK based on STCR, Zn 5 kg ha^{-1})		108.5	39.4	37.9	240.5	3.792	6.468	(-) 5.2	54.27
T_5 (NPK based on STCR, $BGA_{12}PSB_{1.5}Zn_5$ kg ha^{-1})		113.5	43.3	41.5	257.8	4.025	6.680	(+) 0.63	63.75
S Em±		1.02	0.59	0.43	1.17	0.40	0.43	-	-
CD (0.05)		6.87	NS	NS	9.12	NS	NS	-	-
2008	CD (0.05)	5.43	NS	NS	NS	NS	NS	-	-
	CV (%)	1.5	3.6	3.8	0.4	1.8	0.6		
2009	CD (0.05)	4.72	NS	NS	3.97	NS	NS	-	-
	CV (%)	1.4	2.4	2.3	0.6	1.0	1.0		
2010	CD (0.05)	3.92	3.87	4.09	6.34	NS	NS	-	-
	CV (%)	1.3	4.1	4.4	0.8	2.3	0.7		

NS - Non significant.

Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.) for the study area, was used.

Fertilizer N = 4.25 T - 0.45 SN

Fertilizer P_2O_5 = 3.55 T - 4.89 SP

Fertilizer K_2O = 2.1 T - 0.18 SK

Where
T= Target yield, tonne ha^{-1}; SN= Soil available N, kg ha^{-1}; SP= Soil available P, kg ha^{-1}; SK= Soil available K, kg ha^{-1}.

Using the above fertilizer adjustment equations, the quantity of fertilizer nutrients required for achieving 4 tonne ha^{-1} grain yield of rice was worked out. Data on plant height (cm), number of tillers hill^{-1}, panicles plant^{-1}, grains panicle^{-1}, grain and straw yield (tonne ha^{-1}) was recorded at maturity during the experimentation. Data was analysed statistically according to Fisher's analysis of variance technique (Steel et al., 1997) and critical difference (CD) at 5% probability level was applied to compare the treatments' means.

RESULTS AND DISCUSSION

Impact of nutrient management on growth and yield

The data with regard to growth parameters, yield attributes and yield given in Table 1 revealed that all the parameters *viz.* plant height (cm), number of tillers hill^{-1}, panicles plant^{-1}, grains panicle^{-1}, grain and straw yield were recorded to be remarkably high with T_5 (NPK application based on soil test crop response (STCR) equation, BGA @12 kg, PSB @1.5 kg and Zn @ 5 kg ha^{-1}) and lowest with T_1 (Farmer's practice - $N_{41}P_{57}K_0$ kg ha^{-1}).

Plant height varied from 91.0 to 113.5 cm among all the treatments. The highest value was noted in T_5 (NPK based on STCR technology, $BGA_{12}PSB_{1.5}Zn_5$ kg ha^{-1}) and lowest in T_1 (Farmer's practice - $N_{41}P_{57}K_0$ kg ha^{-1}). Among the treatments, significant difference was observed between T_3 ($N_{80}P_{40}K_{30}$ kg ha^{-1} on soil test basis) and T_4 (NPK based on STCR, Zn 5 kg ha^{-1}) only. It was perceived from the Table 1 that number of tillers hill^{-1} varied from 17.2 to 43.3 among all the treatments. Similarly, highest tillers hill^{-1} was distinguished in T_5 and lowest in T_1 treatment. Remarkable increase in tillers hill^{-1} was observed in each preceding treatment over farmer's practice. Panicles plant^{-1} oscillated from 15.8 to 41.5 among all the treatments and observed to be greater in all the treatments over farmers' practice. It is apparent from the data that grains panicle^{-1} was noted from 158.6 to 257.8 in all the treatments under study. Significantly greater values were noted both in soil test crop response (STCR) technology treatments followed by GRD

Table 2. Yield response and net return per Re spent on fertilizer in different approaches of nutrient management.

Treatment	Fertilizer dose $N:P_2O_5:K_2O$	Grain yield tonne ha^{-1}	Yield response (kg) kg^{-1} fertilizer use	Net return (Rs) Re^{-1} spent on fertilizer
T_1	41:57:00	2.458	-	-
T_2	80:40:30	3.140	13.12	10.35
T_3	116:44:33	3.485	10.81	9.79
T_4	111:50:38	3.792	13.21	10.55
T_5	111:50:38	4.025	15.51	10.37

and BD over T_1 (farmers' practice). Grain and straw yields were found in increasing trend to that of the preceding treatments over T_1 and these were varied from 2.458 to 4.025 and 4.135 to 6.68 tonne ha^{-1} respectively among the judged treatments. Among the treatments remarkable difference was also noticed in above parameters. The extent of increase in grain yield was noted to be 27.75, 41.78, 54.27, and 63.75% over farmers' practice (T_1). Similarly the increase in straw yield was recorded to be 19.95, 41.55, 56.42 and 61.55 % in the preceding treatments over T_1 (Farmers' practice).

It was observed from the Table 1 that use of organic inoculants *viz.* BGA and PSB along with NPK fertilizers applied through STCR equation in T_5, and NPK fertilizers alone applied through STCR equation in T_4 treatment resulted in greater values for all the parameters under observation followed by T_3 (GRD on soil test basis) and T_2 (blanket dose of NPK without soil test) which is also mirrored by the per cent increase in grain and straw yields of rice in which the extent of increase was remarkably higher in the above said treatments. Application of fertilizers based on STCR equation in conjunction with organic inoculants in T_5 treatment might have facilitated the applied nutrients efficiently according to the need of crop and enriched nutrient reserve in soil which lead to better uptake of the nutrients by the crop and as outcome of that, it ensued 4.025 tonne ha^{-1} grain yield which was slightly higher (0.63%) than the targeted yield. The results indicate that higher yield target may be achieved through integrated supply of nutrients from different sources. Similar findings were reported by Apoorva et al. (2010). Fertilizers application through STCR technology alone in T_4 treatment, resulted in 3.792 tonne ha^{-1} grain yield which was nearly 95% of the established target and it was appreciably higher than that of T_3 treatment (GRD). The parameters under study were substantially greater in T_3 in comparison to T_2 (Blanket application of NPK without soil test) as the soil test based application of nutrients in GRD, and fulfilled the crop need to the considerable extent. The grain and straw yield under T_5 treatment was estimated 6.14 and 3.28% higher than that of T_4 in which BGA and PSB was not applied. Application of BGA possibly increased the N reserve in soil by fixing the atmospheric N and PSB increased the P uptake efficiency by increasing its solubility resulted in remarkable yield increase of rice. These findings are in agreement with those of Venkaraman (1982) and Pachpade (1990). They reported that BGA inoculation significantly increases paddy yield. Singh et al. (1992) conducted field experiments in Uttar Pradesh to study the effect of various doses of BGA and urea fertilizers on paddy. They observed that there was 0.27 to 6.25% increase in yield. Khairnar and Thakur (2011) conducted the experiments on use of BGA with chemical fertilizers and chemical fertilizers alone in Maharashtra in which they observed that in first year of experiments there was no significant yield difference in both plots but in the second year, BGA treated plots showed statistically significant increase in crop yield. In another study, Anil Kumar et al. (2003) reported that increase in grain yield of finger millet may be due to combined use of FYM, fertilizers and *Azotobacter* inoculation over NPK fertilizer alone.

Yield response and net return

The data relating to yield response and net return per Re spent on fertilizer under various treatments presented in Table 2 revealed that the T_5 treatment (STCR equation based NPK application, BGA @12 kg, PSB @1.5 kg and Zn @ 5 kg ha^{-1}) ensured highest yield response (15.51 kg) kg^{-1} fertilizer use followed by T_4 (13.21 kg) and T_2 (13.12 kg) treatments over T_3 (10.81 kg). Though the yield response was low in T_3 (GRD based on STV), the grain and straw yields were remarkably higher in comparison to that of T_2. Despite enormous fertilizer use in T_2, yield response was discouraging which advocates that blanket application of fertilizers without soil test is not helpful for getting optimum yield; hence, this practice is usually disheartened.

The net return (Rs) Re^{-1} spent on fertilizer was recorded highest in T_4 treatment (Rs.10.55) over T_5 (Rs.10.37) as the use of organic inoculants in conjunction with inorganic fertilizers enhanced the cost of fertilizer; however, the rice yield was highest in the said treatment. The net return (Rs) Re^{-1} spent on fertilizer was noted lowest (Rs.9.79) in T_3 as the quantity of NPK fertilizer was higher as it was based on the soil test value of available NPK nutrients, though the rice yield was appreciably high

Table 3. Economics of rice cultivation under various treatments.

Treatments	Cost of cultivation (Rsha^{-1})	Gross returns (Rsha^{-1})	Net returns (Rsha^{-1})	Benefit cost (B:C) ratio	Additional cost (Rsha^{-1})	Additional net return (Rsha^{-1})
T_1	10721	24649	13928	1.30	-	-
T_2	10930	30908	19978	1.83	209	6050
T_3	11403	34930	23527	2.06	682	9599
T_4	11526	38186	26660	2.31	805	12732
T_5	11744	40199	28455	2.42	1023	14527

Table 4. Soil physicochemical properties and fertility status as influenced by different approaches of nutrient management.

Treatments	Physicochemical properties						Fertility status (kg ha^{-1})					
	pH		EC (dSm^{-1})		OC (%)		N		P_2O_5		K_2O	
	BT	AH	BT	AH	BT	AH	BT	AH	BT	AH	BT	AH
T_1	7.3	7.4	0.22	0.26	0.27	0.20	115.35	95	18.8	21.0	255.8	224.3
T_2	7.3	6.9	0.22	0.29	0.27	0.30	115.35	143	18.8	18.2	255.8	258.4
T_3	7.3	7.1	0.22	0.20	0.27	0.34	115.35	157	18.8	19.6	255.8	247.8
T_4	7.3	7.2	0.22	0.17	0.27	0.41	115.35	180	18.8	22.1	255.8	262.2
T_5	7.3	6.9	0.22	0.20	0.27	0.50	115.35	200	18.8	24.7	255.8	265.5

BT – Before transplanting, AH – After crop harvest.

than that of T_2.

Economic performance

The data given in Table 3 dealt with economics of rice cultivation under various treatments and reveal that the gross and net returns were remarkably higher with the STCR technology treatments. Highest net return was observed in T_5 (STCR equation based NPK application with biofertilizers) with an additional return of Rs.14527 followed by STCR equation based NPK application only in T_4 (Rs.12732) and T_3 (Rs.9599) treatments over farmers' practice (control) respectively. The lowest net return (Rs.19978) was noted in T_2 (Blanket NPK application without soil test).

The BC ratio was remarkably higher in STCR treatments *viz.* T_5 and T_4 in comparison to that of GRD and blanket application of NPK fertilizers. It was also observed that the BC ratio was nearly twofold in the T_5 treatment in comparison to that of farmers' practice which divulges the effective and efficient utilization of the fertilizers through STCR technology. Similar trends were noticed in earlier findings of Bera et al. (2006) and Ramanaiah et al. (2011, 2012).

Soil characteristics

The average value of the soil physicochemical properties and fertility parameters (before transplanting and after crop harvest) given in Table 4 indicates that initially the soils were neutral in reaction with average pH 7.3 and low in soluble salts (0.22 dSm^{-1}) which were observed to be neutral with less soluble salt concentration after three consecutive paddy crops in *kharif* season in all the treatments.

The organic carbon content which was earlier measured low (0.27%) in the experimental fields before transplanting, increased in all the treatments except farmers' practice in 2011. The organic carbon content was noticed to be remarkably high in STCR treatments especially in T_5. The soils were very low in N (115.35 kg ha^{-1}), medium in P (18.8 kgha^{-1}) and high in K (255.8 kg ha^{-1}) before paddy transplanting. The available N increased in all the treatments except farmers' practice in 2011, however, the remarkable rise was observed in STCR treatments as it arose in low category from very low and it varied from 180 to 200 kg ha^{-1}. The P and K status also improved in all the treatments except T_1 (farmers' practice) in case of K_2O and T_2 in case of P_2O_5. The higher values of these parameters were noted in STCR treatments especially in T_5 due to use of PSB which helped in increasing solubility of P_2O_5; however, the availability class in the soil for these parameters remained as such. These results suggest that the specific yield based on STCR equation not only optimizes the crop yield to the desired level but maintains the better soil health which is a prime factor for sustainable crop production.

The above findings suggest that STCR technology may be the appropriate approach for optimum nutrient supply which improves the soil properties especially the soil health and productivity in a long run in comparison to other nutrient management technologies. The results indicated that the integrated nutrient supply with inorganic fertilizers through STCR approach is necessary for both productivity and sustainability and it also results in higher gross returns, net returns and BC ratio.

Conclusion

The study thus revealed that the targeted yield in rice could be achieved within ±5% deviation with STCR technology; however, the integrated nutrient supply using STCR approach optimized the yield level to the desired target. The enhanced productivity of rice may be accredited to improved soil properties and better nutrient use efficiency of applied nutrients.

Conflict of Interest

The authors have not declared any conflict of interests.

REFERENCES

Adhya TK (2011). Vision 2030: Central Rice Research Institute technical bulletin Cuttack, Odisha" pp.1-22.

Agricultural Statistics (2011). Area, production and yield of agricultural crops. Directorate of agriculture, Govt. of Madhya Pradesh, Bhopal, pp.1-164.

Anil Kumar BH, Sharanappa KT Krishne Gowda, Sudhir K (2003). Growth, yield and nutrient uptake as influenced by integrated nutrient management in dry land finger millet. Mysore J. Agric. Sci. 37(1):24-28.

Anonymous (2011). State-wise area, production and productivity of rice during 2007-08 to 2009-10. Directorate of Rice Development, Govt. of India, Patna, pp.1-12.

Anonymous (2011a). KVK at a glance. Jawaharlal Nehru Krishi Vishwa Vidyalaya, Krishi Vigyan Kendra, Katni, pp.1-16.

Apoorva KB, Prakash SS, Rajesh NL, Nandini B (2010). STCR Approach for optimizing integrated plant nutrient supply on growth, yield and economics of finger millet (*Eleusine coracana* (L.) Garten.). EJBS 4(1):19-27.

Bera R, Seal A, Bhattacharyya P, Das TH, Sarkar D and Kangjoo K (2006). Targeted yield concept and a framework of fertilizer recommendation in irrigated rice domain of subtropical India. Zhejiang Univ Sci B. 7(12):963-968.

Khairnar SP, Thakur HA (2011). Blue Green Algae (BGA) biofertilizers : an ecofriendly biotechnology for paddy". Life Sci. Bull. 8(2):269-272.

Pachpade RR (1990). Role of algal biofertilizer for increasing yield of irrigated plantation crops. In Proceedings of National symposium on cynobacterial nitrogen fixation (abstracts), IARI, New Delhi, P. 29.

Ramanaiah KV, Dhanalakshmi G, Giridhara Krishna T, Munirathnam P, Rajender P, Reddy G (2011). Soil test crop response (STCR) based nutrient application in irrigated rice domains of Kurnool district of Andhra Pradesh. Int. J. Agric. Sci. 1:55-61.

Ramanaiah KV, Dhanalakshmi, G, Rajender Reddy G, Krishna Murthy A, M Sudhakar (2012). Study on the impact of site specific nutrient management technologies in rice under irrigated domains of Kurnool district of Andhra Pradesh. Asian J. Biol. Life Sci. 1:154-158.

Rao KV (2011). Site–specific integrated nutrient management for sustainable rice production and growth. Rice Knowledge Management Portal (RKMP) Publication, Directorate of Rice Research, Rajendranagar, Hyderabad, pp.1-71.

Singh AN, Sinha SK, Pandey VP, Dubey AK, Verma DC (1992). Effect of blue green algae inoculation on yield of paddy in different districts of U.P. New Agric. 3(2):189-192.

Steel RGD, Torrie JH, Dickey D (1997). Principles and procedures of statistics: A biometrical approach, 3rd Ed. McGraw Hill Book Co. Inc. New York, pp.172-177.

Tiwari KN (2012). Rice Production and Nutrient Management in India. Better Crops International 16 (Special Supplement): pp. 18-22.

Venkaraman GS (1982). Nitrogen fixation by blue green algae and its economic importance. In Proceedings of symposia papers 1. Non symbiotic nitrogen fixation and organic matter in the tropics .Int. Congress of Soil Sci. New Delhi 12:69-82.

academicJournals

Vol. 10(5), pp. 351-358, 29 January, 2015
DOI: 10.5897/AJAR2014.8919
Article Number: 9F841E149860
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Evaluation of different fungicides, bioagents and botanicals against *Alternaria* blight caused by *Alternaria helianthi* (Hansf) of sunflower

Waghe, K. P.[1], Wagh, S. S.[2]*, Kuldhar, D. P.[2] and Pawar, D. V.[2]

[1]Department of Plant Pathology, College of Agriculture, Latur, VNMKV, Parbhani-431 402, Maharashtra, India.
[2]Department of Plant Pathology, College of Agriculture Parbhani, VNMKV, Parbhani-431 402, Maharashtra, India.

Received 16 June, 2014; Accepted 17 December, 2014

Alternaria blight (*Alternaria helianthi* Hansf) is one of the major diseases of sunflower during *Kharif* season in Maharashtra. Present Lab study was conducted at Department of Plant Pathology and field experiment at Oilseed Research Station, College of Agriculture, Latur, VNMKV, Parbhani, Maharashtra, India. Here, six fungicides were evaluated at 500, 1000, 2000 and 2500 ppm; five botanicals each at 10 and 20%) by poisoned food technique and readymade formulations of four bioagents; three fungal antagonists were evaluated *in vitro* and *in vivo* against *A. helianthi-* an incitant of *Alternaria* blight; in sunflower all the treatments were found fungistatic and significantly inhibited mycelial growth and disease intensity of the test pathogen over untreated control. Among the fungicides, maximum inhibition was observed in treatment with SAAF at 2000 ppm (90.36%), followed by Mancozeb at 2500 ppm (88.88%). Among botanicals, maximum inhibition was recorded with Neem (63.05 and 68.88%) in addition to Karanj (56.38 and 63.60%) at 10 and 20% concentrations. Fungal bioagents, *T. harzianum* was found most effective and recorded maximum mycelial growth inhibition (72.22%), followed by *T. viride* (70.27%). Bacterial antagonist *P. fluorescens* was found comparatively least effective with 48.60% inhibition of the test pathogen. After lab study, effective treatments was tested on field condition; results revealed that fungicide seed treatment with SAAF at 3 g/kg seed + two sprays of SAAF at 0.2% at 30 and 45 DAS recorded highest disease control (82.82%) and highest seed yield (1686 kg/ha) followed by seed treatment with SAAF 12% at 3 g/kg seed + two sprays of Mancozeb at 0.25% at 30 and 45 DAS recorded disease control (78.50%) and seed yield (1595 kg/ha) over untreated control (00.00) (792 kg/ha). Minimum disease control (45.25%) was recorded in seed treatment with Neem seed powder at 10 g/kg + two sprays of Neem extract at 10% at 30 and 45 DAS with 908 kg/ha yield.

Key words: *Alternaria helianthi*, sunflower, fungicides, bioagents, botanicals, management.

INTRODUCTION

Sunflower (*Helianthus annus* L.) is one of the most important oilseed crops. The genus Helianthus is named from the Greek *Helio* meaning sun and *anthos* meaning flower. The family of sunflower is Compositae and the origin is southern U.S.A. and Mexico (Heiser, 1951). Sunflower seed is highly nutritious containing about 20%

*Corresponding author. E-mail: kwkwaghe37atgmail.com

protein and 40 to 50% vegetable oil associated with a very high calorific value. The oil is considered to be of high quality due to its non-cholesterol properties and has been recommended for the patient having heart problem. It contains 60 to 73% linoleic acid, with sufficient amount of calcium, iron and vitamins like A, B, E and K (Gosal et al., 1988).

India is the largest grower of sunflower with an area of 0.90 million hectares, production of 0.62 million tonnes and the average productivity of 696 kg/ha. Important sunflower growing states in the country are Karnataka, Andhra Pradesh, Maharashtra, Tamil Nadu, Bihar, Punjab, Haryana and Uttar Pradesh. Almost 50% of area and production is accounted for by Karnataka followed by Andhra Pradesh and Maharashtra. In Maharashtra sunflower is cultivated on an area of 0.20 million hectares, and production of 0.11 million tonnes with an average productivity of 677 kg/ha (Anonymous, 2011a). Marathwada region of the state accounts for about 70% of area and production of the state. In Marathwada region sunflower is cultivated on an area of 0.13 million hectares, and production of 0.08 million tonnes with an average productivity of 633 kg/ha (Anonymous, 2011b).

Sunflower suffers from many diseases caused by fungi, bacteria, and viruses. Sunflower is the known host of more than 30 pathogens mostly fungi which under certain climatic condition may impair the normal physiology of the plant so that yield and oil quality are reduced significantly (Gulya et al., 1994). Some of the most important fungal diseases of sunflower are *Alternaria* leaf blight (*Alternaria helianthi),* Rust (*Puccinia helianthi*), Powdery mildew (*Erysiphe cichoracearum*), Downy mildew (*Plasmopara halstedii*), Root rot (*Macrophomina phaseoli*), Collar rot (*Sclerotium rolfsii*), Head rot (*Rhizopus* spp.), Verticillium wilt (*Verticillium dahliae*) and Leaf spot (*Helminthosporium helianthi*).

The yield losses due to *A. helianthi* varied from 48 to 57% in sunflower cultivars Morden and APSH-11 at different growth stages, respectively (Mayee and Wankhede, 1997). Sunflower cultivation throughout the country in general and particularly in the state of Maharashtra and Karnataka has been facing serious problem of the *A. helianthi* incidence.

MATERIALS AND METHODS

Isolation

Sunflower leaves showing typical symptoms of disease were collected, washed with tap water to remove dirt, air dried and affected parts were cut into small pieces of about 2 cm in length. These pieces were disinfected with 1:1000 mercuric chloride solutions for a minute and rinsed with three changes of sterilized water to remove traces of corrosive disinfectant. These pieces were then transferred aseptically to sterilized plates poured with potato dextrose agar medium. The plates poured with sterilized medium were then incubated in inverted fashion in an incubator at 27°C±1 temperature. Profuse growth of the fungus on plates was observed after one week. Following hyphal-tip technique, test pathogen was transferred aseptically on the PDA slant in test tubes. Through frequent sub-culturing, the pathogen was purified and its pure culture was maintained on agar slant in test tubes and stored in refrigerator for further studies.

Identification

Pure culture of test pathogen obtained was inoculated aseptically on autoclaved PDA in Petri plates and plates were incubated at 27±1°C. A profuse growth of a fungus in plates was observed after one week. Cultural, morphological and microscopic characteristics of fully developed test pathogen were studied under low power as well as high power magnification of microscope.

Pathogenicity test

Ten days old culture of the organism was used for proving the pathogenicity by applying Koch's postulates. For this purpose, seeds of sunflower hybrid KBSH-44 which is susceptible to *Alternaria* blight (*A. helianthi*) were surface sterilized with 0.1% $HgCl_2$, and sown in the earthen pots filled with steam sterilized potting mixture of soil:sand:FYM (2:1:1). Healthy growing sunflower seedlings were maintained, watered regularly and kept in the screen house for further development. Three weeks old healthy seedlings were selected for inoculation. The spore suspension was prepared and filtered through two layers of sterile muslin cloth to remove residual mycelia. Filtrate obtained was suitably diluted with sterile distilled water to get inoculum concentration of 1×10^6 spores/ml.

The seedlings were inoculated with 10 days old test fungus. Uninoculated seedlings of the same age sprayed with sterilized water served as control. After inoculation, the seedlings pots (both inoculated and uninoculated) were incubated in the screen house, where relative humidity (80 to 90%) and optimum temperature (27±1°C) were maintained for further development of *Alternaria* blight symptoms. Re-isolation was made from inoculated leaves by the isolated fungus which resembled in all respect with the original culture used for inoculation.

Efficacy of fungicides, botanicals and bioagents (*in vitro*)

In vitro evaluation of fungicides

Efficacy of six fungicides *viz.,* SAAF (Mancozeb 63% + arbendazim 12%) 75 WP, Azoxystrobin 25 SC, Mancozeb 75 WP, ropiconazole 25 EC, Chlorothalonil 75 WP, Hexaconazole 5 EC were evaluated *in vitro* against *A. helianthi*, by Poisoned food technique (Nene and Thapliyal, 1993). The requisite quantity of each fungicide based on active ingredient was calculated and mixed thoroughly with autoclaved and cooled (40°C) Potato dextrose agar medium (PDA) in conical flasks to obtain desired concentrations in ppm. Plain PDA medium without fungicide served as control. Fungicide amended PDA medium was then poured aseptically in Petri plates (90 mm dia.). After solidification of the medium, all the plates were inoculated aseptically with 5 mm culture disc of the test fungus obtained from a week old actively growing pure culture of *A. helianthi*. The disc was placed on PDA in inverted position in the centre of the Petri plates and plates were incubated at 27±1°C. Each treatment was replicated thrice. When medium in the untreated control plates was fully covered with mycelial growth of the test fungus, radial mycelial growth was measured in all the treatment plates. Per cent inhibition of mycelial growth in treated plates was calculated by applying the formula given by Vincent (1927).

$$\text{Per cent Inhibition (I)} = \frac{C - T}{C} \times 100$$

Where, C = Growth (mm) of test fungus in untreated control plate.
T = Growth (mm) of test fungus in treated plates.

In vitro efficacy of bioagents

Three fungal antagonists *viz.*, *Trichoderma viride, T. harzianum, T. hamatum,* and one bacterial antagonist *viz., Pseudomonas fluorescens* were evaluated *in vitro* against *A. helianthi* applying dual culture technique (Dennis and Webster, 1971). Seven days old cultures of the test bioagents and test fungus *(A. helianthi)* grown on agar media were used for the study. Discs (5 mm dia.) of PDA along with culture growth of the test fungus and bioagents were cut out with sterilized cork borer. Then two culture discs, one each of the test fungus and bioagents were placed aseptically at equidistance and exactly opposite with each other on solidified PDA medium in Petri plates and plates were incubated at 27±1°C. PDA plates inoculated only with culture disc of test fungus were maintained as untreated control. Observations on mycelial growth of the test fungus and bioagents were recorded at an interval of 24 h and continued till untreated control plate was fully covered with mycelial growth of the test fungus. Per cent inhibition of the test fungus over untreated control was calculated by applying the formula given by Arora and Upadhyay (1978).

$$\text{Per cent growth inhibition} = \frac{\text{Colony growth in control plate} - \text{Colony growth in intersecting plate}}{\text{Colony growth in control plate}} \times 100$$

In vitro evaluation of botanicals (Plant extracts)

Plant extracts of five botanicals *viz.* Karang (*Pongamia glabra),* Neem (*Azadirachta indica*), Nirgudi *(Vetex negundo),* Mehandi *(Lawsonia innermis),* Dhotra *(Dhatura metal)* were evaluated against *A. helianthi*. Leaf extracts were prepared by grinding with mixture-cum grinder the 100 g washed leaves, of each plant species in 100 ml distilled water and filtered through double layered muslin cloth. The filtrates obtained were further filtered through Whatman No. 1 filter paper using funnel and volumetric flasks (100 ml cap.). The final clear extracts filtrates obtained formed the standard plant extracts of 100% concentration, which were evaluated (at 10 and 20%) *in vitro* against *A. helianthi,* applying poisoned food technique. (Nene and Thapliyal, 1993) and using potato dextrose agar as basal culture medium. An appropriate quantity of each plant extract (100%) was separately mixed thoroughly with PDA medium in conical flasks (250 ml cap.) to obtain desired concentrations of 5 and 10% after being autoclaved PDA at 15 lbs/inch^2 pressure for 15 to 20 min. Sterilized and cooled PDA medium amended separately with plant extract was then poured (15 to 20 ml/plate) into sterile glass Petri plates (90 mm dia.) and allowed to solidify at room temperature. Each plant extract and its, respective concentrations were replicated thrice. The plates containing plain PDA without any plant extract were maintained as untreated control. Upon solidification of PDA, all the treatment and control plates were aseptically inoculated by placing in the centre a 5 mm mycelial disc obtained from a week old actively growing pure culture of *A. helianthi*. Plates containing plain PDA and inoculated with mycelial disc of the test fungus served as untreated control. All these plates were then incubated at 27±1°C temperature for a week or till the untreated control plates were fully covered with mycelial growth of the test fungus.

Observations on radial mycelial growth/colony diameter of the test fungus were recorded treatment-wise at 24 h interval and continued till mycelial growth of the test fungus was fully covered in the untreated control plates. Percent inhibition of mycelial growth over untreated control was calculated by applying the formula given by Vincent (1927).

In vivo evaluation of fungicides, botanicals and bioagents

The field experiment was conducted on the research farm of the Oilseed Research Station, Latur during *Kharif*, 2011, to evaluate the efficacy of fungicides, botanical and bioagent. The Neem seed kernel extract obtained from Oilseed Research Station, Latur, fungicides obtained from the Department of Plant Pathology, College of Agriculture, Latur and The talc-based formulations of the bioagent *T. viride* (5×10^6 cfu/g) obtain from the MKV, Parbhani:

Design: R.B.D. (Randomized Block Design)
Variety: KBSH- 44
Replications: Three
Treatments: Eight
Plot size: 4.2 m x 3.0 m
Spacing: 60 cm x 30 cm.
Gross area: 40.6 x 11 m

Treatments

$T_{1:}$ Seed treatment with SAFF (Mancozeb 63% +Carbendazim 12%) 75 WP at 3 g/kg seed.
T_2: T_1 + two spray of SAFF at 0.2%.
$T_{3:}$ T_1 + two spray of Amistar (Azoxystrobin25 SC) at 0.05%.
T_4 : T_1 + two spray of Amistar (Azoxystrobin 25 SC) at 0.1%.
T_5 : T_1 + two spray of Mancozeb 75 WP (Dithane M- 45) at 0.25.
T_6: Seed treatment with *T. viride* at 10 g /kg seed + two spray of *T. viride* at0.5% spray.
T_7 : Seed treatment with Neem seed powder at 10 g /kg seed + two spray of Neem extract at 10%.
T_8 : Control (unsprayed).

The seeds of sunflower hybrid KBSH-44 susceptible to *Alternaria* blight were sown (20.07.2011) on the experimental field Oilseed Research Station, Latur. The crop was raised applying recommended package of practices and protective irrigation was given as and when required. Treatment sprays were undertaken as soon as the disease appeared, that is, on 30th day and second spray was undertaken 15 days after first spray, that is, (45 DAS). Observations on disease severity were recorded.

Percent disease intensity/severity

Percent intensity (severity) was calculated as per the standard area diagram developed by Mayee and Datar (1986). For recording the disease intensity at field conditions 0 to 9 disease rating scale developed by Mayee and Datar (1986) was used. For this purpose two leaves located at the bottom, two at middle and two top of the plant were chosen and scored as per scale given in Table 1.

The average intensity of each plot was worked out by using following formula.

$$\text{P.D.I.} = \frac{\text{Summation of all numerical ratings}}{\text{Total no. of plant} \times \text{Maximum rating scale observed}} \times 100$$

Where, PDI = Percent disease intensity.

Percent disease control (PDC)

Percent disease control (PDC) was worked out by applying the formula:

Table 1. Leaves percent disease intensity/severity.

Percent leaf area infected	Score	Disease reaction
Zero	0	Immune
Less than 1%	1	Highly resistant
1 to 5%	3	Resistant
6 to 25%	5	Moderately resistant
26 to 50%	7	Susceptible
More than 50%	9	Highly susceptible

$$PDC = \frac{\text{PDI in control plot} - \text{PDI in treatment plot}}{\text{PDI in control plot}} \times 100$$

Harvesting and threshing

Harvesting of respective sown crop was done after complete maturity of the crop. Threshing was done one week after harvesting so as to get dried seeds.

Yield

Yield of each treatment in all replications was recorded. Initially, yield of net plot was recorded on plot size basis and then converted into hectare basis.

Economics of fungicides, botanical and bioagent

To find out the most effective and economical treatment, the economics of each treatment was worked out. While calculating the cost of production, the expenditure incurred on the accounts of fungicides, botanicals and bioagents and labour charges for spraying were taken into account. Total monetary gain per treatment on hectare basis was worked out based on the existing sealing rates of the sunflower in the market and finally the B:C ratio of the treatments was worked out.

RESULTS AND DISCUSSION

Disease management strategies

In vitro evaluation of fungicides

Effect of these fungicides on radial growth and inhibition of test pathogen were recorded. All the treatments were replicated thrice and a suitable untreated control (without fungicide) was also maintained.

Results (Tables 2 and 3) revealed that the fungicides tested (at 500, 1000, 2000 and 2500 ppm) significantly inhibited growth of the test fungus over untreated control (00.00%). Further, it was found that per cent inhibition of the test pathogen was increased with the increase in concentration of the fungicides tested. At 500 ppm, concentration maximum inhibition was recorded with Propiconazole (82.22%), this was followed by the fungicides Hexaconazole (79.99%) and Azoxystrobin (72.96%).

At 1000 ppm, concentration maximum inhibition was recorded with Propiconazole (87.03%), this was followed by the fungicides SAAF (86.29%) and Hexaconazole (82.59%). Least growth inhibition was recorded with Chlorothalonil (57.03%) and Azoxystrobin (78.88%).

At 2000 ppm, concentration maximum inhibition was recorded with SAAF (90.36%), this was followed by the fungicides Mancozeb (83.33%). Least growth inhibition was recorded with Chlorothalonil (64.81%).

At 2500 ppm, (Mancozeb) maximum per cent growth inhibition was 88.88% as compared to (00.00%) in untreated control.

From the result it is revealed that the maximum inhibition of the test pathogen recorded by combination of SAAF at 2000 ppm (90.36%); this was followed by Mancozeb at 2500 ppm (88.88%), Propiconazole at 1000 ppm (87.03%), Hexaconazole at 1000 ppm (82.59%) and minimum inhibition recorded by Chlorothalonil at 1000 ppm (57.03%); and was further followed by Azoxystrobin at 500 ppm (72.96%) as compared to (00.00%) in untreated control.

The results obtained in present studies in respect of *in vitro* effect of fungicides on mycelial growth inhibition of the test pathogen for the combination of SAAF, Azoxystrobin, Mancozeb, Propiconazole, Chlorothalonil and Hexaconazole fungicides effect is similar with earlier workers (Amaresh and Nargund, 2004; Akbari and Parakhia, 2007; Mathivanan and Prabavathy, 2007).

In vitro efficacy of bioagents

Three fungal (*T. viride, T. harzianum* and *T. hamatum),* and one bacterial (*P. fluorescens*) bioagents were evaluated *in vitro* against *A. helianthi* applying dual culture technique (Dennis and Webster, 1971) and using Potato dextrose agar (PDA) as basal medium.

Results (Table 4) revealed that all the bioagents evaluated exhibited fungistatic activity and significantly inhibited mycelial growth of *A. helianthi*. Of the four bioagents tested, *T. harzianum* was found most effective which recorded least mycelial growth (25.00 mm) and corresponding highest mycelial growth inhibition(72.22%) of the test pathogen over untreated control (90.00 mm and 00.00%, respectively), followed by *T. viride* (growth: 26.75 mm and inhibition: 70.27%) and *T. hamatum* (growth: 43.50 mm and inhibition: 51.66%). Bacterial

Table 2. *In vitro* effect of fungicides at different concentrations on radial mycelial growth and inhibition of *A. helianthi.*

Fungicides	Concentration (ppm)	Radial growth (mm)*	Inhibition (%)*
Azoxystrobin	500	24.33	72.96 (58.67)**
Propiconazole	500	16.00	82.22 (65.05)
Hexaconazole	500	18.00	79.99 (63.47)
SAAF	1000	12.33	86.29 (68.28)
Chlorothalonil	1000	38.66	57.03 (49.04)
Mancozeb	2000	15.00	83.33 (65.92)
Control	--	90.00	00.00 (0.00)
SE±	--	1.09	0.80
CD	--	3.30	2.43

*Average of three replications; ** Figures in parenthesis are angular transformed values.

Table 3. *In vitro* effect of fungicides at different concentrations on radial mycelial growth and inhibition of *A. helianthi.*

Fungicides	Concentration (ppm)	Radial growth (mm)*	Inhibition (%)*
Azoxystrobin	1000	19	78.88 (62.65)**
Propiconazole	1000	11.66	87.03 (68.89)
Hexaconazole	1000	15.66	82.59 (65.34)
SAAF	2000	8.66	90.36 (71.94)
Chlorothalonil	2000	31.66	64.81 (53.61)
Mancozeb	2500	10	88.88 (70.52)
Control	_	90	00.00 (0.00)
SE±	--	0.90	0.75
CD	--	2.75	2.28

*Average of three replications; ** Figures in parenthesis are angular transformed values.

Table 4. *In vitro* effect of different bioagents on growth and inhibition of *A. helianthi.*

Treatments	Average colony diameter* pathogen (mm)	Per cent inhibition
T. viride	26.75	70.27 (56.96)**
T. harzianum	25.00	72.22 (58.19)
T. hamatum	43.50	51.66 (45.94)
P. fluorescens	46.25	48.60 (44.19)
Control	90.00	00.00 (00.00)
SE±	0.80	0.53
CD	2.41	1.61

* Average of four replications; ** Figures in parenthesis are angular transformed values.

antagonist *P. fluorescens* were found comparatively least effective with 46.25 mm linear mycelial growth and 48.60% inhibition of the test pathogen.

Thus, all the fungal and bacterial bioagents evaluated *in vitro* were found fungistatic against *A. helianthi*; the fungal bioagent was found effective than bacterial bioagent, for inhibition of test pathogen are in conformity to those reported earlier by several workers (Meena et al., 2004; Singh et al., 2005; Rao, 2006).

In vitro efficacy of plant extracts/botanicals

Result (Table 5) revealed that all the plant extracts, that is, Karanj, Neem, Nirgudi, Mehandi, Dhotra (at10 and 20% each), significantly inhibited growth of the test fungus over untreated control (00.00%) Further, it was found that inhibition of test pathogen was increased with increase in concentration of the botanicals tested.

At 10 and 20% concentration, maximum inhibition was

Table 5. *In vitro* effect of different plant extract/botanicals on growth and inhibition of *A. helianthi.*

Plant extracts	Radial growth (mm)*		Mean (mm)	Percent inhibition at concentration*		Mean
	10%	20%		10%	20%	
Karanj	39.25	32.75	36	56.38 (48.66)**	63.60 (52.89)	59.99
Neem	33.25	28	30.62	63.05 (52.56)	68.88 (56.09)	65.96
Nirgudi	45	41.25	43.12	49.99 (44.99)	54.16 (47.38)	52.07
Mehandi	42.75	35.5	39.12	52.49 (46.42)	60.55 (51.09)	56.52
Dhotra	53.5	46.25	49.87	40.55 (39.54)	48.60 (44.19)	44.57
Control	90.00	90.00	90.00	00.00 (00.00)	00.00 (00.00)	00.00
SE±	0.85	0.84	0.84	0.55	0.55	0.55
CD	2.55	2.50	2.53	1.64	1.63	1.63

* Average of four replications; ** Figures in parenthesis are angular transformed values.

recorded with Neem (63.05 and 68.88%), this was followed by Karanj (56.38 and 63.60%), Mehandi (52.49 and 60.55%). Minimum inhibition was recorded with Dhotra (40.55 and 48.60%) which was followed by Nirgudi (49.99 and 54.16%).

Both concentrations (at 10 and 20%) of the plant extract were found effective in the inhibition of the test pathogen. However, higher concentration (at 20%) caused maximum (48.60 to 68.88%) inhibition of mycelial growth compared to lower concentration (at10%) which recorded comparatively minimum inhibition of mycelial growth in the range of 40.55 to 63.05%.

Thus, all the botanicals tested *in vitro* against *A. helianthi* (Hansf.) Tubaki and Nishihara were found effective in inhibiting the mycelial growth of the test pathogen over control. The result agree with the result of research workers (Ranjan et al., 1999; Amaresh, 2000; Rao, 2006).

In vivo evaluation of fungicides, botanicals and bioagents

Disease control, severity and seed yield: The results presented in Table 6 revealed that all treatments were found significantly superior over the control. Among all the treatments used at 30 and 45 DAS spray, treatment T_2 (seed treatment with SAAF 3 g/kg and two sprays with SAAF at 0.2%) was most effective in *Alternaria* blight highest disease control and lowest disease severity (82.82 and 9.22%) with highest seed yield 1686 kg/ha followed by T_5 (seed treatment with SAAF 3 g/kg and two sprays with Mancozeb at 0.25%) disease control and severity (78.50 and 11.55%) with 1595 kg/ha seed yield, T_4 (seed treatment with SAAF 3 g/kg and sprays with Azoxystrobin at 0.1%) disease control and severity (74.12 and 13.90%) with 1468 kg/ha seed yield and T_3 (seed treatment with SAAF 3 g/kg and sprays with Azoxystrobin 0.05%) disease control and severity (70.21 and 16.00%) with 1344 kg/ha seed yield.

Minimum disease control and high disease severity was observed in treatment seed treatment with Neem seed powder at 10 g/ha seed + two spary of Neem extract at 10% (45.25 and 29.38%) with lowest 908 kg/ha seed yield, followed by T_6 (seed treatment with *T. viride* 10 g/kg and sprays with *T. viride* 0.5%) disease control and severity (47.04 and 28.42%) with 956 seed yield and T_1 (seed treatment with SAAF 3 g/kg) disease control and severity(53.17 and 25.13%) with 1026 seed yield.

Thus the new fungicides Mancozeb + Carbendazim (SAAF) evaluated against *A. helianthi* under field condition effectively controlled the *Alternaria* blight of sunflower and could be exploited on large scale for the management of the disease.

However, efficacy of fungicides, botanicals and bioagent in controlling *Alternaria* blight disease was reported earlier by several workers (Amaresh et al., 2000; Mathivanan and Prabavathy, 2007; Singh and Singh, 2007; Rao, 2006; Arunakumara et al., 2010).

Economics (Benefit:Cost ratio) of fungicides

The data presented in Table 7 indicated that highest B:C ratio of 4.02 was recorded in the treatment T_2 (seed treatment with SAAF at 3 g/kg seed + two sprays of SAAF at 0.2% at 30 and 45 DAS). Next best treatment was treatment T_5 (seed treatment with SAAF at 3 g/kg seed + two sprays of Mancozeb at 0.25% at 30 and 45 DAS) which recorded B:C ratio of 3.85 followed by the treatment T_1 (seed treatment with SAAF at 3 g/kg seed) and T_3 (seed treatment with SAAF at 3 g/kg seed + two sprays of Azoxystrobin at 0.05% at 30 and 45 DAS), T_6 (seed treatment with *T. viride* 10 g/kg and sprays with *T. viride* 0.5% at 30 and 45 DAS), T_4 (seed treatment with SAAF at 3 g/kg seed + two sprays of Azoxystrobin at 0.1% at 30 and 45 DAS), and T_7 (seed treatment with Neem seed powder 10 g/kg and sprays with Neem extract 10% at 30 and 45 DAS) which recorded the B:C ratio of 2.82, 2.69, 2.39, 2.37, and 2.27 respectively over treatment T_8 (untreated control) recorded lowest B : C ratio of 2.18.

Table 6. *In vivo* efficacy of fungicides, bioagent and botanical against *Alternaria* blight severity, disease control and yield in sunflower.

Treatment No.	Treatment details	*Alternaria* severity (%)*	Disease control (%)*	Mean yield (kg/ha)*
T1	Seed treatment with SAFF at 3 g/kg seed.	25.13 (30.07)	53.17 (46.81)**	1026
T2	T1 + two sprays of SAFF at 0.2% at 30 and 45 DAS	9.22 (17.67)	82.82 (65.51)	1686
T3	T1 + two sprays of Azoxystrobin at 0.05% at 30 and 45 DAS	16.00 (23.57)	70.21 (56.91)	1344
T4	T1 + two sprays of Azoxystrobin at 0.1% at 30 and 45 DAS	13.90 (21.88)	74.12 (59.42)	1468
T5	T1 + two sprays of Mancozeb at 0.25% at 30 and 45 DAS	11.55 (19.86)	78.50 (62.36)	1595
T6	Seed treatment with *T. viride* at 10 g/kg seed + two sprays of *T. viride* at 0.5% at 30 and 45 DAS	28.42 (32.21)	47.04 (43.31)	956
T7	Seed treatment with Neem seed powder at 10 g/kg seed + two sprays of Neem extract at 10% at 30 and 45 DAS	29.38 (32.81)	45.25 (42.26)	908
T8	Control (untreated)	53.71 (47.12)	00 (0.00)	792
	S.E. ±	0.34	0.54	40.23
	C.D.	1.06	1.66	122.03

* Mean of three replications; ** Figures in parenthesis are angular transformed values.

Table 7. Economics of fungicides, bioagent and botanical for management of *Alternaria* blight in sunflower.

Treatment No.	Treatment details	Mean yield (kg/ha)*	Gross monitory returns (Rs.)	Cost of fungicide (Rs.)	Total Cost of cultivation (Rs.)	Net returns (Rs.)	B:C ratio
T_1	Seed treatment with SAFF at 3 g/kg seed.	1026	25650	25	9075	16575	2.82
T_2	T_1 + two sprays of SAFF at 0.2% at 30 and 45 DAS	1686	42150	1425	10475	31675	4.02
T_3	T_1 + two sprays of Azoxystrobin at 0.05% at 30 and 45 DAS	1344	33600	3425	12475	21125	2.69
T_4	T_1 + two sprays of Azoxystrobin at 0.1% at 30 and 45 DAS	1468	36700	6425	15475	21225	2.37
T_5	T_1 + two sprays of Mancozeb at 0.25% at 30 and 45 DAS	1595	39875	1300	10350	29525	3.85
T_6	Seed treatment with *T. viride* at 10 g/kg seed + two sprays of *T. viride* at 0.5% at 30 and 45 DAS	956	23900	930	9980	13920	2.39
T_7	Seed treatment with Neem seed powder at 10 g/kg seed + two sprays of Neem extract at 10% at 30 and 45 DAS	908	22700	925	9975	12725	2.27
T_8	Control (untreated)	792	19800	-	9050	10750	2.18
	S.E. ±	40.23	-	-	-	-	-
	C.D.	122.03	-	-	-	-	-

* Mean of three replication; ** Figures in parenthesis are angular transformed values; Market price of sunflower is 2500 Rs/qt. Cost of cultivation: 9050 Rs/ha.

Thus all spray treatments of fungicides, were found economically effective and bioagent; botanicals were found economically less effective for management of *Alternaria* blight disease of sunflower. The maximum B : C ratio was recorded with T_2 (seed treatment with SAAF at 3 g/kg seed

+ two sprays of SAAF at 0.2% at 30 and 45 DAS), that is, 4.02 and minimum 2.27 with T_7 (seed treatment with Neem seed powder 10 g/kg and sprays with Neem extract 10% at 30 and 45 DAS).

These results obtained on the economics of fungicidal spraying treatments for the management of sunflower *Alternaria* blight disease are in conformity with those reported earlier by several workers (Singh, 2000; Mathivanan and Prabavathy, 2007).

Conflict of Interest

The authors have not declared any conflict of interest.

REFERENCES

Anonymous (2011a). Annual report 2010-2011.Directorate of Agriculture, Andhra Pradesh.

Akbari LF, Parakhia AM (2007). Management of *Alternaria alternata* causing blight of sesame with fungicides. J. Mycol. Plant Pathol. 37(3):426-430.

Amaresh YS (2000). Epidemiology and management of Alternaria leaf blight and rust of sunflower (*Helianthus annus* L.). Ph.D. Thesis, Univ. Agric. Sci., Dharwad, Karnataka, India, pp. 15-16.

Amaresh YS, Nargund, VB (2004). *In vitro* evolution of fungicides against *Alternaria helianthi* causing leaf blight of sunflower. Indian J. Plant Pathol. 22(1 &2):79-82.

Anonymous (2011b). Annual report of sunflower Oilseeds Research Station, Latur (Maharashtra).

Arora DK, Upadhyay RK (1978). Effect of fungal staling growth substances on colony interaction. Plant Soil 49:685-690.

Arunakumara KT, Kulkarni MS, Thammaiah N, Yashoda H (2010). Fungicidal management of early blight (*Alternaria solani*) of tomato. Indian Phytopathol. 63(1):96-97

Dennis C, Webster J (1971). Antagonistic properties of species group of *Trichoderma* and hyphal interactions. Trans. British Mycol. Soc. 57:363-369.

Gosal SS, Vasiljevic L, Brar DS (1988). Plant biotechnology and sunflower improvement. Proceedings of 12th International Sunflower Conference, Novisad, Yugoslavia, July, 25-29, P. 599.

Gulya T, Berlin N, Lamey A (1994). Sunflower disease in Sunflower production. Extension Bulletin (Ed. Berjlund, D. R., 1994. North Dakota Agricultural Experiment Station and North Dakota State University 98:44-62.

Heiser CB (1951). The sunflower among American Indian text. Proc. Am. Philosophical Soc. 95:43.

Mathivanan N, Prabavathy VR (2007). Effect of carbendazim and mancozeb combination on *Alternaria* leaf blight and seed yield of sunflower. Arachis Phytopathol. Plant Protect. 40(2):90-96.

Mayee CD, Datar VV (1986). Phytopathometry. Tech. Bull. J. Marathwada Agricultural University, Parbhani. P. 146.

Mayee CD, Wankhede PB (1997). Integrated management of the *Alternaria* disease. IPS Golden Jubilee International Conference on Integrated Plant Disease Management for Sustainable Agril. held on 10-15 Nov. 1997. New Delhi India P. 116.

Meena PD, Meena RL, Chattopadhyay C, Kumar A (2004). Identification of critical stage for disease development and biocontrol of *Alternaria* blight of Indian mustard (*Brassica* juncea). J. Phytopathol. 152(4):204 209.

Nene YL, Thapliyal RN (1993). Evaluation of fungicides in Fungicides for Plant Disaease Control (3rd ed.). Oxford, IHB Pub. Co. New Delhi. P. 331.

Ranjan S, Lal HC, Ojha KL, Ranjan S (1999). Efficacy of plant extracts against *Alternaria* leaf blight of sunflower *in vitro*. J. Appl. Biol. 9(1):93-94.

Rao MSL (2006). Studies on seed borne fungal diseases of sunflower and their management. Ph.D. Thesis, University of Agricultural Sciences, Dharwad pp. 55-90.

Singh HK, Singh RB (2007). Integrated management of *Alternaria* blight of Rapeseed-mustard. Indian Phytopathol. 60(3):396.

Singh SB, Kuwar S, Abhimanyu B (2005). Evaluation of native bio-agents against *Alternaria brassicae* causing *Alternaria* blight of mustard. Farm Sci. J. 14(2):64.

Singh SN (2000). Relative efficacy of fungicides against seedling mortality and *Alternaria* blight of sunflower (*Helianthus annuus* L.). J. Mycol. Plant Pathol. 39(1):119-120.

Vincent JM (1927). Distortion of fungal hyphae in the presence of certain inhibitors. Nature pp. 159-180.

academicJournals

Vol. 10(5), pp. 359-364, 29 January, 2015
DOI: 10.5897/AJAR2014.9010
Article Number: 2BA055649864
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Effect of Copper (Cu) application on soil available nutrients and uptake

M. O. Azeez[1]*, O. O. Adesanwo[1] and J. A. Adepetu[2]

[1]Department of Soil Science and Land Resources Management, Obafemi Awolowo University, Ile-Ife, Nigeria.
[2]Department of Soil, Crop and Environmental Science, Ekiti State University, Ado-Ekiti, Nigeria.

Received 16 July, 2014; Accepted 9 January, 2015

Effects of annual spraying of copper (Cu) fungicide by cocoa farmers in Nigeria needs immediate investigation to avoid copper toxicity which will affect uptake of other essential nutrients for plant growth. Laboratory and Screenhouse studies were carried out to investigate the effects of Cu application on availability of P, Zn, Fe and growth of maize. In the laboratory, copper was applied as $CuSO_4$ at 0, 10, 20, 30, 40 and 50 mg Cu kg^{-1} to 100 g soil and left for 5 weeks for equilibration while in the Screenhouse, the same rate of Cu was thoroughly mixed with 1 kg soil in a plastic container. Maize was used as the test crop and growth parameters were monitored. Soil and tissue samples were analysed for Cu, P, Zn and Fe at the end of Laboratory and Screenhouse experiments. The experiment was arranged in a completely randomized design and replicated three times. Data obtained were subjected to analysis of variance; differences in means were tested using the Duncan Multiple Range Test. The results from Laboratory and Screenhouse experiments showed significant decrease in soil available P, Zn and Fe as rates of Cu increase over control experiment. The effect was more pronounced at application rate above 20 mg Cu kg^{-1}. Gradual decrease in maize plant height, stem girth, leaf areas index, P, Zn and Fe uptake were observed as rate of Cu application increased. For instant, at application rate of 10 and 20 $mgkg^{-1}$, available P uptake was 5.49 mg/pot and 3.08 mg/pot respectively. The negative impact of Cu accumulation on available P was consistent in all the experiments. The result of the experiment clearly revealed strong negative impact of excess Cu on availabilities and uptake of P, Zn and Fe in soil.

Key words: Copper, fungicides, application rate, Screenhouse, nutrients.

INTRODUCTION

Copper is an essential element for various metabolic processes in soils (Scheiber et al., 2013). It is required only in trace amounts and becomes toxic at high concentrations (Delas, 1963; Alva and Chen, 1995). The critical copper deficiency level in vegetative plant parts is generally 3 to 5 mg kg^{-1} dry weight (Robson and Reuther, 1981). Contrastingly, high Cu levels may inhibit root elongation and damage of root cell membranes of non-tolerant plants (Wainwright and Woolhouse, 1977). Particularly, cocoa farmers in Nigeria apply Cu fungicides

*Corresponding author. E-mail: azeezmusy@yahoo.com, mazeez@oauife.edu.ng. Tel: +2348056268259.

annually to curb the menace of black pod disease, which is caused by *Phythophthora* spp*.* However, high application rates of Cu reduced soil nutrients which affects plant productivity (Lindsay, 1974). When copper gets into the soil, it binds strongly to organic matter, clay minerals and hydrated oxides of iron (Fe), aluminium (Al) and manganese (Mn) (Schnitzer, 1969), and either reduces the concentration of these nutrients (Fe, Mn and Al) in the soil or makes them unavailable for plant uptake. For example, Savithri et al. (2003) found that as the copper content in the soils of grape farms increased with continuous application of copper fungicides in form of Bodeaux mixture ($CuSO_4$ + $Ca(OH)_2$), the amount of micronutrient such as zinc, manganese and iron decreased. Similarly, some macronutrients are also affected, for example, available phosphorus contents of the soils decreased with application of Cu fungicide at both surface and subsurface layers (Spencer, 1966). Akinnifesi et al. (2006) reported that increasing copper content of soils in cocoa plantations reduced the amount of plant available phosphorus that caused nutrient imbalance, which may affect nutrient uptake by plants. In fact, increasing amounts of Cu in soil may cause translocation of Cu to various vegetative parts. Grain crops such as maize requires relatively high amount of Cu to improve quality and yield but at some certain level, it becomes toxic to the plants (Rogerio et al., 2013). Thus, this study was carried out to determine both the interactions between increasing application rates of Cu and soil available P, Zn and Fe as well as to determine the effect of increasing Cu application rates on nutrient uptake (P, Zn and Fe) and plant growth of maize plant.

MATERIALS AND METHODS

Soil samples (0 to 15 cm) were collected from Teaching and Research Farm (T&RF), Obafemi Awolowo University, Ile-Ife in Southwestern Nigeria. The T&RF is situated within the rain forest zone and located between latitudes 7° 32' N and 7° 33' N and longitudes 4° 32' E and 4° 40' E. The altitude is 244 m above the sea level. The local classification of the soil is Iwo series while the USDA equivalent is Ultisol. The soil samples were air dried and subjected to physical and chemical analysis. These were particle size analysis, soil pH, organic matter, exchangeable cations, Total N, available P and micronutrients. Experiments were carried out for five weeks at the Department of Soil Science and Land Resources Management, Obafemi Awolowo University, Ile-Ife, Nigeria, to determine the effect of Cu on soil P, Zn and Fe, growth parameters and nutrient uptake of maize plant. The particle size analysis was carried out using the modified hydrometer method by Bouyoucous (1965). Soil pH in 0.01 M $CaCl_2$ was determined using the soil-solution ratio 1:2 (Peech et al. 1953). The soil organic matter content of the soil was determined using the Chromic Acid Digestion Method by Walkley-Black (1934) as reviewed by Allison (1965). Exchangeable basic cations (Ca, Mg, K and Na) were extracted with 1 N NH_4OAc at pH 7 (Thomas, 1982) while available P was determined by Bray 1 method (Bray and Kurtz*,* 1945). Available Cu, Zn and extractable Fe were extracted with 0.1 N HCl (Wears and Sommer, 1948). The micronutrients (Cu, Zn and Fe), Ca and Mg were determined using an Atomic Absorption Spectrophotometer (AAS) (PG 990 model) while Na, K were determined using Flame photometer. Laboratory experiment was carried out for 5 weeks in order to assess the effect of addition of copper to soil on other soil chemical properties. Copper was applied as $CuSO_4$ at 0, 10, 20, 30, 40 and 50 mg Cu kg^{-1} to 100 g soil and left for 5 weeks to equilibrate. The moisture content was determined by filling 1000-ml flask with soil and cotton wool was spread on the soil. 100 ml water was poured into the flask and covered with polythene bags with 6 holes on it for good aeration. The experiment was left for 48 h. Soil sample was taken from the middle of the flask and oven-dried until constant weight was achieved. The soil field moisture content was then determined.

In the screenhouse, the same rate of Cu was applied to 1 kg soil in a plastic container and moistened to 70% field moisture capacity to determine the effects of increasing rate of Cu application on nutrient uptake and plant growth of maize. The experiment was replicated three times and arranged in completely randomized design. 17 ml of water per 100 g of soil was calculated for field moisture content while 70% of that gave 12 ml. 120 mls of deionized water was then added to 1 kg soil. The watering was done every 3 days throughout the experimental period in the Screenhouse to maintain moisture content. Maize (*Zea mays* L.) was used as the test crop and growth parameters (plant height, stem girth and leaf areas) were monitored forthnightly. Soil and tissue samples were analysed for Cu, P, Zn and Fe. All the experiments were carried out in triplicates and arranged in completely randomized design. Data obtained were subjected to analysis of variance; differences in means were tested using the Duncan Multiple Range Test.

RESULTS AND DISCUSSION

Physical and chemical properties of the soil used for laboratory and screenhouse studies

The results of physical and chemical properties of the soil used for the experiment are presented in Table 1. The soil was slightly acidic. The soil organic matter (OM) was low while total nitrogen was moderate. The exchangeable bases were moderately high. The available P was equally high while that of available Cu was moderately high. The extractable Fe and available Zn were generally high. In general, the soil may be considered as moderately fertile.

Effects of added Cu on available P, Zn and Fe in the incubation experiment

The available Cu increased significantly ($p<0.05$) over the Control as rates of Cu application increased (Table 2). Soil P, Zn and Fe decreased as Cu rates increased. Available P showed significant ($p<0.05$) decrease with increasing rates of Cu application over the Control experiment. For instant, at 0 mg Cu kg^{-1} and 10 mg Cu kg^{-1}, available P were 27.66 and 26.35 $mgkg^{-1}$ respectively. The result showed antagonistic interaction between available Cu and P. Similarly, application of Cu resulted in significant ($p<0.05$) decrease in available Zn values when compared with the Control. This might be due to the fact that Cu and Zn have similar charge and ionic size. Robson and Pitman (1983) reported that such interactions are more common between nutrients of

Table 1. Physical and chemical properties of Iwo series, the reference soil used for the experiments.

Properties	Values
Sand (gkg^{-1})	728
Silt (gkg^{-1})	107.2
Clay (gkg^{-1})	164.8
Textural class	Sandy loam
pH (0.01 M ($CaCl_2$)	6.1
Organic matter (%)	1.31
Total N (%)	0.18
Available P (mg kg^{-1})	27.45
Available Cu (mg kg^{-1})	1.19
Available Zn (mg kg^{-1})	6.43
Extractable Fe (mg kg^{-1})	13.47
Exchangeable cations ($cmolkg^{-1}$):	
K	0.49
Ca	0.56
Mg	1.05
Na	0.32

Table 2. Effect of rates of Cu on available P, Zn and Fe in the equilibration experiment after 5 weeks.

Cu rates	Cu	P	Zn	Fe
	(mg kg^{-1})			
0	1.11^{f}	27.66^{a}	6.43^{a}	13.46^{a}
10	11.63^{e}	26.35^{b}	5.62^{b}	11.91^{b}
20	19.43^{d}	24.74^{c}	4.90^{c}	11.28^{b}
30	25.93^{c}	22.82^{d}	3.95^{d}	9.81^{c}
40	32.56^{b}	21.39^{e}	3.40^{ed}	8.34^{d}
50	35.80^{a}	20.04^{f}	2.79^{e}	7.73^{d}

Means with the same letter within the columns are not significantly different ($p<0.05$) according to Duncan's multiple range test.

similar size, charge and geometry of coordination and electronic configuration. Similarly, available Fe decreased significantly ($p<0.05$) following the application of different rates of Cu when compared with the Control (Table 2).

Effect of Cu additions on available P, Zn and Fe in the screenhouse experiment

Soil available P, Zn and Fe

The experiment was carried out in the Screenhouse for five weeks after which the soil was analyzed to determine the interactions among Cu, Zn, Fe and P following the application of different rates of Cu (Table 3). The Cu content in the soil after harvesting increased significantly ($p<0.05$) as the rate of application increased when compared with the Control. Significant ($p<0.05$) decrease in available P after harvesting over the Control was also observed. It was observed that significant difference ($p<0.05$) was recorded among Cu treated pots. Application rate above 20 mg Cu kg^{-1} significantly reduced available P. For instance, available P at 20 mg Cu kg^{-1} was 18.09 mg P kg^{-1} while 12.76 mg kg^{-1} was recorded at application rate of 30 mg Cu kg^{-1}. Similarly, significant decrease in available Zn ($p<0.05$) was observed following the application of different rates of Cu to the soil over the Control. As copper and Zn have similar ionic size, the presence of Cu in the soil may, therefore, have some negative effects on Zn as both elements compete for the same adsorption sites. There was no significant ($p>0.05$) difference in extractable Fe

Table 3. Effect of Cu addition on available P, Zn and Fe after maize harvesting.

Cu rates	Cu	P	Zn	Fe
	(mg kg^{-1})			
0	0.92^{f}	22.38^{a}	5.25^{a}	13.46^{a}
10	9.10^{e}	18.84^{b}	4.19^{b}	11.67^{b}
20	19.29^{d}	18.09^{b}	3.77^{b}	9.82^{c}
30	25.14^{c}	12.76^{c}	3.09.^{c}	8.17^{d}
40	38.20^{b}	12.60^{c}	2.72^{c}	7.04^{e}
50	45.80^{a}	10.88^{c}	2.44^{c}	4.96^{f}

Means with the same letter within the columns are not significantly different (p<0.05) according to Duncan's multiple range test.

content following the application of 10 mg/kg of Cu salt when compared with the Control but significant decrease (p<0.05) was recorded as application rate increased beyond 10 mg Cu kg^{-1}. Significant difference was recorded in extractable Fe among Cu treated pots, for example, 8.17 mgkg^{-1} and 7.04 mgkg^{-1} at 30 and 40 mg Cu kg^{-1} were recorded. Presence of excess Cu in the soil has negative effect on extractable Fe content as earlier observed in the equilibration study (Table 3). Cu applications changed availability of nutrients, which affected plant nutrition (that is, total contents in biomass). This points to the fact that an excessive use of Cu fungicides may reduce plant productivity.

Growth of maize plant

The effects of different rates of Cu on growth parameters, viz, plant height, stem girth and leaf areas and nutrient uptake by maize were also monitored in the screenhouse. The plant height showed no significant difference (p>0.05) in all the Cu treated pots except at the application rate of 50 mg Cu kg^{-1} when compared with the Control (Table 4). This confirms earlier work reported by Karataglis and Babalonas (1985), that plant height, shoot and root biomass, flower and fruit production decreased with increasing Cu concentration. This suggests that excess Cu in soil affects uptake of other nutrients for plant height development and invariably results into low productivity. No significant effect (p>0.05) of added Cu was found on stem girth when compared with the Control. The results showed gradual reduction in stem girth following different rates of Cu application to soil. Leaf area index showed significant decrease (p<0.05) at 30, 40 and 50 mgkg^{-1} Cu treated pot when compared with control. However, there was no significant effect (p>0.05) of added Cu on leaf area index at 10 and 20 mg/kg Cu treated pot when compared with the Control. This implies that the presence of Cu in the soil had negative impact on the ability of maize plant to absorb nutrients necessary for leaf area development. This is in line with a report of Zheng et al. (2004) that excessive Cu reduced plant root length, root dry weight, total dry weight, and root to shoot ratio, leaf area and specific leaf area in three ornamental crops grown in solution culture.

Nutrients uptake

There was no significant effect (p>0.05) of added Cu in Cu uptake by maize as Cu rates increased in all the Cu treated pots (Table 4). However, significant decrease (p>0.05) was observed when compared with the Control. This may be attributed to immobilization of Cu by humic substances in the soil. This result showed that increase in Cu content of the soil may lead to low absorption of Cu by plant. No significant effect of added Cu was observed in P uptake at application rate of 10 mg Cu kg^{-1} when compared with the Control. Significant decrease was observed among Cu treated pots, for instance, P uptake at 10 and 20 mg Cu kg^{-1} were 5.49 and 3.08 mgkg^{-1}. There was gradual reduction in P uptake as rate of Cu increased. This result also supports the observation made in the equilibration study and analysis of soil after harvesting of maize plant in the Screenhouse. Significant decrease in Zn uptake was recorded in all the Cu treated pots over the Control. Gradual decrease was observed in Zn uptake as the rate of Cu application increases. This result follows the same pattern as observed in the equilibration study. Other studies have shown that Cu and Zn interact with each other due to antagonistic relationship (Dangarwala, 2001). The application of Cu significantly reduced the Fe content in the plant tissue in all the Cu treated pots over the Control, a finding similar to the observation in the equilibration study. The results were in agreement with those of Brar and Sekhon (1978), who observed that excess Cu antagonistically affected the translocation of Fe from stem to the leaves. Excess Cu in the soil may cause Fe chlorosis in plants and thereby affecting the productivity and biodiversity (Alva and Graham, 1991). It was reported that response of excess Cu has frequently been attributed to an interference with Fe metabolism (Yau et al., 1991; Ouzounidou et al., 1995). Kim et al. (1978) and Gonçalves et al. (2009) reported that the interference of heavy metals in excess amounts with normal Fe metabolism was known to induce physiological Fe deficiency.

Conclusions

The study investigated the effects of Cu fungicides on available P, Zn and Fe and on growth and nutrient uptake by maize (*Zea mays* L.). The results of the study showed that available Cu increased significantly over the Control as rate of Cu application increased. Significant decrease in available P was observed as rate of Cu increased. The

Table 4. Effect of Cu additions on heights (cm), stem girth (cm) and leaf areas (cm^2) and nutrient uptake (mg/pot) of maize in the Screenhouse.

Cu rates (mg/kg)	Plant height (cm)	Stem girth (cm)	Leaf areas (cm)	Nutrient uptake			
				Cu	P	Zn	Fe
0	57.20[a]	2.40[a]	150.70[a]	0.06[a]	5.56[a]	0.02 [a]	0.50 [a]
10	53.97[a]	2.37[a]	150.97[a]	0.02[b]	5.49[a]	0.02[b]	0.19[b]
20	50.87[a]	2.27 [ab]	146.28[a]	0.02[b]	3.08[b]	0.02[bc]	0.06[c]
30	50.50[a]	2.23[ab]	138.90[b]	0.02[b]	2.58[b]	0.01[cd]	0.05[c]
40	49.07 [a]	2.13[bc]	126.20[c]	0.01[b]	2.68[b]	0.01[d]	0.04[c]
50	48.13[a]	2.07[c]	116.77[d]	0.01[b]	1.91[b]	0.01[d]	0.02[c]

Means with the same letter within a column are not significantly different ($p<0.05$) according to Duncan's multiple range test.

result showed antagonistic relationship between available Cu and P as the rate of Cu application increased. It could be that accumulation of Cu hindered the uptake of P by the plant or reduced its availability in soil. Significant decrease was observed in Zn contents as the rate of Cu application increased. This relationship might be due to the fact that Cu and Zn have similar charges and ionic sizes. Significant decrease was also observed in extractable Fe content over the Control as the rate of Cu application increased. Gradual decrease in plant height, stem girth and leaf area index were recorded as the rate of Cu application increased. This pointed to the fact that presence of excess Cu in the soil prevented the absorption of essential nutrients needed for adequate development of plant height, stem girth and leaf area. There should be proper monitoring of Fe, P and Zn levels in soils after Cu applications to ensure nutrient balance because excess Cu may reduce plant productivity and thus reduce economical income by farmers.

Conflict of Interest

The authors have not declared any conflict of interests.

REFERENCES

Akinnifesi TA, Asubiojo OI, Amusan AA (2006). Effects of fungicide residues on the physico-chemical characteristics of soils of a major cocoa-producing area of Nigeria. Sci. Total Environ. 366:876-879.

Allison LE (1965). Organic Carbon. In: Black et al. (ed.) Methods of Soil Analysis. Part 2 Monograph No 9. America Soc. Agro. Madison pp. 1367-1378.

Alva AK, Chen Q (1995). Effects of external copper concentrations on uptake of trace elements by citrus seedlings. Soil Sci.159:59-64.

Alva A, Graham JH (1991). The role of copper in citriculture. Adv. Agron. 1:145-170.

Bouyoucos GJ (1965). Hydrometer methods improved for making particle size analysis of soils. Soil Sci. Soc. Am. Proc. 26:917- 925.

Brar MS, Sekhon GS (1978). Effect of zinc and copper application on the yield and micronutrient content of wheat. J. Ind. Soc. Soil Sci. 26:84-86.

Bray RH, Kurtz LT (1945). Determination of total, organic and available form of Phosphorus in soils. J. Soil Sci. 59:45-59.

Dangarwala RT (2001). Need for sustaining balanced supply of micronutrients in soil rather than their correction. J. Ind. Soc. Soil Sci. 49:647-652.

Delas J (1963). The toxicity of copper accumulated in soils. Agrochemica 7:258-288.

Gonçalves JF, Antes FG, Maldaner J, Pereira LB, Tabaldi LA, Rauber R, Rossato LV, Bisognin DA, Dressler VL, de Moraes Flores EM and Nicoloso FT (2009). Cadmium and mineral nutrient accumulation in potato plantlets grown under cadmium stress in two different experimental culture conditions. Plant Phy. Biochem. 47:814-821.

Karataglis S, Babalonas D (1985). The toxic effects of copper on the growth of *Solanum lycopersicum* L. collected from Zn and Pb-soil. Angewandte Botanik 59:45-52.

Kim BY, Kim KS, Kim BJ, Han KM (1978). Uptake and yield of heavy metal Cu, Ni, Cr, Co and Mn. Rep. Off. Rural Development pp. 1-10.

Lindsay WL (1974). "Role of Chelation in Micronutrient Availability." In: *The Plant Root and Its* Environment, edited by EE Carson 507-524. Charlottesville: University Press of Virginia. Ornamental Crops in Solution Culture. Hortsci. 39:1116-1120.

Ouzounidou G, Ciamporova M, Moustakas M, Karataglis S (1995). Responses of maize (*Zea mays* L.) plants to copper stress--I. Growth, mineral content and ultrastructure of roots. Environ. Exper. Bot. 35(2):167-176.

Peech M, Olsen RA, Bolt GH (1953). The significant of potentiometric measurements involving liquid junction in clay and soil suspension. Soil Sci. Soc. Am. Proc. 17:214-220.

Robson AD, Pitman MG (1983). Interactions between Nutrients in higher plants. Encyclopedia of plant physiology 15:147-180.

Robson AD, Reuther DJ (1981). Diagnosis of copper deficiency and toxicity. In: Loneragan JF, Robson AD, Graham RD (Ed.). Copper in soils and plants. Orlando: Academic Press. pp. 287-312.

Rogério HB, Luciane AT, Fábio RM, Márcio P, Samir OK, Daísa B (2013).Foliar copper uptake by maize plants: effects on growth and yield. Cienc. Rural vol.43 no.9 Santa Maria. http://dx.doi.org/10.1590/S0103-84782013000900005

Savithri P, Joseph BIJU, Poongothai S (2003). Effect of copper fungicide sprays on the status of micronutrient in soils of hot semi-arid region of India. Tamil Nadu Agricultural University, Coimbatore 641 003.

Scheiber Ivo D, Ralf M, Julian FB (2013). "Chapter 11. Copper: Effects of Deficiency and Overload". In Astrid Sigel, Helmut Sigel and Roland K. O. Sigel. Interrelations between Essential Metal Ions and Human Diseases. Metal Ions in Life Sciences 13:359-387. doi:10.1007/978-94-007-7500-8_11.

Schnitzer M (1969). Reactions between fulvic acid, a soil humic compound and inorganic soil constituents. Soil Sci. Soc. Am. Proc. 33:75-81.

Spencer WF (1966). Effect of copper on yield and uptake of phosphorus and iron by citrus seedlings grown at various phosphorus levels. Soil Sci.102:296-299.

Thomas GW (1982). Exchangeable cations In.; AL Page, R. H. Miller, D. Keeney (Eds.): Methods of Soil Analysis. 22nd Edition. Medison: America Soci. Agron. 57-164.

Wainwright SJ, Woolhouse HW (1977). Some physiological aspects of copper and zinc tolerance in Agrostis tenuis Sibth: Cell elongation and membrane damage. J. Exper. Bot. 28:1029-1036.

Walkley A, Black IA (1934). An examination of the method for determining soil organic matter and proposed modification of the chromic acid titration method. Soil Sci.37:29-38.
Wears JI, Sommer AL (1948). Acid extractable zinc of soils in relation to occurrence of zinc deficiency symptoms of corn: A method of analysis. Soil Sci. Soc. Am. Proc. 12:143-144.
Yau PY, Loh CF, Azmil IAR (1991). Copper toxicity of clove (*Syzygium aromaticum* (L.) Merr. and Perry) seedlings. Mardisson, J. Res. 19:49-53.
Zheng YB, Wang LP and Dixon MA (2004). Response to copper toxicity for three ornamental crops in solution culture. Hortscience 39:1116-1120.

academicJournals

Vol. 10(5), pp. 365-372, 29 January, 2015
DOI: 10.5897/AJAR2014.9358
Article Number: 1A42C3249871
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Soil hydrophobicity and crop evapotranspiration of two indigenous vegetables under different wastewater irrigations in southwest Nigeria

Abegunrin, T. P.[1]*, Adegbola, S. O.[1] Adejumobi, M. A.[1], Awe, G. O.[2], Ojediran, J. O.[1] and Ojo, A. A.[1]

[1]Department of Agricultural Engineering, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria.
[2]Department of Crop, Soil and Environmental Sciences, Faculty of Agricultural Sciences, Ekiti State University, Ado Ekiti, Ekiti State Nigeria.

Accepted 22 January, 2015; Received 20 November, 2014

The increased demand for irrigation to boost food supply has placed emphasis on the use of wastewaters. However, the indiscriminate use of wastewaters could impair soil functions and influence other hydrologic processes. The objective of this study was to evaluate soil hydrophobicity and evapotranspiration of two indigenous vegetables under wastewater irrigation in southwest Nigeria. The study was a factorial experiment, laid out in randomized complete block design (RBCD) with three replications. The vegetable factor consisted of SM - Eggplant (*Solanum macrocarpon*) and CA – Lagos spinach (*Celosia angentea*), while the wastewaters were abattoir wastewater (AW), bathroom and laundry wastewater (BW) and cassava effluent (CE), with rainwater (RW) as control. Soil hydrophobicity was determined before the experiment and after harvest using water-droplet penetration time (WDPT) method while the crop evapotranspiration was determined using soil water balance technique. Wastewater irrigation significantly ($p<0.05$) influenced soil hydrophobicity, as the initially wettable soil became slightly hydrophobic, with the highest degree from CE wastewater. The evapotranspiration of both vegetables was significantly ($p<0.05$) affected, with none of the wastewater treatments dominating the temporal distribution of crop evapotranspiration. Continuous application of wastewater for irrigation could increase the level of water repellency, affect soil water dynamics and availability.

Key words: Soil water repellency, wastewater effluent, evapotranspiration.

INTRODUCTION

The increased competition for water among urban and semi-urban centers, industries and agriculture has put agriculture particularly irrigated agriculture under severe pressure as irrigation has been the largest user of water (Van der Hoek et al., 2002). Therefore, the problem of water shortage due to demand for increased irrigation (Yao et al., 2013) to boost food supply has placed emphasis on the use of treated, partially-treated and untreated wastewater. Kauser (2007) reported that at least one-tenth of the world's population are now

*Corresponding author. E-mail: tpabegunrin@lautech.edu.ng, Tel: +2348083298782.

consuming food produced by wastewater and it is estimated that about 200 million hectares in 50 countries are irrigated with raw or partially-treated wastewater (United Nations, 2003). As populations continue to increase and more freshwater is diverted to cities for domestic use, 70% of which later returns as wastewater (Ashraf et al., 2013). Khalil and Kakar (2011) reported that 80% of the inhabitants in Pakistan are using untreated wastewater for irrigation because of the relatively high levels of essential nutrients, such as phosphorus, nitrogen and potassium.

Untreated wastewater has become a preferred source of water for irrigation (Ensink et al., 2002) since there is no need for conventional fertilizers which are beyond the reach of most farmers. Rijsberman (2004) highlighted some direct benefits of wastewater collection and reuse, including double cropping and lower input costs for agricultural crop productions. Despite these advantages, the use of untreated wastewaters poses threat to the environment, such as impairment of certain soil functions, pollution of water bodies, interference with crop performance and so on.

Soil physical processes such as water movement and retention is affected by soil water repellency or hydrophobicity (Mataix-Solera et al., 2007). Hydrophobicity is a phenomenon of difficulty in wetting the soil, associated with coating of soil particles by hydrophobic organic substances, which reduces soil sorptivity (Vogelmann et al., 2013). According to these authors, the organic substances responsible for repellency can be of various origins, such as type of vegetation, bush burning, and microbial activities. Soil water repellency has become a subject of global concern with substantial effects on crop production, soil use and management (Müller and Deurer, 2011).

As a primary effect, Cerdà and Doerr (2007) cited a reduction in water infiltration and hence the amount of plant available water, thereby affecting seed germination, crop growth and development. Kawamoto et al. (2007) asserted that increased hydrophobicity has serious implications for soil management, affecting the water dynamics and consequently crop growing conditions. Tabatabaei et al (2007) observed that continuous use of wastewater for irrigation could alter water entry. Madsen et al. (2011) mentioned that due to reduced infiltration rate; surface runoff may be increased, accelerating the risk of erosion. Wastewater effluents, especially household wastewater, in untreated state, contain appreciable amount of organic substances among others, thus could contribute to coating of soil particles and cause soil hydrophobicity (Wallach et al., 2005). Because the plant available water is altered due to reduced water entry by wastewater irrigation, therefore different soil water status could result when wastewater is sourced from different sources as they contain different levels of hydrophobic organic compounds. In this context, the differences in plant available water will also influence plant water uptake.

We hypothesized that wastewater irrigation significantly affected soil hydrophobic character and water use pattern of two contrasting vegetables. Therefore, the objective of this study was to evaluate soil hydrophobicity and water use pattern of two indigenous vegetables under different wastewater irrigations in southwest Nigeria.

MATERIALS AND METHODS

Experimental site

The experiment was conducted in the screen house of the Department of Agricultural Engineering, Ladoke Akintola University of Technology (LAUTECH), Ogbomoso (latitude 8° 10°N and longitude 4° 10°E, about 342 m above the mean sea level) in southwest Nigeria during the 2013 growing season. The study site is characterized by bimodal rainfall pattern, with peaks in June and September and phenomena break in the month of August. The mean annual rainfall is about 1200 mm while the mean maximum and minimum temperatures are 33 and 28°C, respectively. The relative humidity of the area is relatively high (74%) throughout the year except in January when dry wind (harmattan) blows from the north (Olaniyi, 2006). The soil of the area is classified as Hapludalf (SSS, 2010), sandy loam texture and the particle size distribution analysis showed that the 0 to15 cm layer of the soil is composed of 78% sand, 11% silt and 11% clay.

Wastewater sampling and analysis

Three types of raw untreated wastewaters were collected and rainwater (RW) was used as the control. The waste waters are abattoir wastewater (AW), bathroom and laundry wastewater (BW) and cassava effluent (CE). AW was collected from the outlet of the drain of the slaughtering slab at Atenda abattoir in Ogbomoso. This was done immediately after the animals were slaughtered and the slab flushed. BW was collected from bathrooms and laundries in some student hostels of LAUTECH, while the CE was collected from a garri processing factory at A*arada* market in Ogbomoso. RW was collected through a clean roof gutter attached to the roof of the screen house. The raw wastewater samples were kept in bottles that have been soaked for 24 h in HNO_3 solution to kill any microbes. The bottles were labeled accordingly, sealed, refrigerated and taken to the laboratory within 24 h of collection for analysis. The chemical properties analyzed include HCO_3^-, Na^+, Ca^{2+}, Mg^{2+}, Total suspended solid (TSS), Total Dissolved Solid (TDS), Biochemical Oxygen Demand (BOD_5), pH, Electrical Conductivity (EC) and CN^-, using standard laboratory procedures.

Experimental design and preparation of mini-lysimeters

The study was a two factor (wastewater versus type of vegetable) experiment, laid out in a randomized complete block design (RBCD) with three replications. The vegetable factor consisted of SM - Eggplant (*Solanum macrocarpon*) known as Igbagba or Igbo in Yoruba (Ojo et al., 2011) and CA - Cockscomb (USDA, 2013) or Lagos Spinach (*Celosia angentea*) while the wastewater factor were: abattoir wastewater (AW), bathroom and laundry wastewater (BW), cassava effluent (CE) and rainwater (RW) as control. Thus, twenty-four buckets (22 cm high and 25.5 cm diameter), perforated at the bottom (for drainage) were used. The buckets were filled with soil sample from the same area (used for soil physico-chemical analysis), after air dried and passed through a 2 mm sieve.

To obtain soil condition in the mini-lysimeter similar to the natural state (field), subsample was weighed from the sieved soil sample based on the volume of the mini-lysimeters and determined field bulk density. The subsample was re-wetted using determined field moisture content and packed in the marked lysimeters using fabricated circular wood (with the same diameter as the lysimeter) and soft-head hammer. A gap of about 5 cm was left between the tip of the lysimeter and soil surface to prevent surface runoff. The lysimeters were placed on planks and arranged in such a way that drained water was easy to collect.

Planting, irrigation application and crop management

The vegetables were nursed and transplanted into the mini-lysimeters. The transplanted vegetables were adequately irrigated with rainwater until they are established. After a week, the plants were subjected to wastewater irrigation treatment. Because there was no established water requirement for the two vegetables, a preliminary investigation was carried out based on the surface area of the lysimeters and which will not cause overflow and saturation, thus four hundred cubic centimeters (400 cm^3) of each of the wastewater treatments and rainwater was arrived at. The water treatments were added at intervals based on visual observation when the soil surface becomes relatively dry. There was no fertilizer application and unwanted plants were removed manually. Other management procedures for the two indigenous vegetables were followed according to cultural practices.

Determination of soil hydrophobicity

The hydrophobicity test was performed using water droplet penetration time (WDPT) method on disturbed soil samples, after air-dried, crushed and passed through a 2 mm sieve. The soil samples were later placed in Petri dishes (volume of 25 cm^3) for the test. The WDPT method consisted of applying a drop of water using a precision pipette, and then recording the time taken for the drop to penetrate the soil sample (King, 1981). Each drop was released from a height of 10 mm above the soil surface to minimize the impact on the soil surface, the test was replicated 9 times for each treatment and the mean values were used to characterize the hydrophobic level. Five classes of water repellency were distinguished: wettable (WDPT < 5s); slightly repellent (5s < WDPT < 60s); strongly repellent (60s < WDPT < 600s); severely repellent (600s < WDPT < 3600s); and extremely repellent (WDPT > 3600s) (Dekker and Jungerius, 1990).

Determination of reference crop evapotranspiration and water use

Reference crop evapotranspiration ET_o was calculated using Penman-Montieth equation (Allen et al., 1998; Valipour, 2014) using FAO reference crop evapotranspiration calculator (FAO EToCalc, version 3.1) from daily meteorological data recorded in the screen house. The crop water use (crop evapotranspiration, ET_C) of each vegetable during the growth period was calculated using soil water balance equation proposed by Martin and Gilley (1993):

$$ET_C = \frac{(I - Q - \Delta S + R_o)}{A} * 10$$

Where: ET_C = crop evapotranspiration or consumptive water use (mm); I = irrigation water added, (cm^3); Q = deep percolation (cm^3), measured from the base of the mini-lysimeter as drainage water collected; ΔS = soil water storage (cm^3), the difference between mini-lysimeter weights between two consecutive days during the growing period; R_o = runoff (cm^3), (= 0 in this study because there was no runoff from the mini-lysimeters); and A = cross sectional area of the mini-lysimeter (cm^2); 10 is a conversion factor from cm/d to mm/d.

Statistical analysis

Data were subjected to analysis of variance (ANOVA) of the General Linear Model (GLM) and where the F-value of the effect of wastewater and interaction between wastewater and type of vegetable was significant, Fisher's Least Significant Difference (LSD) was used to separate means. All statistical analyses were performed using the statistical package, SPSS (*SPSS, IBM version 20.0*).

RESULTS AND DISCUSSION

Physical and chemical properties of wastewater and rainwater samples

The results of the physico-chemical characteristics of the various wastewaters and rainwater used for the experiments are presented in Table 1. The concentrations of Na, Ca, Mg, EC, CN^- and HCO_3^- were below the limits recommended by Food and Agricultural Organization standards (FAO; Pescod, 1992) for the reuse of wastewater for irrigation. The TDS values were within the 450-2000 mg/L standard. However, all the wastewater samples had SAR values above the FAO standard limit (FAO; Pescod, 1992) of 9, with abattoir (AW) and domestic (BW) wastewaters having higher SAR, 25.5 and 24.5, respectively while that of RW was below the limit. Likewise, the total suspended solids (TSS) concentration was also higher than the FAO limit of 20 mg/L, with the highest value (1875 mg/L) from AW sample and the lowest value (26 mg/L) from rainwater (RW) sample.

The biochemical oxygen demand (BOD_5) was below the FAO limit in RW; however, other wastewaters had values above the limit. Valipour et al. (2013) developed an environmental flow diagram (EFD) for the determination of sources of pollutants from wastewater irrigation and division sources based on acceptor environment (soil) found the concentration of BOD_5 from wastewater higher than that of irrigation standard, indicating as warming for irrigation purpose. The pH values from RW and cassava effluent (CE) samples were within the FAO limit of 6.5-8.4, whereas those of AW and BW were below the minimum threshold.

The pH determines the availability of nutrients, the potency of harmful substances as well as the physical properties of the soil (Osakwe, 2012) and the implication is that the soil pH can either be elevated or decreased. Osakwe (2012) and Abegunrin et al. (2013) found decreased soil pH due to wastewater application.

Table 1. Physico-chemical characteristics of rain and waste waters used for the experiment

Parameter	Standard*	Wastewater type			Control
		BW	CE	AW	RW
Ca (mg/L)	230	198	151	212	101
Mg (mg/L)	100	23	32	22	21
Na (mg/L)	69	50	28	48	20
Co (ppm)	0.05	nd	nd	nd	nd
Cr (ppm)	0.1	nd	nd	nd	nd
Cd (ppm)	0.01	nd	nd	nd	nd
Pb (ppm)	5.0	nd	nd	nd	nd
Ni (ppm)	0.2	nd	nd	nd	nd
EC (µS/cm)	2700	836	408	281	54
SAR	9	25.5	13.2	24.5	1.2
TDS (mg/L)	450-2000	589	309	229	35
TSS (mg/L)	20	104	312	1875	26
BOD_5 (mg/L)	20	67	73.4	455	6.8
pH	6.5-8.4	5.7	4.0	6.7	7.5
CN^- (mg/L)	0.10	0.04	0.08	0.016	0.001
HCO_3^- (mg/L)	1.5-8.5	0.25	0.96	0.48	0.19

Ca: Calcium; Mg: Magnesium; K: potassium; Na: Sodium; Co: Cobalt; Cr: Chromium; Cd: Cadmium; Pb: Lead; Ni: Nickel; EC: electrical conductivity; TDS: total dissolved solids; TSS: total soluble solids; BOD_5: biologically oxygen demand; O&G: oil and grease; CN^-: cyanide; HCO_3^-: carbonate AW: abattoir wastewater; BW: bathroom and laundry wastewater; CE: cassava effluent; RW: rainwater; nd: not detected. *Wastewater reuse standards for irrigation. Source: (FAO; Pescod, 1992).

According to Mojiri (2011), the soil pH decreases initially with wastewater application but subsequently increases.

Interestingly, none of the trace elements and heavy metals, Co, Cr, Cd, Pb and Ni, was detected in all the wastewater and rainwater samples analyzed. Also, Valipour et al. (2013) did not detect the presence of heavy metals (Fe, Al, Mn, Zn, Li), thus posing no threat to the environment.

Degree of soil hydrophobicity

The level of soil water repellency depends on the proportion of soil particles with a hydrophobic surface coating (Doerr et al., 2006), which is strongly influenced by the surface area of the soil. The descriptive statistics of maximum, minimum, median and quartile values of water droplet penetration time (WDPT) of the soil under different wastewater irrigation and control, rainwater are shown by the Box-whisker plot in Figure 1. Table 2 shows the classification of the degree of soil hydrophobicity under different wastewater treatments and vegetables. Irrespective of vegetables, wastewater had significant ($p<0.05$) effect on WDPT.

The CE treatment had the maximum WDPT while the lowest value was obtained from RW. However, the median value was highest in CE treatment and also lowest in RW treatment. In general, the descriptive statistics from AW and CE treatments were in the high range while that of RW were low (Figure 1). The initial hydrophobicity test showed that the pre-wastewater irrigated soil was wettable, with an average WDPT of 5.4 s. At the end of wastewater application, there was varying degree of WDPT values under the different wastewater treatments and vegetables, with average values ranging between 8.5 and 12.3 s.

The highest and lowest values from CE and RW treatments, respectively, with all values greater than the initial value (Table 2). The classification of the degree of soil hydrophobicity showed that the soils changed to slightly hydrophobic. This confirms that increased use of wastewater effluent for irrigation could increase the level

of water repellency and adversely affect soil hydraulic properties and water dynamics. The low degree of hydrophobicity in this study is attributed to the relatively short period of evaluation. Wallach et al. (2005) working on soil water repellency under prolonged irrigation withtreated sewage effluent in a semiarid environment found extreme to severe soil water repellency. The significant difference in the occurrence of hydrophobicity may be attributed to different organic matter load from these wastewaters, although further research is needed to ascertain this. Keizer et al. (2007) and González-Peñaloza et al. (2012) reported that soil hydrophobicity results from the input of hydrophobic organic compounds as a result of the addition of organic materials. Although, there was no significant difference ($p<0.05$) in the degree of repellency between the vegetables, however

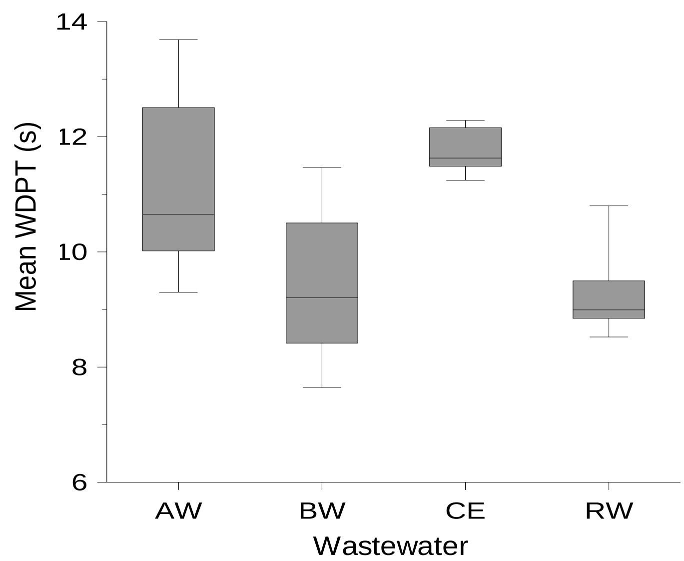

Figure 1. Box-whisker plot showing the maximum, minimum, median, and quartile values of water droplet penetration time (WDPT) of the soil under different wastewater irrigation and control, rainwater.AW: abattoir wastewater; BW: bathroom and laundry wastewater; CE: cassava effluent; RW: rainwater.

Table 2. Classification of the degree of water repellency of the soil under different wastewater irrigation and vegetables.

Treatment	WDPT, s		WDPT, s		WDPT, s	
	Initial	Classification	CA	Classification	SM	Classification
AW	5.4	WT	12.3	SR	10.0	SR
BW	5.4	WT	10.5	SR	10.3	SR
CE	5.4	WT	11.7	SR	13.7	SR
RW	5.4	WT	7.2	SR	9.4	SR
Average	5.4	WT	10.4	SR	10.3	SR
WW				9.92*		
Veg				0.02ns		
WW x Veg				4.53*		

SM: Eggplant (*S. macrocarpon*); CA: Lagos spinach (*C. argentea*); AW: abattoir wastewater; BW: bathroom and laundry wastewater; CE: cassava effluent; RW: rainwater; WW: wastewater effect; Veg: vegetable effect; WW x Veg: wastewater x vegetable interaction. WDPT: water droplet penetration time, seconds. WT: wettable; SR: slightly repellence. *: significant; ns: not significant at 5% level of probability by Fisher`s Least Significant Difference (LSD) test.

significant interaction on water repellency was obtained between the wastewaters and vegetables (Table 2).

Effect of wastewater irrigation on crop evapotranspiration

Crop evapotranspiration is a combined result of evaporation from the soil surface as well as transpiration from the plant. The evaporation from the soil surface is a function of the soil moisture condition, crop growth stage, the fraction of the soil surface covered by plant canopy etc., while transpiration depends on leaf area index, evaporative demand of the atmosphere and soil moisture condition.

The temporal variability of average values of crop evapotranspiration (ETc) of both vegetables and evaporative demand of the screen house microclimate (ETo) during the growing period are presented in Figure 2 while Table 3 shows the statistical comparison of the temporal distribution of consumptive water use and total water use (ETcTot) of both vegetables under different wastewater irrigation. Based on the limited weather data (maximum and minimum as well as wet- and dry-bulb

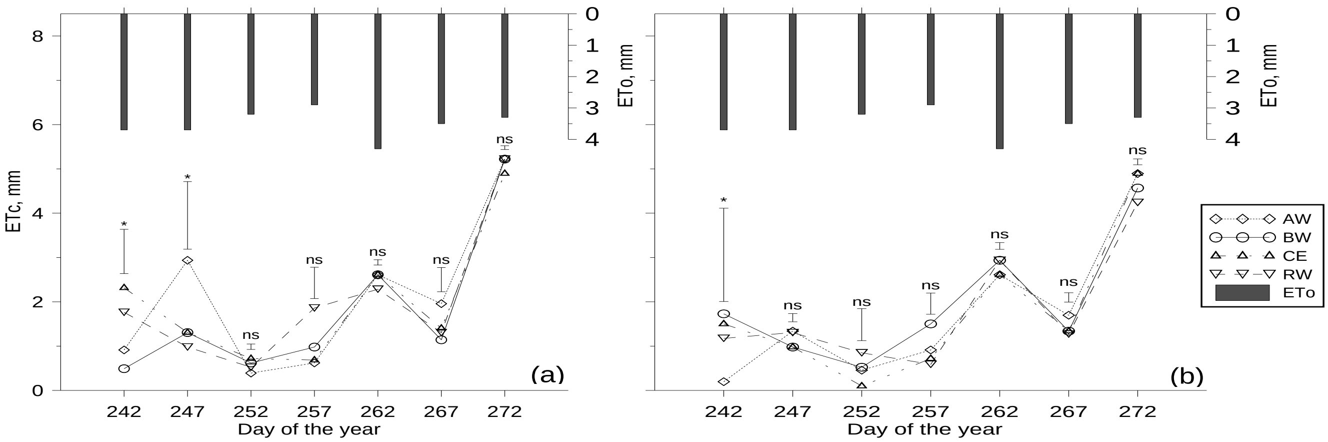

Figure 2. Temporal variability of average values of crop evapotranspiration (ETc), mm, of (a) Eggplant (*S. macrocarpon*), and (b) Lagos spinach (*C. argentea*) vegetables and evaporative demand of the screen house microclimate (ETo), mm, during the growing period between August and September 2013.AW: abattoir wastewater; BW: bathroom and laundry wastewater; CE: cassava effluent; RW: rainwater*significant and ns: not significant at 5% probability level by Fisher`s LSD test.

temperatures) of the screen house, the evaporative demand of the screen house climate (ETo) was not more than about 4 mm/day (Figure 2). The reliability of the ETo values was compared with Valipour (2014) who evaluated the potential evapotranspiration in Iran provinces using combinations of limited weather data of temperature only; temperature and relative humidity only; and temperature, relative humidity and wind speed. The author found the coefficient of determination, R^2, greater than 0.93 when compared with full weather data set.

There was significant effect of wastewater on ETc during the first two weeks of monitoring (Table 3), however, there was no discernible trend as regards the daily ETc with respect to crop growth stage as the average ETc values either rise or fall throughout the growing period (Figure 2). For the SM vegetable, the average ETc at the onset of the monitoring period (a week after transplanting) ranged between 0.49 and 2.32 mm/day, with the significantly ($p<0.05$) highest value from CE treatment. At the middle of the evaluation period, the ETc was low in some cases, with the average ETc values ranging between 0.62 and 1.86 mm/day, and no significant difference among the wastewater treatments. At the end of the evaluation period, the ETc was high, ranging between 4.90 and 5.22 mm/day, also with no significant difference among the wastewater treatments (Figure 2a). For the CA vegetable, similar trend was observed on the temporal distribution of ETc but different results were obtained from the wastewater treatments (Figure 2b).

At the initial period of evaluation, the average values of ETc ranged between 0.20 and 1.73 mm/day, with the significantly highest value from BW. At the middle of the evaluation period, the ETc was also low, with values between 0.59 and 1.50 mm/day, with no significant effect from the wastewaters. At the end of the evaluation period, the ETc was not more than 4.90 mm/day, with no wastewater treatment superior over one another (Figure 2b).

A comparison of both vegetables showed no significant difference in the values of ETc throughout the growing period, however there was significant interaction between the wastewater treatments and vegetables only at the first week of evaluation (Table 3). The trend in the ETc values agrees with the findings of Igbadun (2012) who used mini-lysimeters to estimate the crop water use of maize and groundnut in northern Nigeria. Shukla et al. (2007) in their study on water use and crop coefficient(Kc) for watermelon in southwest Florida reported that the Kc of watermelon determined from the lysimeter study was comparable to the Kc by FAO-Penman Monteith (Allen et al., 1998). The ETc trend is a function of the evaporative demand of the screen house microclimate which is also influenced by that of the outside air. Comparing the two vegetables, there was differences in the trend of ETc. Igbadun (2012) also found different ETc values for maize and groundnut crops, respectively. The differences in the response of the two vegetables to wastewater treatments were not unexpected because crop response to different management practices is not always the same as a result of differences in crop specie and physiology.

Table 4 shows the results of the soil water balance of the wastewater irrigated vegetables. For the entire evaluation period, the total amount of waste- and rainwater applied was 109.64 mm, the total deep percolation (Dp) ranged from 39.84 to 50.00 mm while the change in soil water storage (ΔS) had values between 4.89 and 12.07 mm (Table 3).

The total crop evapotranspiration (ETc) of the SM vegetable under the different wastewater treatments ranged between 52.96 and 57.72 mm while that of CA

Table 3. Statistical comparison of the temporal distribution of consumptive water use and total water use (ETcTot) of both vegetables under different wastewater irrigation.

Statistical parameter	Day of the year during the growing period							
LSD(p<0.05)	242	247	252	257	262	267	272	ETcTot
WW	5.16*	3.88*	0.78^{ns}	1.38^{ns}	0.07^{ns}	2.34^{ns}	0.16^{ns}	1.48^{ns}
Veg	0.76^{ns}	3.62^{ns}	0.30^{ns}	0.18^{ns}	0.60^{ns}	0.05^{ns}	2.12^{ns}	2.26^{ns}
WW x Veg	3.76*	2.54^{ns}	1.80^{ns}	2.66^{ns}	0.24^{ns}	0.28^{ns}	0.39^{ns}	1.52^{ns}

WW: wastewater effect; Veg: vegetable effect; WW x Veg: wastewater x vegetable interaction; ETcTot: total crop evapotranspiration.
*: significant; ns: not significant at 5% level of probability by Fisher`s Least Significant Difference (LSD) test.

Table 4. Soil water balance of the wastewater irrigated vegetables showing total irrigation applied, I; deep percolation, Dp; change in soil water storage, ∆S and crop evapotranspiration, ETc.

Vegetable	Wastewater	I (mm)	Dp (mm)	∆S (mm)	ETc (mm)
SM	AW	109.64	39.84	12.07	57.72
	BW	109.64	50.00	4.89	54.75
	CE	109.64	49.83	6.85	52.96
	RW	109.64	47.02	6.20	56.42
CA	AW	109.64	43.07	11.75	54.82
	BW	109.64	40.82	9.79	59.03
	CE	109.64	44.41	11.09	54.13
	RW	109.64	43.17	5.22	61.25

SM: Eggplant (*S. macrocarpon*) CA: Lagos spinach (*C. argentea*)AW: abattoir wastewater; BW: bathroom and laundry wastewater; CE: cassava effluent; RW: rainwater.

vegetable was between 54.13 and 61.25 mm, with SM vegetable having slightly higher ETc. The differences in soil water storage were attributed to the effect of the wastewater treatments on soil hydraulic properties and water dynamics. Cerdà and Doerr (2007) said a reduction in water infiltration due to wastewater irrigation could reduce amount of plant available water, with negative effect on crop growth and development. Although, the soil samples were packed into the mini- lysimeters using field bulk density and moisture content, however such natural condition is rarely attainable because of the rearrangement of soil particles due to alternate drying and wetting cycles caused by irrigation. During the reconsolidation process the effective stress in the soil approaches zero, causing the soil matrix to collapse under its own weight, thus decreasing the size and number of macropores at varying degree. Also the dynamic forces (adsorption and momentum) of the wastewater moving through the pores tend to compress the soil matrix. Thus, the marked differences in deep drainage and soil water storage among the treatments.

Conclusion

The occurrence of soil hydrophobicity and water use pattern of two indigenous vegetables under different wastewater irrigations was investigated. Wastewater irrigation significantly (p<0.05) influenced the occurrence of soil hydrophobicity, as the initially wettable soil changed to slightly hydrophobic, with the highest degree from cassava effluent wastewater treatment. The ETc of both vegetables was significantly (p<0.05) affected, although not more than two weeks after sowing while none of the wastewater treatments was dominant as regards the temporal distribution of the ETc. The continuous application of wastewater for irrigation will tend to increase the level of water repellency, adversely affect soil hydraulic properties and water dynamics and influence soil water retention.

Conflict of Interest

The authors have not declared any conflict of interest.

REFERENCES

Abegunrin TP, Awe GO, Idowu DO, Onigbogi OO, Onofua OE (2013). Effect of wastewater irrigation on soil properties and growth of cucumber (*Cucumis sativa*). J. Soc. Sci. Environ. Manage. 4(7):139-145.

Allen RG, Pereira LS, Raes D, Smith M (1998). Crop evapotranspiration: guidelines for computing crop water requirements. FAO. Irrigation and Drainage Rome: Italy. 56:328.

Ashraf E, Shah F, Luqman M, Younis M, Aziz I, Farooq U (2013). Use of untreated wastewater for vegetable farming: a threat to food safety. Int. J. Agric. Appl. Sci. 5(1):27-33.

Cerdà A, Doerr SH (2007). Soil wettability, runoff and erodibility of major dry-Mediterranean land use types on calcareous soils. Hydrolog. Proc. 21:2325-2336. Available online: <http://onlinelibrary.wiley.com/doi/10.1002/hyp.6755/pdf>.
Accessed: 20th June, 2014. doi: 10.1002/hyp.6755.

Dekker LW, Jungerius PD (1990). Water repellency in the dunes with special reference to The Netherlands. Catena 18:173–183.

Doerr SH, Shakesby RA, Dekker LW, Ritsema CJ (2006). Occurrence prediction and hydrological effects of water repellency amongst major soil and land-use types in ahumid temperate climate. Euriron. J. Soil Sci. 57:741-754.

Ensink JHJ, van der Hoek W, Matsuno Y, Munir S, Aslam MR (2002). Use of untreated wastewater in peri-urban agriculture in Pakistan: Risks and opportunities. Research Report 64. Colombo, Sri Lanka: Int. Water Manage. Institute, P. 32.

González-Peñaloza FA, Cerdà A, Zavala LM, Jordán A, Giménez-Morera AG, Arcenegui V (2012). Do conservative agriculture practices increase soil water repellency? A case study in citrus-cropped soils. Soil. Tillage Res, 124:233–239.

Igbadun HE (2012). Estimation of crop water use of rainfed maize and groundnut using mini-lysimeters. Pacific J. Sci. Tech. 13(1):527-535.

Khalil S, Kakar MK (2011). Agricultural Use of Untreated Wastewater in Pakistan, Asian J. Agri. Rural Develop. 1: 21-26.

Kauser S (2007). Water use in vegetable production in district Faisalabad. MSc Thesis, Department of Environmental and Resource Economics, University of Agriculture, Faisalabad, Pakistan.

Kawamoto K, Moldrup P, Komatsu T, de Jonge LW, Oda M (2007). Water repellency of aggregate size fractions of a volcanic ash soil. Soc. Sci. Soc. Am. J. 71:1658-1666. Available online: <https://www.soils.org/publications/sssaj/pdfs/71/6/1658>. Accessed on: 20th June, 2014. doi: 10.2136/sssaj2006.0284.

Keizer JJ, Doerr SH, Malvar MC, Ferreira AJD, Pereira VMFG (2007). Temporal and spatial variations in topsoil water repellency throughout a crop-rotation cycle on sandy soil in north-central Portugal. Hydrol. Proc. 21:2317–2324.

King PM (1981). Comparison of methods for measuring severity of water repellence of sandy soils and assessment of some factors that affect its measurements. Austr. J. Soil Res. 19:275–285.

Madsen MD, Zvirzdin DL, Petersen SL, Hopkins BG, Roundy BA, Chandler DG (2011). Soil water repellency within a burned pinon–juniper woodland: sparial distribution, severity, and eco-hydrologic implications. Soc. Sci. Soc. Am. J. 75:1543–1553.

Martin DL, Gilley GP (1993). Irrigation water requirements. In: National Engineering Handbook, Chapter 2, Part 623, USDA/SCS, P. 284.

Mataix-Solera J, Arcenegui V, Guerrero C, Mayora AM, Morales J, González J, García-Orenes F, Gómez I (2007). Water repellency under different plant species in a calcareous forest soil in a semiarid Mediterranean environment. Hydrol. Proc. 21:2300–2309.

Müller K, Deurer M (2011). Review of the remediation strategies for soil water repellency. Agric. Ecosyst. Environ. 144:208-221. Available online: <http://www.sciencedirect.com/science/article/pii/S0167880911002878>. Accessed: 20th June, 2014. doi: 10.1016/j.agee.2011.08.008.

Ojo DO, Olaleye O, Alabi OO, Atobatele JT, Chianu JN (2011). Integrated Harvesting Techniques for African Egg Plant (*Solanum macrocarpon* L. cv. Igbagba). Am. J. Exper. Agric. 1(4):458-465.

Olaniyi JO (2006). Influence of Nitrogen and Phosphorus fertilizers on seed yield and quality of Wgusi melon (*Citrullus lanatus* (Thumb) Mansf) in Ogbomoso, Southwest Nigeria. Ph.D Thesis, University of Ibadan, pp. *57-155.*

Osakwe SA (2012). Effect of cassava processing efluente on physical and chemical properties of soils in Abraka and Environs, Delta State, Nigeria. Chem. Mat. Res. 2(7):27-39.

Pescod MB (1992). Wastewater treatment and use in agriculture, FAO Irrigate. Drain. P. 47. FAO, Rome.

Rijsberman F (2004). Sanitation and access to clean water. In: Lomborg B (ed) Global crises, global solutions. Cambridge University Press, London.

Soil Survey Staff (2010). Keys to Soil Taxonomy, 11th ed. USDA - Natural Resources Conservation Service, Washington, DC.

Shukla S, Jaber F, Srivastava S, Knowles J (2007). Water use and crop coeficiente for watermelon in southwest Florida. Final Report, Report No. WRP-LY-0009, Deliverable 9. Institute of Food and Agricultural Sciences (IFAS), University of Florida, Immokalee, 70pp.

Tabatabaei SH, Najafi P, Amini H (2007). Assessment of Change in Soil Water Content Properties Irrigated with Industrial Sugar Beet Wastewater. Pak. J. Biol. Sci. 10:1649-1654.

United Nations (2003). Water for people, water for life. The United Nations world water development report. Barcelona: UNESCO.

USDA (2013). Cockscombs or Silver cock's comb (*Celosia argentea*). US Department of Agriculture. Accessed on 13 December, 2013.

Valipour M, Mousavi SM, Valipour R, Rezaei E (2013). Deal with environmental challenges in Civil Engineering projects using a new technology. J. Civil Environ. Eng. 3:126. Doi.10.4172/2165-784X.1000126.

Valipour M (2014). Analysis of potential evapotranspiration using limited weather data. Appl. Water Sci. Doi. 10.10071S1320-014-0234-2.

van der Hoek W, Ul Hassan M, Ensink JHJ, Feenstra S, Raschid-Sally L, Munir S, Aslam R, Ali N, Hussain R, Matsuno Y (2002). Urban wastewater in Pakistan: A valuable resource for agriculture. Research Report 63. Colombo, Sri Lanka: IWMI.

Vogelmann ES, Reichert JM, Prevedello J, Awe GO (2013). Hydro-physical processes and soil properties correlated with origin of hydrophobicity. Ciência Rural 43(9):1582-1589.

Wallach R, Ben-Arie O, Graber ER (2005). Soil water repellency induced by long-term irrigation with treated sewage effluent. J. Environ. Qual. 34:1910-1920.

Yao H, Zhang S, Xue X, Yang J, Hu K, Yu X (2013). Influence of the sewage irrigation on the agricultural soil properties in Tongliao City, China. Front. Environ. Sci. Eng. 7(2):273-280.

academicJournals

Vol. 10(5), pp. 373-383, 29 January, 2015
DOI: 10.5897/AJAR2014.8783
Article Number: 2F15F5149876
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Analysis of the laying characteristics of Nera black hens in a hot and humid environment

Ogbu, C. C.[1]*, Ani, A. O.[2] and Okpara, M. O.[2]

[1]Department of Animal Health and Production, College of Veterinary Medicine, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.
[2]Department of Animal Science, University of Nigeria Nsukka, Enugu State, Nigeria.

Received 21 April, 2014; Accepted 9 January, 2015

The study was conducted to analyze the laying characteristics of Nera black hens in a hot and humid environment and assess the physical characteristics of good, intermediate and poor layers. Seventy-five eight months old Nera black hens of mean body weight 1.35 ± 0.24 kg (range: 1.20 -1.65 kg) in their 12th week of lay and housed individually in battery cages were used for the study. Eggs were collected daily and recorded for each hen. The hens were subsequently divided into three classes based on their laying performance as follows: Good layers, intermediate layers and poor layers and their physical conditions appraised. Results showed that the peak of lay was between 06:00 to 08:00 h and egg production declined gradually throughout late afternoon hours until no egg was laid between 17:00 and 18:00 h. About 88.75 and 11.25% of the eggs were laid in the morning and afternoon hours, respectively. Eggs laid between 6:00 and 7:00 h had the heaviest (P<0.05) mean egg weight (70.10 ± 0.92 g) and the first eggs in a clutch were the heaviest eggs (P>0.05). Hens with the longest clutches and shortest number of pause days produced the greatest number of eggs. Good and intermediate layers had smooth, pinkish and full combs and wattles, moist and enlarged vents and flexible pubic bones with wide space in-between. Poor layers had dry combs and wattles, tight and hard abdomen and narrow space between pubic bones. It was concluded that Nera black hens could lay up to 229.68 eggs/annum and lay most eggs between 06:00 and 08:00 h of the day. Egg collection especially in floor managed flocks should be intensified within this time period to minimize losses from cracks and egg eating by the birds.

Key words: clutch traits, egg production, Nera black, oviposition time, pause days.

INTRODUCTION

Increased table egg production is one of the fastest means of providing quality animal protein at minimum cost in Nigeria (Oluyemi and Roberts, 2000). Today's commercial layer chicken is well suited for table egg production due to the tremendous genetic improvement in laying performance (Pym, 2010; Ogbu, 2012) as well as in management and husbandry techniques. Egg production of the individual bird is influenced by a number

*Corresponding author. E-mail: coschi07@yahoo.com

of laying traits such as clutch/sequence number, clutch/sequence length, the rate of lay, oviposition time, oviposition interval, lag time, frequency of pauses (pause number), number of pause days (pause length or size), tendency to go broody, and length of the broody period (Romanove et al., 2002; Eltayeb et al., 2010; Al-Nedawi et al., 2008; Erensayin and Camci, 2003; Gumulka et al., 2010). Longer sequence lengths, fewer pauses, shorter pause lengths, and uniform oviposition time indicate good layer performance (Etches, 1996; Jakowski and Kaufman, 2004; Reddy et al., 2004). Good layers lay sequentially and persistently (Miles and Jacob, 2000; Smith, 2003; Van Der Molen, 2004; Clauer, 2005). The laying status of a hen had been assessed using some physical characteristics such as appearance of the comb and wattles, eyes, beaks, distance between the two pubic bones, and wideness and moistness of the vent (Reddy et al., 2004; Ani and Nnamani, 2011). Apart from the laying traits enumerated above, egg production is also affected by such environmental factors as nutrition, ambient temperature, photoperiod, and relative humidity. These environmental factors change over time hence flocks should be continuously evaluated for performance.

Egg production varies within a flock indicating individual bird differences in laying performance. Though overall flock performance may be high, not all hens in the flock lay at the same rate. Furthermore, while some hens may be laying at a very high rate, some others may not be laying at all (Miles and Jacob, 2000; Ani and Nnamani, 2011) or laying at sub economic levels. Knowledge of good laying attributes enables the farmer to identify and cull poor layers from time to time thereby optimizing his profit. Knowledge of the distribution of oviposition during the day is also necessary in recommending frequency of egg collection to minimize cracks and associated vices. When buying birds at point of lay, knowledge of the physical features that indicate well being and laying potentials will enable the farmer make informed choices. Nera black, the subject of the current study was newly introduced in our teaching and research farm. The need therefore arose to study their laying characteristics and performance.

MATERIALS AND METHODS

Location and duration of study

The study was conducted at the Poultry Unit of the Department of Animal Science Teaching and Research Farm, University of Nigeria, Nsukka. Nsukka lies in the derived savannah region, and is located on longitude 6° 25´ N and latitude 7° 24´E at an altitude of 430 m above sea level (Breinholt et al., 1981). The climatic data obtained from the Energy Centre of the University of Nigeria, Nsukka during the period of the experiment showed that the study area had a natural day-length of 13 to 14 hours, mean maximum daily indoor and outdoor temperatures of 29.2 and 30.5°C, respectively, mean relative humidity of 76.6% and mean monthly rainfall of 781.33 mm (Energy Centre, University of Nigeria, Nsukka, 2011). The study lasted for 10 weeks. During this period, hens were observed daily and egg collection was done hourly between 06:00 and 18:00 h for the first eight weeks.

Experimental birds and management

The experiment was carried out in accordance with the provisions of the Ethical Committee on the use of animals and humans for biomedical research of the University of Nigeria, Nsukka (2006). Seventy-five eight months old Nera black hens in their 12th week of lay were used for the study. The hens were randomly selected from a flock of laying Nera black hens in the farm and weighed 1.35 ± 0.24 kg on the average (range: 1.20 to 1.65 kg). The hens were identified with hen numbers and housed in individual battery cages in an open-sided building with a block wall of 90 cm high and wire netting to the roof which was of asbestos. Hens were fed commercial layers mash containing 16.5% crude protein, 2650 kcal/kg of metabolizable energy, 4% crude fat, 6.5% crude fiber, 3.6% calcium and 0.4% phosphorus at 125 g/bird/day with *ad libitum* supply of cool and clean water. Routine vaccination and medication of the birds were carried out to maintain optimal health of the flock. To control wetness and odour from the litter, wood shavings were spread under the battery cages to absorb moisture. Litters were removed weekly. No supplemental light was provided during the period of the study. Data collected on each hen were oviposition time, total egg production, clutch/sequence length, total number of pause days, and individual egg weight (g) in relation to egg sequence and oviposition time.

Physical characteristics

After the eight week data collection on egg production traits, the hens were divided into three groups namely good layers (birds that laid 39 eggs and above or ≥ 69.6%), intermediate layers (28 to 38 eggs or 50.0 to 68.0%) and poor layers (< 28 egg or < 50.0%) and the physical characteristics associated with laying namely colour and general appearance of comb, wattles, eyes, beaks, cloaca, vent, and space between the pubic bones were assessed in the three groups.

Statistical analysis

Data collected were analyzed and presented using descriptive statistics such as means, standard deviation and frequency distribution. Good, intermediate, and poor layers were compared for laying performance using analysis of variance (ANOVA) for completely randomized design (CRD) using the SPSS Computer Package (SPSS, 2007). Significantly different means were separated using Duncan's New Multiple Range Test option in SPSS.

RESULTS

The trend in laying (oviposition) with oviposition time in the population of Nera black hens is presented in Figure 1 while Figure 2 presents the distribution of layers according to range of eggs laid. As shown in Figure 1, most eggs (88.7%) were laid in the morning hours (06:00 to 11:59 h), 11.1% of eggs in the afternoon hours (12:00 to 15:59 h), and only 0.2% between 16:00 and 18:00h. Oviposition reached a peak between 07.00 and 07:59h and declined progressively as the day advanced. Figure

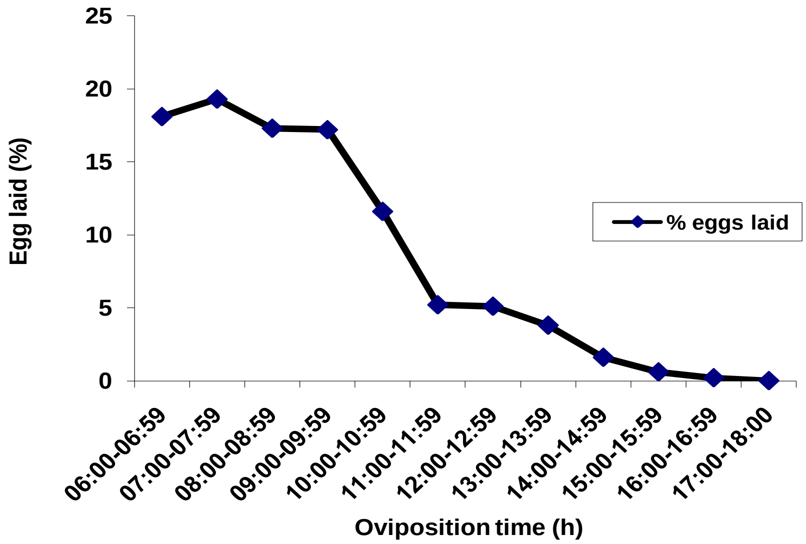

Figure 1. Trend in oviposition (% egg production) with oviposition time for Nera black layers.

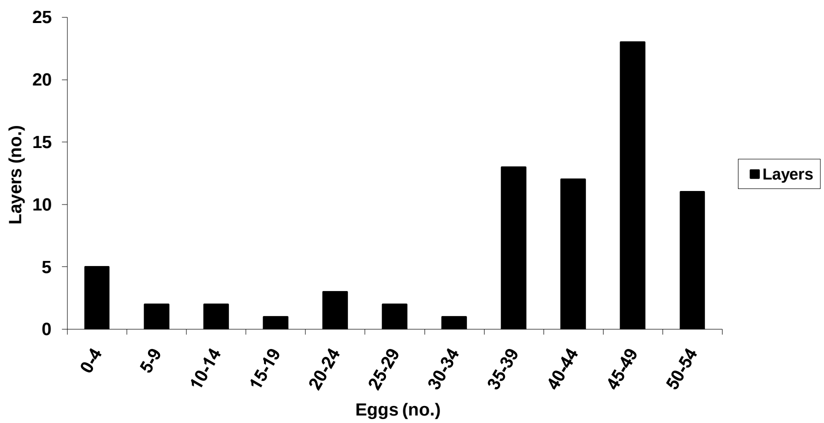

Figure 2. Distribution of Nera black layers according to egg classes.

2 shows that the highest number of birds (23) laid between 45 and 49 eggs (80.4 to 87.5% lay). These were followed by those that laid 35 - 39 eggs (13 birds, 62.6 - 69.6% lay), 40 to 44 eggs (12 birds, 71.4 to 78.6% lay), and 50 - 54 eggs (11 birds, 89.3 to 96.4% lay). A total of ten birds laid between 0 and 19 eggs (0.0 to 33.9% lay) during the experimental period. Thus 61.3% of the birds produced at between 71.4 and 96.4%, 25.3% of birds between 35.7 and 69.6%, and 13.3% of birds between 0 and 33.9%. Thus the least number (and percentage) of birds laid at the lowest percentages of production. In terms of the economics of laying performance, 59 birds (78.7%) laid above 50% (economic threshold) while 16 birds (21.3%) laid below 50% production level.

The distribution of Nera black layers according to range of clutch number is presented in Figure 3. The number of clutches (egg sequences) in the present study ranged from 0 to 19. Birds with clutches in the range of 5 to 9 were highest in number (33 or 44.0%) followed by those that produced 10 to 14 clutches (25 or 33.3%). Birds of 15 to 19 clutches were least in number (3 or 4.0%).

The distribution of clutch length among 75 Nera Black layers is presented in Figure 4. Clutch length ranged from 2 to 17 eggs. Clutches of 2, 4, 5, 3 and 6 eggs (in decreasing order) were highest in number (cumulative: 42 clutches or 56.0% of all clutches) followed by those of 7, and 8 eggs which were 4 clutches each (cumulative: 8 clutches or 10.7%). Nine (9), 10, 11, 12, 13, 14, and 15 egg clutches were 3, respectively (cumulative: 21 clutches or 28.0%) while 16, and 17 egg clutches were 2, respectively (cumulative: 4 clutches or 5.3%).

The classification of Nera black layers according to

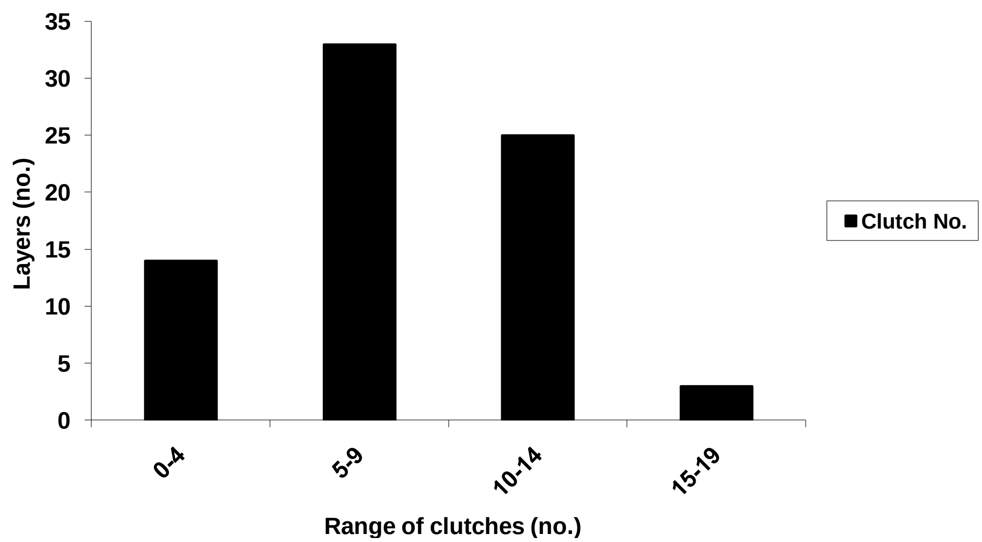

Figure 3. Distribution of clutch number in a population of Nera black layers.

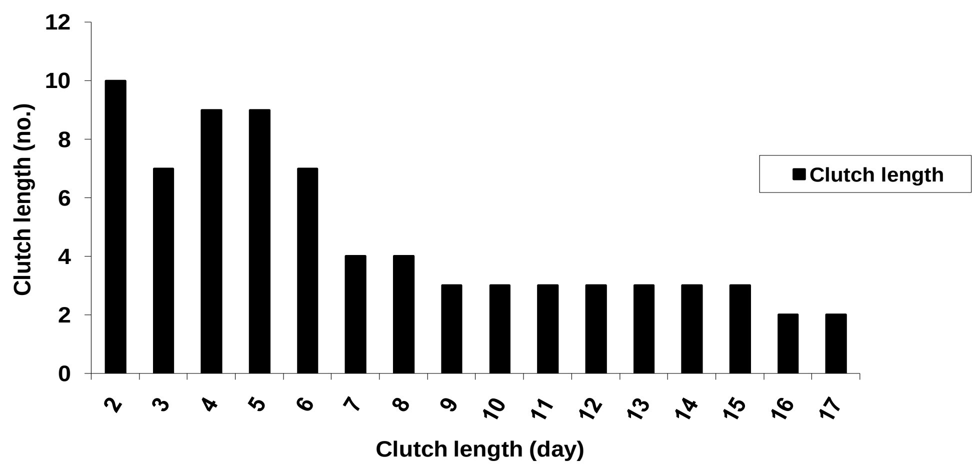

Figure 4. Distribution of clutch length in a population of Nera black laying hens.

Laying performance (good, intermediate, and poor layers) is presented in Figure 5 while the laying characteristics (egg production, pause days, clutch length, and clutch number) of these groups of layers are presented in Figure 6. As shown in Fig. 5, good layers (birds that laid 39 eggs and above during the experimental period) were 49 (65.3% of experimental birds); intermediate layers (birds that laid between 28 - 38 eggs) were 12 (16.0%), and poor layers (birds that laid less than 28 eggs) were 14 (18.7%). There were significant ($P < 0.05$) differences between layer groups in egg production, total pause days and clutch length but not for clutch number (Figure 6). As expected, good layers laid the highest number of eggs (46.76 ± 3.96) followed by intermediate layers (34.75 ± 2.83), while the least number of eggs was laid by poor layers (10.93 ± 9.39) (Figure 6A).

The variation in egg production within groups was highest (9.39 SD) in poor layers compared to good layers (3.96 SD) and intermediate layers (2.83 SD). Egg production in this group ranged from 0 to 27 eggs in 56 days (8 week) compared to 39 to 54 eggs and 28 to 37 eggs for good and intermediate layers, respectively. Good layers had the least ($P < 0.05$) number of pause days (9.04 ± 3.80 pause days, range: 2 to 17 pause days) followed by intermediate layers (21.25 ± 2.83 pause days, range: 19 - 28 pause days), while poor layers had the highest number of pause days (45.07 ± 9.39 pause days, range: 29 - 56 pause days) (Figure 6B). Clutch length was longest ($P < 0.05$) in good layers (7.26 ± 3.53 days, range: 2.73 - 17.0 days) followed by intermediate layers (3.99 ± 1.62, range: 2.18 - 7.20 days) but shortest in poor layers (1.45 ± 0.62, range: 0.00 - 2.50 days) (Figure 6C).

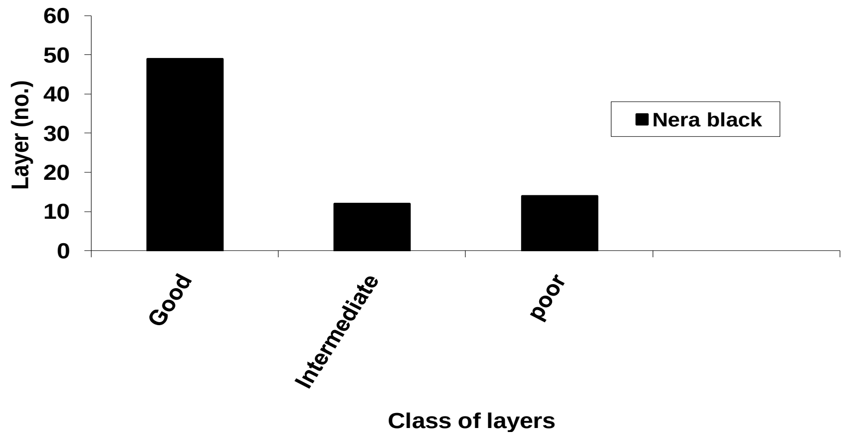

Figure 5. Classification of Nera black hens according to laying characteristics.

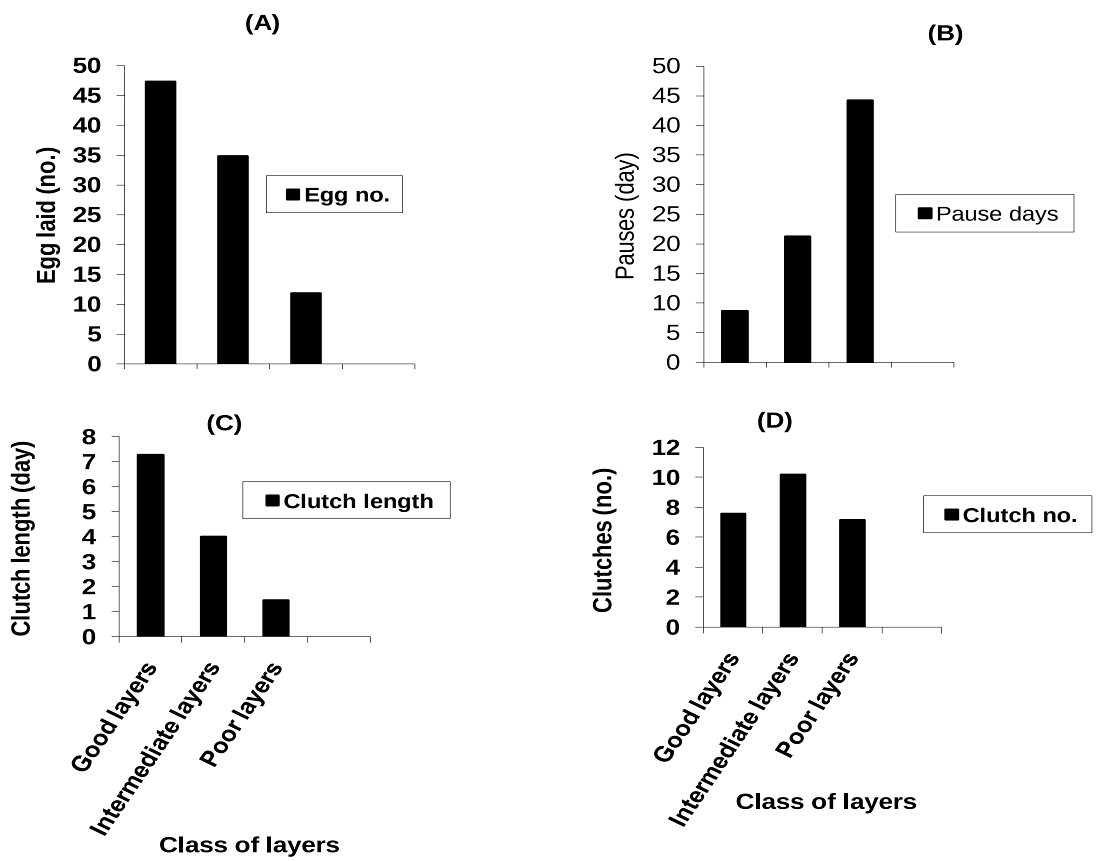

Figure 6. Laying characteristics of good, intermediate, and poor Nera black layers.

Clutch number also differed significantly (P < 0.05) among the layer groups with good and intermediate layers having the highest number of clutches (7.72 ± 2.93 and 10.17 ± 4.15 clutches, respectively). Poor layers had the least clutch number of 6.64 ± 5.14 clutches (range: 0 - 14 clutches) (Figure 6D).

There was a gradual reduction in egg weight as oviposition time advanced (Figure 7). Eggs laid between 06:00 and 08:59h had the highest egg weights (70.1 ± 0.92, 69.46 ± 0.71, and 68.51 ± 0.72 g, overall mean = 69.36 ± 0.46 g) and these were significantly (P < 0.05) higher than eggs laid between 09:00 and 11:59h (67.94 ±

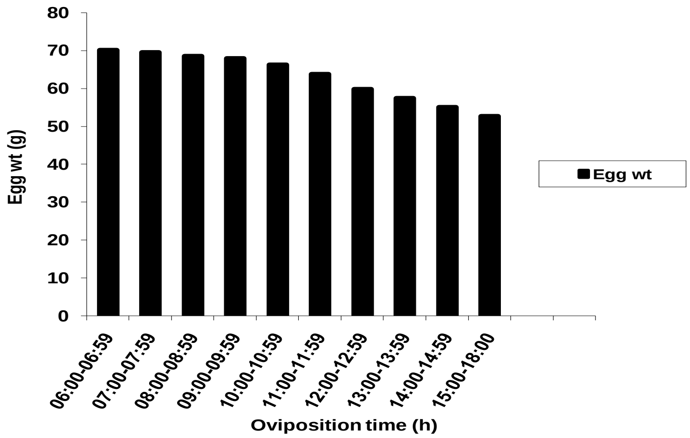

Figure 7. Effect of oviposition time on egg weight of Nera black layers.

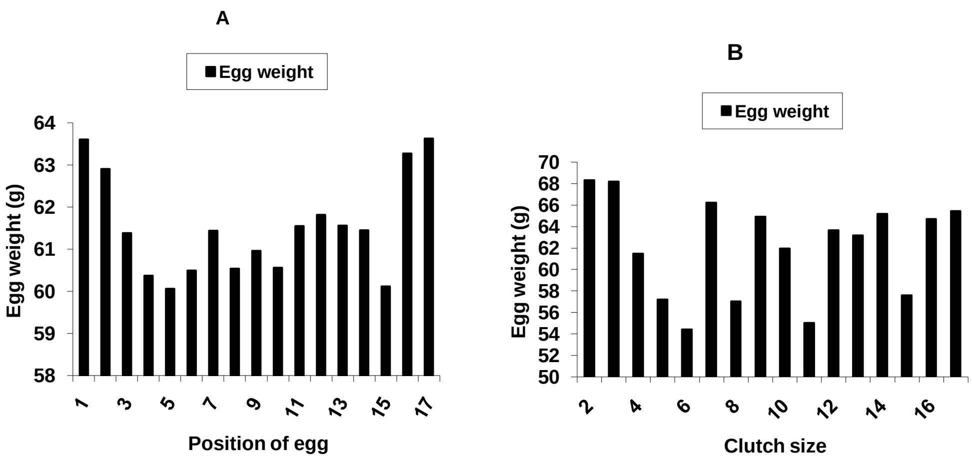

Figure 8. Effect of position of egg in a clutch (A) and clutch size (B) on egg weight.

0.64, 66.21 ± 0.55, and 63.79 ± 0.64 g, overall mean = 65.98 ± 0.49 g) which were in turn heavier than those laid between 12:00 and 18:00h (59.79 ± 0.51, 57.39 ± 0.47, 54.97 ± 0.58, and 52.66 ± 0.71 g, overall mean = 56.20 ± 0.55 g). Across the oviposition period from 11:00 to 14:59h, egg weight decreased significantly ($P < 0.05$) with every two hour increase in oviposition time (namely, 63.79 ± 0.64 vs. 59.79 ± 0.51 g, 59.79 ± 0.51 vs. 57.39 ± 0.47 g, and 57.39 ± 0.47 vs. 52. 97 ± 0.58 g, for 11:00 - 11:59 vs. 12:00 - 12:59 h, 12:00 - 12:59 vs. 13:00 – 13:59h, and 13:00 - 13:59 vs 14:00 - 14:59 h, respectively). The mean weight of eggs laid between 14:00 and 14:59, and 15:00 and 18:00 h, were similar (52. 97 ± 0.58 g, and 52.66 ± 0.71 g, respectively).

The effects of egg position and clutch size on egg weight of Nera Black layers are presented in Figure 8. Significant ($P < 0.05$) differences existed between eggs of different positions in egg sequences (Figure 8A) as well as between egg sequences (clutches) (Figure 8B). First-in-sequence eggs (FI) weighed significantly heavier than eggs in the 3rd to 15th position (in 3 to 15 egg clutches) but were similar to those in the 16th and 17th position (for 16 and 17 egg clutches). Second-in-sequence eggs also weighed heavier than 3rd to 11th, and 13th to 15th in-sequence eggs but were similar to those in the 16th and 17th position. Third (3rd) to 15th-in-sequence eggs were similar in weight but significantly ($P < 0.05$) lower than those of 16th and 17th positions. For length of clutches (Figure 8B), 2 and 3-egg clutches had the highest ($P < 0.05$) egg weights followed by those of 7, 17, 9, 14, and 16 egg clutches which were similar in egg weight. Clutches of least egg weight were those of 12, and 13; 4, and 10; 5, 8, and 15; and 6, and 11 eggs in decreasing order.

Appraisal of the physical characteristics associated with good, intermediate, and poor egg production (appearance of the comb, wattles, beaks, shank, cloaca, and space between the pubic bones) showed that good and intermediate Nera Black layers displayed the usual physical features associated with high rates of egg production: Bright and attentive facial expression, alertness, bright eyes, pinkish and moist mucous membranes of the eyes, mouth, vent and cloaca, bright red/pink comb that is full (for the age), bleached beak, thin and flexible pubic bones with a wide space in between (could accommodated 2-3 average fingers). Poor layers on the other hand were not as bright and robust as good layers and had a space between pubic bones that could barely accommodate two average fingers. In addition they showed high excitability.

DISCUSSION

Effect of oviposition time on egg production

The significant variations in oviposition with oviposition time (Figure 1) show that oviposition is not equally or randomly distributed over the diurnal period. Most eggs (88.7%) were laid between 06:00 and 11:59 h indicating that this is the most critical oviposition period in this genotype. Oviposition period of 06:00 to 11:59h was found the most critical for oviposition in layers (Ajaero and Ezekwe, 2006; Ani and Nnamani, 2011). Zakaria et al. (2005) reported that a flock of 34 week old broiler breeders laid most of their eggs between 0700 and 1300h when feeding was at 0800h, with the greatest number of eggs for a single hour being between 0900 and 1000h. The same authors reported that oviposition in an older (59 week) broiler breeder flock under the same management schedule was more evenly distributed between 0700 and 1500h. Lillipers and Wilhelmson (1993) however noted that early afternoon was the main egg laying period in a White Leghorn layer flock housed in individual cages. In an earlier study in the same environment as the present study Orji and Nwakalor (1984) reported that Hypeco Goldline and Shaver Brown hens laid 76 and 71% of their eggs before 12:00h, respectively. More recently Ani and Nnamani (2011) studied the physical and laying characteristics of Golden Sex-Linked hens in the same environment and reported that the time period 06:00 to 11:59h was the most critical period for egg laying. In the present study, oviposition peaked between 07:00 and 07:59h but laying was more or less evenly distributed within the first 4h of day light (06:00 – 09:59h). The high frequency of oviposition in early morning hours compared to afternoon hours in the present study could be ascribed to the high rate of egg production in layers compared to broilers. Lewis *et al.* (2004) reported that in commercial crossbreeds of laying hens, the mean oviposition time was about 1h earlier in comparison with broiler breeder hens. Our results indicate that egg collection by attendants should be intensified within time period 06:00 to 11:59h to minimize losses in eggs and revenue through egg soiling, cracks and egg eating by hens especially in deep litter operations. Furthermore, management lapses that affect oviposition (e.g., inadequate and irregular feeding and watering, and undue disturbances of birds during peak period of lay, etc) should be avoided as these could adversely affect egg laying. Almost all the eggs for a particular day (99.8%) were laid between 06:00 and 15:59h (11 h) which was in agreement with the report by Zakaria et al. (2005) and also of Smith (2001) that chickens do not normally lay eggs in the late afternoon. This suggests that once laying is delayed beyond early afternoon (12:00 - 15:30h), oviposition is differed to the following day. Gumulka et al. (2010) however presented data on individual pattern of successive ovipositions in sequences of broiler breeder hens in which some eggs were laid during darkness. These ovipositions which were of varying percentages were defined as out-of-lay rhythm. The range of oviposition time in the present study suggests that oviposition during the day is mainly regulated by a circadian rhythm, entrained by the daily light-dark cycle related to the open period for preovulatory LH surge (Gumulka et al., 2010; Wolc et al., 2010) and maturation of ovarian follicle (Wolc et al., 2010) although within breed genetic differences may also be important (Wolc et al., 2010). Prolific layers are known to lay early and as clutch length increases, first ovipositions were reported to occur earlier and oviposition interval shortened (Gumulka et al., 2010).

Total egg production and other egg production parameters

The observation that 56 birds (78.7% of the total Nera black hens used in the study) produced at between 62.5 and 96.4% (Figure 2) shows that this population accounted for the majority of eggs laid each day and hence the greater proportion of the revenue due to egg production in this flock. Twenty-three percent (21.3%) of the birds (16 hens) produced at/or below economic threshold. Careful selection and elimination of unproductive birds and birds laying at below economic threshold would reduce wastage, and increase revenue for the farmer. The average number of eggs laid by each hen for the period of the experiment (56 days or 8 week) was 38.28 eggs. Total egg production of exotic commercial laying hens in Nigeria has been estimated to about 280 eggs per annum (Oluyemi and Roberts, 2000).

Clutch number and Length

The observed frequency of 33 (44%) for 5 to 9 egg clutches and 25 (33.3%) for 10 to 14 egg clutches (Figure 3) indicate that the clutch numbers of a majority (73.3%, that is, 44% + 33.3%) of the Nera black hens in the current study fall within these ranges. Numerous egg clutches indicate frequent pauses which could mean lesser eggs. On the other hand, scanty clutches could indicate prolonged clutches (long clutch lengths, bigger clutch sizes) and more eggs (Miandmients et al., 1993; Gumulka et al., 2010; Wolc et al., 2010) or prolonged pause days and lesser eggs while a zero clutch means lack of egg production by the hen. Generally, clutch number and clutch length (as well as egg production) are negatively correlated phenotypically and genetically (Erensayin and Camci, 2003; Wolc et al., 2010). Clutch numbers of 5 to 14 appear to be intermediate between 0 and 19 (the extreme clutch numbers in the present study) and were associated with the greater number of birds (58 or 77.3%). However, as described above, clutch number alone may not reveal much concerning the laying performance of a hen.

Clutch length or sequence length (Figure 4) indicates the number of days a hen laid without a break or pause. The longer the clutch length, the fewer would be the clutch number and the higher the egg production of a hen within a given period (Gumulka et al., 2010; Wolc et al., 2010). Hens which had the longest clutch length (17 days) produced the highest number of eggs (54) in the present study which agrees with the reports by Miandmients et al. (1993), and Ani and Nnamani (2011). Ani and Nnamani (2011) reported that hens with the longest clutches produced the largest number of eggs each laying year because they have the fewest number of non-productive days. Short clutch lengths indicate frequent pauses, more number of small sized clutches, and lesser eggs within a given period. The differences recorded in the clutches of the experimental hens might be due to individual bird differences in rate of follicular maturation which could be genetic or environmental in origin (Wolc et al., 2010). Slow follicular maturation (26 - 28 h or more) lead to shorter (2-3 days) sequences or clutches while hens that lay very long sequences typically have maturation rates of 24 h or less (Jakowski and Kaufman, 2004; Ajaero and Ezekwe, 2006).

Good, intermediate, and poor layers

It was observed that good layers (birds that laid at ~ 70% and above) accounted for 65.3% of the experimental birds while intermediate layers (birds that laid between 50 and 68%) accounted for 16.0% of the flock (Figure 5). These values indicate that birds that were economically viable were 81.7% of the entire flock while birds that laid below 50% constituted 18.7% of the flock. These birds were identified as poor layers and in commercial egg production such hens should be culled as they constitute a drain on the income of the enterprise. The physiological basis for the distinction between good, intermediate and poor layers relate to the rate of egg formation (Gumulka et al., 2010; Wolc et al., 2010) which is related to the rate of ovulation (follicular maturation) (Zakaria et al., 2005, 2009; Wolc et al., 2010) and the time spent in the various sections of the oviduct (Warren and Scott, 1935). The rate of egg production depend largely upon the size of the clutch and this is conditioned by the interval length (oviposition interval or lag period between successive ovipositions) and the length of the pause between clutches. Whereas good layers have long clutches and short interval lengths, poor layers have small clutches and long intervals lengths (Brun et al., 2003). The greater percentage of the variability in interval length between high and low intensity birds has been attributed to differences in the time for egg formation (Brun et al., 2003) and the delay in ovulation (longer pauses between clutches) (Brun et al., 2003). The longer interval and pause lengths of poor layers result from longer period of egg formation in the oviduct and delay in ovulation, respectively. Since birds do not lay at night (Smith, 2001), long interval lengths lead to short clutches due to the termination of clutches on account of photoperiod effect. Gumulka et al. (2010) reported that with increasing sequence length, time intervals (lag periods) between subsequent ovipositions within a sequence were shortened. The authors reported mean oviposition lag in hours as highest (4.03 ± 1.26 SD) for 2-egg sequences and tended to decrease with sequence length (3.20 ± 1.11, 2.18 ± 0.57, 1.46 ± 0.59, and 1.06 ± 0.56, for 3, 4, 6, and 9 egg clutches, respectively).

Egg production, pause days and clutch traits of classes of Nera black layers

The variations in egg production, total pause days, clutch length and clutch number among the performance classes of Nera black layers (Figure 6) were expected. These parameters characterize the egg production performance of individual birds as well as the entire flock. The shortest (9.04 ± 3.80 days, range: 2 - 17 days) and longest (45.07 ± 9.39 days, range: 29 - 56 days) total pause days observed for good and poor layers, respectively reflect the intensity of egg production in the two groups. Jakowski and Kaufman (2004) showed that egg sequences in prolific hens are separated by not more than a day of rest and that total pause days of prolific hens were lower than that of poor layers. In a Japanese quail (*Coturnix coturnix japonica*) flock of high egg rate, Erensayin and Camci (2003) reported 70.4% one-day pauses, 16.0 and 4.11%, 2- and 3-day pauses, respectively with mean pause length as 1.40 ± 0.04 days. In a study of the effect of pause size and number on egg mass of White Leghorns, Al-Nedawi et al. (2008) found the highest egg mass for the lowest pause size, and pause number, respectively. They reported that differences in egg mass belonged to pause size and pause number and that egg mass decreased as pause size and pause number increased. Erensayin and Camci (2003) reported significant negative correlations between hen-day production and number of pauses and pause length in Japanese quail.

Clutch length was longest in good layers compared to intermediate and poor layers (7.26 ± 3.53, range: 2 - 17 vs. 1.45 ± 0.62, range: 0 - 2.5 day or eggs) showing that egg sequences were more in this group. Wolc et al. (2010) reported maximum and average clutch length (mean ± SD) of 49.19, and 9.10 ± 5.07 eggs, respectively in a Rhode Island White flock of hens. In the study by Gumulka et al. (2010), the number of eggs laid in the longest sequences averaged 17.6 ± 2.0 eggs and the highest number of sequences was those of 2 to 9 eggs. Within breed differences in sequence length under the same management practices have since been recognized in laying hens (Johnson and Gous, 2007). Reasons for variability in egg sequence length within a flock range from differences in the length of open period for LH release to the dynamics of ovarian follicle maturation (Gumulka et al., 2010; Wolc et al., 2010). It has also been suggested that in some hens daily photoperiod is not synchronized with the ovulatory cycle (Gumulka et al., 2010) while Johnson and Gous (2007) suggested that this could be as a result of internal ovulation in some layers which is difficult to reveal in commercial production conditions. Generally, rate of egg production (laying intensity) is strongly positively correlated with clutch length or clutch size (Erensayin and Camci, 2003).

Clutch number did not differ significantly between good and poor layer groups. Furthermore, the values for clutch number in the three groups (7.72 ± 2.93, 10.17 ± 4.15, and 6.64 ± 5.14 for good, intermediate, and poor layers, respectively) were closer when compared to those of pause days (9.04 ± 3.80, 21.25 ± 2.83, and 45.07 ± 9.39 days, respectively) and clutch length (7.26 ± 3.53 days, 3.99 ± 1.62, and 1.45 ± 0.62 days, respectively). This could mean that clutch number may not be an independent criterion for comparing laying performances as obtained with pause days and clutch length. It has also been reported (Bednarczyk et al, 2000; Chen and Boichard, 2003b; Rosinski et al., 2006; Wolc et al., 2010) that number of clutches and average clutch length are negatively correlated while egg production and maximal clutch length are positively correlated (Wolc et al., 2010). This indicates that clutch length can be improved (with correlated improvement in egg production) by selecting against clutch number. The greater variation in egg production, within the poor layer group (9.39 SD) compared to other groups resulted from the wide range of performance values (0 - 27 eggs or 0.0 - 48.2%) observed for this group as well as the small number of birds (14 or 18.7%) in the group. Total pause days and clutch number also varied more in the poor layer group on account of the same reasons as well as the extremely low and high values observed for these parameters in this group.

Effect of oviposition time on egg weight

Egg weight showed a polynomial distribution with a gradual decrease as oviposition time advanced (Figure 7). Eggs laid between 06:00 and 08:59 were the heaviest followed by eggs laid between 09:00 and 11:59. Eggs laid between 12:00 and 18:00 were therefore the least in weight.

These results agreed with earlier reports (Zakaria et al., 2005; Tumova et al., 2007, 2009; Zakaria et al., 2009; Laughlin, 2011; King'ori, 2012). Zakaria et al. (2005) reported that early laid eggs were significantly heavier than mid-sequence eggs which were in turn heavier than late laid eggs in two broiler breeder layer flocks differing in age. Tumova et al. (2007) reported that eggs laid in the early morning are heavier than those laid late in the day while Laughlin (2011) reported a strong correlation between early and late egg weights among other parameters. Gumulka et al. (2010) reported that weight of eggs laid successively in a sequence decreased. These authors as well as Zakaria et al. (2005) suggested that a greater proportion of the early laid eggs were first-in-sequence eggs.

Effect of egg position and clutch length on egg weight

First and second-in-sequence eggs were found to be the heaviest eggs. This is in agreement with earlier reports (Robinson et al., 1991a; Novo et al., 1997; Zakaria et al., 2005; Gumulka et al., 2010). These eggs were heavier than those of 3rd to 15th position in the present study but of the same weight with eggs in the 16th and 17th positions. The reason for this similarity is yet to be understood. Significant differences in egg weight due to egg position in a sequence was not noticed among 3rd to 15th position eggs which were lower than those of 16th and 17th positions. Positional differences in egg weight have been attributed to differences in follicular growth period (Zakaria, 1999a, b; Zakaria et al., 2005, 2009). Zakaria et al. (2009) summarized the result of a number of studies (Zakaria et al., 1983; 1984a, b; Zakaria, 1999a, b) which among other findings indicated that average follicle growth period increased as sequence size decreased, follicular growth period decreased as egg position in a sequence increased from second to sixth, follicular volume tended to be less in terminal follicles in sequences of 2 to 5 eggs, and that the follicular growth period of the first-in-sequence egg was longer than for terminal follicles. From these findings differences in egg weight due to position effect can be attributed to differences in yolk weight and a definite trend would be expected from the 2nd to the 5th egg positions. Also Figure

8A reveals a steep decline in egg weight from the second to the fifth egg which in agreement with the foregoing. Beyond this position no definite trend was evident. Thus for sequences of 2 to 5 eggs, the rapid growth phase of terminal follicles was probably shorter while that of the first follicles was probably longer to account for the differences in the egg weight between first and terminal eggs of such sequences. King'ori (2012) reported that longer intervals of egg formation result in an increase in egg weight, albumen weight and a decrease in yolk percentage. Gumulka et al. (2010) reported that egg weight variation with laying order and sequence length is typical of wild and domestic birds. The authors however reported non significant differences in the weight and percentage of yolk and albumen in eggs in relation to position in egg sequences of broiler breeder hens used in their study. Whereas Tumova and Ebeid (2005) and Tumova et al. (2007) found lower yolk percentages in eggs laid in the afternoon compared to those laid in the morning hours, Tumova et al. (2009) did not show the effect of oviposition time on yolk weight in three genetic groups of laying hens. Cluthch size (or length) had significant effect on egg weight (Figure 8B) which could be as a result of the negative phenotypic and genotypic relationship between rate of egg production (laying intensity) and egg weight (Erensayin and Camci, 2003; Zakaria, 2001; Brun et al., 2003; Jonhson and Gous, 2003; Zakaria et al., 2009). In the present study, 2 and 3 egg clutches were the highest in egg weight in agreement with the findings of Gumulka et al. (2010) and Zakaria et al. (2005). The reports by Zakaria et al. (1983; 1984a, b; Zakaria, 1999a, b) indicate that average follicle growth period is negatively correlated with sequence length. Thus longer clutches experience shorter growth periods and hence smaller eggs. The trend of decrease in egg weight with clutch length was specifically observed between 2 to 5 egg clutches with no definite trend for longer clutches.

Lillipers and Wilhelmson (1993) had observed that egg weight decreased significantly with increasing clutch length, but only for sequences with less than 18 eggs. Egg weight variation with laying order and clutch length has evolutionary significance in wild birds (Sanchez-Lafuente, 2004; Gumulka et al., 2010) and could be important in determining fitness (Tinbergen and Both, 1999; Sanchez-Lafuente, 2004; Aslan and Yavuz, 2010). Also in sexually dimorphic species, within sequence variation in egg weight could be important in sex determination (Blanco et al., 2003; Magrath and Brouwer, 2003). These phenomena could be important in the unimproved domestic chicken.

Conclusion

Ovipositions occurred mainly (88.75%) between 6:00-11:00h. Egg collection should be frequent over this period to minimize losses. Clutch number is not a reliable index of laying efficiency compared to clutch length, pause number and pause length. Where individual bird performance cannot be measured (e.g., deep litter operations), farmers should use the physical features of poor layers to identify and cull unproductive hens to minimize losses of revenue and enhance profit.

Conflict of Interest

The authors have not declared any conflict of interest.

REFERENCES

Ajaero OI, Ezekwe AG (2006). The laying and physical characteristics of Shaver brown hens in a hot humid environment. Agro-Sci. J. Agric. Food Environ. Ext. 5:25-32.

Al-Nedawi AM, Al-Samarai FR, Al-Soudi KA (2008). Effect of pause size and its number on egg mass for a stock of White Leghorn in Iraq. Intern. J. Poult. Sci. 7(3):240-242. http://dx.doi.org/10.3923/ijps.2008.240.242

Ani AO, Nnamani ME (2011). The physical and laying characteristics of golden sex-linked hens under the humid tropical environment. Pak. J. Nutr. 10(11):1041-1047. http://dx.doi.org/10.3923/pjn.2011.1041.1047

Aslan A, Yavuz M (2010). Clutch and egg size variation, and productivity of the House Sparrow (*Passer domesticus*): Effects of temperature, rainfall, and humidity. Turk J. Zool. 34:255-266.

Bednarczyk M, Keilczewski K, Szwaczkowski T (2000). Genetic parameters of the traditional selection traits and some clutch traits in a commercial line of laying hens. Arch. Geflugelk. 64:129-133.

Blanco G, Martinez-Padilla J, Serrano D, Davilla AJ, Vinuela J (2003). Mass provisioning to different-sex eggs within the laying sequence: consequences for adjustment of reproductive effort in a sexually dimorphic bird. J. An. Ecol, 72:831-838. http://dx.doi.org/10.1046/j.1365-2656.2003.00753.x

Breinholt KA, Gowen FA, Nwosu CC (1981). Influence of environmental and animal factors on day and night grazing activity of imported Holstein Freisian cows in the humid lowland tropics of Nigeria. Trop. Anim. Prod. 6:4.

Brun JM, Delaunay I, Sellier N, Alletru B, Rouvier R, Tixier-Boichard M (2003). Analysis of laying traits in first cycle geese in two production systems. Anim. Res. 52:125-140

Chen CF, Boichard M (2003b). estimation of genetic variability and selection response for clutch length in dwarf brown-egg layers carrying or not the naked neck gene. Genet. Sel. Evol. 35: 533-537.

Clauer PI (2005). Poultry–A Small Scale Agriculture Alternative. Animal and Poultry Sciences Department, 3300 Litton Reaves Hall, VA Tech, Blacksburg, VA. http://www.afn.org/~poultry/flkman8.htm.

Eltayeb NM, Wani CE, Yousif IA (2010). Assessment of broodiness and its influence on production performance and plasma prolactin level in native chicken of the Sudan. Asian J. Poult. Sci. 4(1):1-6. http://dx.doi.org/10.3923/ajpsaj.2010.1.6

Energy Centre UNN (2008). Annual weather records of University of Nigeria, Nsukka(UNN), Nigeria, 2008.

Erensayin C, Camci O (2003). Effect of clutch size on egg production in Japanese quails. Arch. Geflugelk 67(1):38-41.

Etches RI (1996). Reproduction in Poultry. CAB International. University press, Cambridge. Uk. pp. 128-148.

Gumulka M, Kapkowska E, Maj D (2010). Laying pattern parameters in broiler breeder hens and intrasequence changes in egg composition. Czech J. Anim. Sci. 55:428-435. http://dx.doi.org/10.1051/animres:2003010

Jakowski R, Kaufman G (2004). Avian Reproductive Diseases. Zoological Medicine lectures. Tufts University Sciences Knowledgebase, (TUSK). Boston, Ma.

Jonhson SA, Gous RM (2003). An improved mathematical model of the ovulatory cycle of the laying hen. British Poultry Sci. 44: 752-760.

Jonhson SA, Gous RM (2007). Extent of variation within a laying flock: attainment of sexual maturity, double-yolked and soft-shelled eggs, sequence lengths and consistency of lay. British Poult. Sci. 48:609-616. http://dx.doi.org/10.1080/00071660701573037 PMid:17952733

King'ori AM (2012). Poultry egg characteristics: egg weight, shape and shell colour. Res. J. Poultry Sci. 5 (2):14-17. http://dx.doi.org/10.3923/rjpscience.2012.14.17

Laughlin K (2011). Management and control of egg size. Accessed from http://www.thepoultrysite.com/article/460/management-and-control-of-egg-size.

Lewis PD, Backhouse D, Gous RM (2004). Photoperiod and oviposition time in broiler breeders. British Poult. Sci. 45:561-564.

Lillipers K, Wilhelmson M (1993). Genetic and phenotypic parameters for oviposition pattern traits in three selection lines of laying hens. British Poult. Sci. 34:297-308. http://dx.doi.org/10.1080/00071669308417586

Magrath MJL, Brouwer L (2003). Egg size and laying order in relation to offspring sex in the extreme sexually size dimorphic brown songlark, Cinclorhamphus cruralis. Behav. Ecol. Sociobiol. 54:240-248. http://dx.doi.org/10.1007/s00265-003-0627-y

Miandmient P, Hiammal J, Rummiel K (1993). Length of eggs' clutches and time interval in white and brown layers (in Russian). Pticevodstvo 42:14-15.

Miles RD, Jacob JP (2000). Feeding the commercial egg type laying hen. Department of Animal and Poultry Sciences. University of Florida. Cooperative Extension Services, Institution of Food and Agricultural Sciences. http://edis.ifas.ufl.edu.

Novo RP, Gama LT, Soares MC (1997). Effects of oviposition time, hen age and extra dietary calcium on egg characteristics and hatchability. J. Appl. Poult. Res. 6:335-343. http://dx.doi.org/10.1093/japr/6.3.335

Novo RP, Gama LT, Soares MC (1997). Effects of oviposition time, hen age and extra dietary calcium on egg characteristics and hatchability. J. Appl. Poult. Sci. 6:335-343. http://dx.doi.org/10.1093/japr/6.3.335

Ogbu CC (2012). Phenotypic response to mass selection in the Nigerian Indigenous chickens. Asian J. Poult. Sci. 6(3):89-96. http://dx.doi.org/10.3923/ajpsaj.2012.89.96

Oluyemi JA, Roberts FA (2000). Poultry Production Spectrum Books, ltd, Ibadan. pp. 1-155.

Orji BI, Nwakalor LN (1984). The pattern of egg laying in domestic fowls kept in warm tropics. Nig. J. An. Prod. 11(2):123-129. PMid:15484734, PMid:6728790, PMid:6739415

Pym R (2010). Poultry genetics and breeding in developing countries. Food and Agricultural Organisation of the United Nations Poultry Development Review.

Reddy BLN, Prahaj NK, Reddy MR, Ray SVR (2004). Layer Breeding-Concepts and Principles. Poulvet.com. rhythm and reproductive trait of geeze. Folia Biol. Krakow 54:145-152. http://dx.doi.org/10.3409/173491606778557509

Robinson FE, Hardin RT, Robinson NA, Williams BJ (1991). The influence of egg sequence position on fertility, embryo viability and embryo weight in broiler breeders. Poult. Sci. 70:769-765. http://dx.doi.org/10.3382/ps.0700760

Robinson FE, Hardin RT, Robinson NA, Williams BJ (1991a). the influence of egg sequence position on fertility, embryo viability, and embryo weight in broiler breeders. Poult. Sci. 70:760-765. http://dx.doi.org/10.3382/ps.0700760 PMid:1876554

Romanov MN, Talbot RT, Wilson PW, Sharp PJ (2002). Genetic control of incubation behavior in the domestic hen. Poultry Sci. 81:928-931.http://dx.doi.org/10.1093/ps/81.7.928 PMid:12162351

Rosinski A, Nowaczewski S, Kontecka H, Bednarczyk M, Elminowska-Wenda G, Bielinka H, Maczynska A (2006). Analysis of the laying

Sanchez-Lafuente AM (2004). Trade-off between clutch size and egg mass, and their effects on hatchability and chick mass in semi-precocial purple swamphen. Ardeola 51(2):319-330.

Smith AJ (2001). Poultry. The Tropical Agriculturalist. 2nd (revised) ed. Macmillan Education Ltd. U.K. pp. 1-73.

Smith KI (2003). The reproductive system. The Hen, Incubation and Embryo development. Bulletin 633. Ohio State University. http://ohioline.osu.edu/b633/index.htm.

SPSS.Com.(2007). IBM(R)SPSS(R) Advantage for Microsoft (R)IBM.Corporation 2010,IBM Corporation Route,100,Somers,N4. 10589.

Tinbergen JM, Both C (1999). Is clutch size individually optimized? Behav. Ecol. 10(5):504-509. http://dx.doi.org/10.1093/beheco/10.5.504

Tumova E, Ebeid T (2005). Effect of time of oviposition on egg quality characteristics in cages and litter housing system. Czech J. Anim. Sci. 50:129-134.

Tumova E, Skrivan M, Englmaierova M, Zita L (2009). The effect of genotype, housing system and egg collection time on egg quality in egg type hens. Czech. J. Anim. Sci. 54:17-23.

Tumova E, Zita L, Hubbny M, Skrivan M, Ledvinka Z (2007). The effect of oviposition time and genotype on egg quality characteristics in egg type hens. Czech J. Anim. Sci. 52:26-30.

Van der Molen WH (2004). Laying an Egg. An interesting event. Retrieved November 14, access from http://www.afn.org/~poultry/egghen.htm.

Warren DC, Scott HM (1935). Physiological factors influencing the rate of egg formation in the domestic hen. J. Agric. Res. 51:6

Wolc A, Bednarczyk M, Lisowski M, Szwaczkowski T (2010). Genetic relationship among time of egg formation, clutch traits and traditional selection traits in laying hens. J. An. Feed Sci. 19:452-459.

Zakaria AH (1999a). ovarian follicle development in young and old laying hens. Arch. Geflugelk 63:6-12.

Zakaria AH (1999b). ovarian follicle growth in laying hens in relation to sequence length and egg position in various sequence lengths. Arc. Geflugelk 63:264-269.

Zakaria AH (2001). Egg production of the domestic hen is a reflection of ovarian physiology-A review: Part 1. Egg laying characteristics. Damascus Univ. J. Agric. Sci. 17:131-147.

Zakaria AH, Miyaki T, Imai K (1983). The effect of aging on ovarian follicle growth in laying hens. Poult. Sci. 62:670-674.

Zakaria AH, Miyaki T, Imai K (1984a). The relationships of clutch length and egg position on ovarian follicular growth in laying hens. Poult. Sci. 63:1250-1254.http://dx.doi.org/10.3382/ps.0631250

Zakaria AH, Plumstead PW, Romero-Sanchez H, Leksrisompong N, Brake J (2009). The effects of oviposition time on egg weight loss during storage and incubation, fertility, and hatchability of broiler hatching eggs. Poult. Sci. 88:2712-2717. http://dx.doi.org/10.3382/ps.2009-00069PMid:19903972

Zakaria AH, Sokai H, Imai K (1984b). Time of follicular transformation to the rapid growth phase in relation to the ovulatory cycle of layin hens. Poult. Sci. 63:1061-1063. http://dx.doi.org/10.3382/ps.0631061

Zakaria HH, Plumstead PW, Romero-Sanchez H, Leksrisompong N, Osborne J, Brake J (2005). Oviposition Pattern, Egg weight, Fertility and Hatchability of young and old broiler breeders. Poult. Sci 84(a):1505-1509.

academicJournals

Vol. 10(5), pp. 384-393, 29 January, 2015
DOI: 10.5897/AJAR2013.8429
Article Number: 118778E49879
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Impact of age and gender on postural stress of dairy workers

Deepali Chauhan

D/O Shri Samar Jeet Singh, Plot No. 67, Krishana Vihar Colony, Chinhat, Faizabad Road, Lucknow-227105, Uttar Pradesh, India.

Received 22 December, 2013; Accepted 22 January, 2015

Postural stress was measured by assessing time spent in different body postures, frequency of adopting various body postures and angle of body deviations in lumber region of dairy workers during milking. Findings of study suggested that squatting posture was adopted for the longest period of time along with standing posture as a frequently adopted posture by all dairy workers. Further, time spent in different posture was maximum in females of the higher age group and minimum in males of lower age group. However, frequency of adopting different posture was same for all dairy workers. Angle of body deviation was observed with the help of flexi curve by dividing whole process of milking operation into five parts-lifting of empty bucket (p1), placing of bucket on ground (p2), milking (p3), lifting of bucket containing milk (p4), carrying of bucket containing milk (p5), angle of body deviation was maximum during milking operation (p3) with maximum value in females of the higher age groups.

Key words: Postural stress, age of the dairy workers, gender of the dairy workers.

INTRODUCTION

India is one of the world's largest agriculture economies and has the second largest agricultural work force with two hundred and sixty million workers. The number of person/hour expended in crop production in India is measured in billions. India's human population has approached one billion marks and is rising at a compound growth rate of about 2.1%. It is expected to reach 1.5 billion marks in the next twenty-five years (Anonymous, 2003-2004). Rapidly increasing population of India is continuously decreasing the land available for farm operations. Except it, urbanization, industrialization and land fragmentation is also responsible for decreased land holding. The average size has decreased from 2.28 ha in 1977 to 1.55 ha in 1990-1991 (Chowdhary, 2005).

In these conditions, dairy farming has emerged as an important source of income to rural people especially to small and landless farmers. In a study carried out in Karnal district of Haryana, Patel and Mehta (1988) evaluated that, landless women spent more number of hours in dairying than men and their per hour earning from dairying was 4 times than that of agriculture.

Livestock is the fastest growing source of

E-mail: deepali_chauhan20@rediffmail.com, Tel: 9839946033. Fax: 0512 -2534164.

productive employment as compared to any other sector of Indian economy (Alagh, 2000). Within India, the livestock sector supports the livelihood of nearly two hundred million poor (Ahuja et al., 2000). Evidence showed that contribution has increased with decrease in land holding under mixed farming system prevalent in our country.

However, unlike developed country, dairy farming requires manual material handling with heavy lifting, pushing and pulling. All these have been recognized as risks factors for occupational health by NIOSH. More than 1 million workers annually sustain severe injuries enough to result in lost time from work due to overexertion or repetitive motion (Anonymous, 1999). There is a clear relationship between back disorders and physical load with the main physical risks factors being manual material handling (MMH), load moment, frequent bending and twisting during work awkward postures of stooping, squatting and kneeling (Anonymous, 2001). Manual material handling (MMH) has been recognized as a major cause of industrial accident, acute overexertion injury and chronic repetitive strain injury. Osteoarthritis of hip and upper limb complaints and hand arm syndrome are the occupational disease and hazards associated with work related risks factors prevalent in dairy farming activities.

Gustafsson et al. (1994) investigated the presence of musculo-skeletal symptoms in Swedish dairy farmers and observed that 82% of males and 86% of females were bearing musculo-skeletal symptoms. Guo et al. (1994) investigated the prevalence of work related to back pain for gender in agricultural production crops and reported the prevalence for males was 16.7 and 10.8 for females. For male workers, an average of 14.9 (SE = 9.4) work days was lost per back incident case. Another study was related to prevalence rate (29.5) among the males for Dutch trades and professionals (Hildebrandt et al., 1995b). Dairy farmers perceived frequent symptoms in the shoulders, elbows, lower back, hips and knees. In addition, female dairy farmers reported severe hand and wrist problems. As compared to women, men reported more back and knee problems. Women reported more symptoms in the neck, upper back and upper extremities than men. This statement was similar to the findings by Hildebrandt et al. (1995b) in which 75% of farm workers reported experiencing musculo-skeletal symptoms during the previous 12 months.

Myers et al. (1995) found many risk factors associated with the development of musculo-skeletal disorders in agricultural tasks. Occupational risk factors included static positioning, forward bending, heavy lifting, carrying, kneeling and vibration. Further, work force of dairy sector in India is heterogeneous, that is, females and males of various age groups are engaged in dairy sector. There was no single operation of dairy farming which was exclusively performed by men whereas cleaning of cattle shed, preparation of cow dung cakes and 'ghee' making were found to be the exclusive domains of women in the Hisar district of Haryana (Jain and Verma, 1995). Women constitute seventy-one percent of labour force in livestock sector (GOI, 2004). In dairy sector, there is an estimated seventy-five million women as compared to fifteen million men (Padmanabhan, 2001). Data on gender division of labour in livestock rearing show that the total mean working hours of women was significantly higher than that of men (Upadhyay, 2003).

Women who work in dairy farming may be at special risk for occupational injury (Nordstrom et al., 1995) because women have anatomical and physiological differences with men that may place them at risk for work related injuries (Engberg, 1993). On an average, upper body strength is 40.75% less in females than in males while lower body strength is 5.30% less in females (Falkel et al., 1986). Female's internal organs are more vulnerable to infections, external trauma and environmental irritants (Abbot, 2003). Whole body vibration affects women more than men because of anatomical and physiological characteristics. Fifty-two percent of the injuries occurred among women. Many injuries were reported to have occurred in bones, or while carrying out tasks such as feeding and milking (Boyle et al., 1997). Women who work in dairy farming may be at special risk for occupational injury. Nordstrom et al. (1995) reported that dairy farmers were 2.5 times more likely to be injured than residents of other types of farms.

Nordstrom et al. (1996) observed that although crude rate for falls was higher for men, the rate based on hours worked was higher for women. Among a case series of 154 injured farm women, 26% of injuries resulted from falls (McCoy, 2000). A study among farm women in Texas and Louisiana (U.S.A.) found falls to be the second leading cause of external injury (Carruth et al., 2001). In a case study of dairy farmers, Boyle et al. (1997) found that milking and feeding caused most injuries among the women. Many injuries were reported to have occurred in burns, or while carrying out tasks such as feeding and milking (Nordstorn et al., 1995; Pickett et al., 1995; Reed et al., 1999; Boyle et al., 1997; Stueland et al., 1997).

In a Swedish study, female milkers had a greater risk of developing hand and wrist MSDs as compared to agricultural workers that were non milkers (Stal et al., 1996). In the same study, symptoms of numbness and white finger related to vibration exposure were also reported. Triple burden of child rearing, farm work with dairy farming activities and household has fallen on the women. Economic pressure and third shift phenomenon result in long hours without rest and increased hours of exposure to potential injury producing agents. As we know that males and females have different body capacity to perform the work and as the age of workers increases, various physiological changes take place in human bodies which reduce worker's working capacity.

Thus, age and sex of dairy workers are contributing factors in developing occupational diseases. As with many developing and even developed countries, India has a dearth of accurate statistics on the incidences and prevalence of occupational health hazards exposure. The problem of work related risk factors specifically stooped and squatting posture of greater magnitude in developing countries as in India. Milking is a very common practice performed by dairy workers in squatting posture. In present study, an attempt has been made to find out postural stress among males and females of lower and higher age groups during milking and to find out impact of age and sex on postural stress caused during milking. Findings of the study will be useful in improving the working conditions of the dairy sector and enhancing work and health status of the workers through developing appropriate tools and techniques for milking operations while keeping age and sex factors of the workers in consideration.

MATERIALS AND METHODS

Research design

Experimental research design was planned for the study. In experimental research design, researcher tests the hypothesis of casual relationship between variables. Experimental research designs require procedures that will not only reduce bias and increase reliability but will permit drawing inferences about casualty.

Sampling design

Multistage random cum purposive sampling design was used to select the study area and respondents. The following stages were included for selection of locale, block, villages and respondents.

Selection of locale: District Kanpur (U.P.) was selected purposively for the present study with the assumption that the rural population of district was intensively engaged in dairy farming activities.

Selection of block: District Kanpur was covered by 10 developmental blocks. Out of 10 blocks, Kalyanpur was selected randomly. The total population of Kalyanpur block was 140, 285 lakh comprised of 75, 666 lakh males and 64,619 lakh females.

Selection villages: Three villages namely Hirdayapur, Ishwariganj and Dharampur were selected randomly from the list of villages of Kalyanpur block (Lottery or chit system).

Selection of respondents: Forty male and thirty female respondents of two age groups (30 to 40 years and 40 to 50 years) were selected purposively on the basis of physical fitness. Thirty male and twenty-two female respondents of 30 to 40 years and ten male and eight female respondents of 40 to 50 years were found physically fit from the selected samples of Phase – 1. Physical fitness was assessed through body mass index, body temperature, body pressure and heart rate.

The subjects who met the following conditions were selected for the experiments –

Physical fitness	:	BMI index
Body temperature	:	Not above 99°F
Blood pressure	:	$12/80^{+-10}$
Heart rate	:	70-90 beats/min.

METHOD OF DATA COLLECTION

Postural stress was measured by assessing time spent in different body postures, frequency of adopting various body postures and angle of body deviation in lumber region of dairy workers during milking. Time spent in different body postures by dairy workers was recorded with the help of stop watch and frequency of adopting various body postures by dairy workers was observed by simple count and record method from start to end of work without splitting up the whole activity into its various parts and without giving rest in-between stages of the activity. Angle of body deviation in lumber region of dairy workers was analyzed with the help of flexi curve. The shape adopted by flexi curve was immediately drawn on paper and angle of deviation of normal curve and deviated curve were measured with the help of protractor.

<x is the required angle
Measure <y
$<x = 360^0 - < y$.

ANALYSIS OF DATA

The collected data were tabulated and analyzed with the help of tabulation, subjective frequency, arithmetic mean, standard deviation, paired 't' test one way classification, ANOVA, Adjusted ANOVA (Snedecor and Cocharan, 1967). Before analyzing data related to angle of body deviation were transformed on the basis of their size and unit given by Federor (1955).

RESULTS AND DISSCUSSION

Time spent in different body postures by female and male dairy workers of lower and higher age groups during milking

In milking, F–values for group means of time spent by dairy workers in different body postures (S_1 B_1, S_3) were highly significant at 0.1% level of significance for all male and female dairy workers of lower and higher age group (A_1B_1, A_1B_2, A_2B_1 and A_2B_2) in complete cycle of milking. Table 1 suggests the mean values of time spent in different body postures by dairy workers of each group were significantly differ from one another. Further, time spent by dairy workers in different body postures (standing–S_1, bending–B_1, squatting–$S_{3)}$ during complete cycle of milking was maximum in females of higher age group (A_2B_1) and minimum in males of lower age group (A_1B_2). Further, it is also evident from that during milking, maximum time spent by dairy workers of all the four groups was in squatting postures followed by standing and bending posture (Table 2).

In complete cycle of milking, 't' values for the difference of means for time spent by dairy workers in different body postures (S_1, S_2, B_1) were significant for each two groups of dairy workers taken at a time (Table 3). It is also evident from the Table 4 that in complete cycle of milking,

Table 1. ANOVA for the group means of time spent (min) in different body postures by diary workers in milking (complete cycle).

Source	d.f.	Body postures (milking)							
		Sanding (S_1)		Sitting (S_2)		Bending(B_3)		Squatting (S_3)	
		M.S.	F	M.S.	*F*	M.S.	F	M.S.	F
Groups	3	5.615	64.95***	-	-	0.121	7.745***	1.867	298.2***
Error	66	0.086	-	-	-	0.016	-	0.006	-
Total	69	0.327	-	-	-	0.020	-	0.009	

Table 2. Mean values of time spent by dairy workers in different body postures of milking (complete cycle).

Body postures (Milking)	Time spent (min.) in different body postures (Mean values)				F
	Groups of dairy workers				
	$A_1B_1 = G_1$ (n = 22)	$A_1B_2 = G_2$ (n = 30)	$A_2B_1 = G_3$ (n = 8)	$A_2B_2 = G_4$ (n = 10)	d.f. = 66
Standing (S_1)	3.829(14.16)	2.844(7.588)	4.241(14.16)	3.502(11.76)	64.95***
Sitting (S_2)	-	-	-	-	-
Bending (B_1)	1.660(2.256)	1.545 (1.887)	1.762 (2.604)	1.608(2.086)	7.745***
Squatting(S_3)	4.316(18.13)	3.859 (14.39)	4.690 (21.49)	4.012(15.60)	-

A_1B_1 = Females of lower age group (G_1), A_1B_2 = Male of lower age group (G_2), A_2B_1 = Female of higher age group (G_3), A_2B_2 = Male of the higher age group (G_4).

Table 3. Comparison of groups of dairy workers on the basis of time spent in different body posture during milking (complete cycle).

Group	Time spent (min.) in different body postures (Milking)					
	Standing (S_1)		Bending (B_1)		Squatting (S_3)	
	$S.E_D$	't'$_{66}$	$S.E_D$	't'$_{66}$	$S.E_D$	't'$_{66}$
G_1 vs G_1	0.083	7.980***	0.035	3.253**	0.022	20.57***
G_1 vs G_3	0.121	-6.08***	0.052	-2.992**	0.033	11.43***
G_1 vs G_4	0.112	-2.912***	0.048	2.080*	0.030	10.08***
G_2 vs G_3	0.117	-11.94***	0.050	-4.361***	0-.032	26.38***
G_2 vs G_4	0.107	-2.659**	0.046	-3.37**	0.029	-5.286***
G_3 vs G_4	0.140	2.955**	0.059	2.602*	0.038	18.06**

$G_1 = A_1B_1$ (Females of lower age group), $G_2 = A_1B_2$ (Males of lower age group), $G_3 = A_2B_1$ (Females of higher age group), $G_4 = A_2B_2$ (Males of higher age group).

main effect age (A) and sex (B) of dairy workers on time spent in different body postures was significant while their interaction effect (A×B) was

Table 4. Adjusted ANOVA for the age (a) and sex (A) of dairy workers and their interaction (A × B) effect on adjusted means of time spent in different body postures of milking (complete cycle).

Group	d.f.	Time spent (min.) in different body postures (Milking)					
		Standing (S_1)		Bending (B_1)		Squatting (S_3)	
		M.S.	F	M.S.	F	M.S.	F
		10.28	118.9***	0.086	5.513*	0.833	133.1***
B	1	6.061	70.11***	0.266	17.01***	4.532	723.7***
A × B	1	0.200	2.313	0.005	0.340	0.160	0.862
Error	66	0.086	-	0.016	-	0.006	-

Sitting was not adopted during milking.

Table 5. Adjusted means of groups of dairy workers for time spent in different body postures during milking (complete cycle).

Body postures (Milking)	Time spent (min.) in different body postures (Adjusted means)			
	Groups of dairy workers			
	A_1	A_2	B_1	B_2
Standing (S_1)	3.168 (9.537)	3.694 (13.15)	4.045 (15.86)	3.099 (9.105)
Sitting (S_2)	-	-	-	-
Bending (B_1)	1.603 (2.070)	1.684 (2.334)	1.686 (2.343)	1.561 (1.939)
Squatting (S_3)	4.092 (16.25)	4.324 (18.35)	4.413 (18.98)	3.899 (14.70)

A_1 = Lower age group (30-40), A_2 = Higher age group (40-50), B_1 = Females, B_2 = Males.

non-significant. Non-significant interaction effect (A×B) infers that effect of sex on time spent in different body postures of dairy workers has not varied along with age of dairy workers. Moreover, mean value (adjusted) of time spent in different body postures was maximum in females (B_1) and minimum in males (B_2) [for complete cycle of milking (Table 5). Except that, among dairy workers of higher age group (A_2), mean value (adjusted) of time spent in different body posture in milking was significantly higher than that dairy workers of lower age group (A_1). Further, it was also significantly higher in females (B_1) than that of males (B_2) in complete cycle of time spent in milking (Table 6).

Thus, on the basis of above analysis, it can be said that age (A) and sex (B) of dairy workers have a significant impact on time spent in different body postures during milking and age of dairy worker has similar effect on time spent by dairy workers of both sex. Female dairy workers of higher age group had taken more time to complete the work; hence their time duration on different body posture was greater than dairy workers of other groups. Among all the body posture, squatting posture was adopted for longest period by dairy workers of all the four groups.

Frequency of adopting various body postures by female and male dairy workers of lower and higher age group during milking

From Table 7, it is clear that frequency of adopting different body posture during milking was the same for both female and male dairy workers of lower and higher age group. Furthermore, frequency of adopting standing posture was

Table 6. Comparison of groups of dairy workers on the basis of time spent in different body postures during milking (complete cycle).

Source	Time spent (min.) in different body postures (Milking)							
	Standing (S_1)		Sitting (S_2)		Bending (B_1)		Squatting (S_3)	
	$S.E_D$	't'$_{66}$	$S.E_D$	't'$_{66}$	$S.E_D$	't'$_{66}$	$S.E_D$	't'$_{66}$
A_1 vs A_2	0.080	-10.90***	-	-	0.034	-2.348*	0.022	-11.53***
B_1 vs B_2	0.071	8.372***	-	-	0.0302	4.125***	0.019	26.90***

A_1 = Lower age-group (30-40), A_2 = Higher age-group (40-50), B_1 = Females, B_2 = Males.

Table 7. Mean values of frequency of adopting different body postures by dairy workers during milking (complete cycle).

Body postures (Milking)	Frequency of adopting body postures (Mean value)			
	Groups of dairy workers			
	A_1B_1	A_1B_2	A_2B_1	A_2B_2
Standing (S_1)	9	9	9	9
Sitting (S_2)	-	-	-	-
Bending (B_1)	7	7	7	7
Squatting (S_3)	3	3	3	3

No statistical test was applied for the above table because of same data for all the male and female dairy workers was recorded during milking. A_1B_1 = Females of lower age group, A_1B_2 = Male of lower age group, A_2B_1 = Female of Higher age group and A_2B_2 = Male of the Higher age group.

maximum whereas frequency of adopting squatting posture during whole work period was minimum which points out that during Stage–2 (milking), squatting postures was adopted for longer period by all dairy workers without any change in their body position.

Angle of body deviation in lumber region of female and male dairy workers during selected dairy farming activities

In milking, the following activities were studied to assess the postural stress caused by body deviation from normal body curve: lifting of empty bucket in bend posture (P_1), placing bucket on ground in bend posture (P_2), milking in squatting posture (P_3), lifting of bucket containing milk in bend posture (P_4), carrying bucket containing milk in bend postures (P_5). Further, it is evident from Table 8 that, F-values of the angle of body bend in lumber region were highly significant for the dairy workers of all the four groups, during all activities of milking, that is, lifting empty bucket (P_1), placing bucket on ground (P_2), milking (P_3) lifting bucket containing milk (P_4) and carrying bucket containing milk (P_5). Furthermore, Table z9 explicit that average values for the angle of body deviation in lumber region was found maximum in females of higher age group (A_2B_1) and minimum in males of lower age group (A_1B_2) during all the working postures (P_1, P_2, P_3, P_4 and P_5) in complete cycle of cleaning of cattle shed.

Furthermore, it is also observed that average value of angle body deviation was maximum during milking, (P_3) followed by lifting bucket containing milk (P_4) by workers of four groups (A_1B_1, A_1B_2, A_2B_1 and A_2B_2). On the other hand, Table 10 highlights that difference of the mean of angle of body bend in lumber region of dairy workers was significantly different for each of the

Table 8. ANOVA for the group means of angle of body deviation in lumber region of dairy workers in different work postures of milking (complete cycle).

Source	d.f.	Work postures (milking)									
		P_1		P_2		P_3		P_4		P_5	
		M.S.	F	M.S.	F	M.S.	F	M.S.	F	M.S.	F
Groups	3	133.49***	72.603***	102.58	51.260***	242.37	88.537***	159.83	40.032***	50.91	48.45***
Error	66	1.839		2.001		2.737		3.992		1.051	
Total	69	7.563		6.375		13.15		10.768		3.218	

P_1 = Lifting of empty bucket, P_2= Placing of bucket on ground, P_3 = Milking, P_4 = Lifting of bucket containing milk and P_5 = Carrying bucket containing milk.

Table 9. Mean values of angle of body deviation in lumber region of dairy workers in different activities of milking (complete cycle).

Activities (Milking)	Angle of body deviation (Mean values)				
	Groups of dairy workers				
	$A_1B_1 = G_1$ (n=22)	$A_1B_2 = G_2$ (n=30)	$A_2B_1 = G_3$ (n=8)	$A_2B_2 = G_4$ (n=10)	'F' d.f. = 66
P_1	8.955	5.000	12.00	6.600	72.60***
P_2	10.10	5.933	11.25	7.900	51.26***
P_3	16.00	12.50	20.50	13.00	88.54***
P_4	14.00	8.900	18.38	10.30	40.03***
P_5	5.00	2.967	7.625	4.500	48.45***

P_1 = Lifting of empty bucket, P_2 = Placing of bucket on ground, P_3 = Milking, P_4 = Lifting of bucket containing milk, P_5 = Carrying bucket containing milk, A_1B_1 = Females of lower age group (G_1), A_1B_2 = Male of lower age group (G_2), A_2B_1 = Female of higher age group (G_3) and A_2B_2 = Male of the higher age group (G_4).

Table 10. Comparison of groups of dairy workers on the basis of angle of body deviation in lumber region during different activities of milking (complete cycle).

Group	Angle of body deviation (Activities of milking)									
	P_1		P_2		P_3		P_4		P_5	
	$S.E_D$	't'$_{66}$	$S.E_D$	't'$_{66}$	$S.E_D$	't'$_{66}$	$S.E_D$	't'$_{66}$	$S.E_D$	't'$_{66}$
G_1 vs G_2	0.3806	10.389***	0.3971	10.470***	0.464	10.982***	0.5609	6.2405***	0.2877	7.067***
G_1 vs G_3	0.559	-5.439***	0.5841	-1.984*	0.683	-6.404**	0.8249	-5.455**	0.4232	-6.203***
G_1 vs G_4	0.517	4.5529***	0.5395	4.0608**	0.631	5.8636***	0.7620	3.9368***	0.3909	2.2790*
G_2 vs G_3	0.539	-12.97***	0.5629	-9.444***	0.658	-14.392***	0.7951	-10.06***	0.4079	-11.42***
G_2 vs G_4	0.495	-3.231**	0.5166	-3.807***	0.604	-2.317*	0.7296	-0.685	0.3743	-4.046***
G_3 vs G_4	0.643	8.395***	0.6710	4.992***	0.784	10.289***	0.9478	7.913***	0.4862	6.427***

P_1 = Lifting of empty bucket, P_2 = Placing of bucket on ground, P_3 = Milking, P_4 = Lifting of bucket containing milk, P_5 = Carrying bucket containing milk, G_1 = A_1B_1 (Females of lower age group), G_2 = A_1B_2 (Males of lower age group), G_3= A_2B_1 (Females of higher age group), G_4 = A_2B_2 (Males of higher age group).

Table 11. Adjusted ANOVA for age (A) and sex (B) of dairy workers and their interaction effect (A×B) on adjusted means of angle of body deviation in lumber region during different activities of milking (complete cycle).

Source	d.f.	Angle of body deviation (Activities of milking)									
		P_1		P_2		P_3		P_4		P_5	
		M.S.	F	M.S.	F	M.S.	F	M.S.	F	M.S.	F
A	1	66.74	36.29***	34.74	17.36***	57.86	35.75***	68.00	17.03***	54.14	51.53***
B	1	321.2	174.7***	267.1	133.5***	590.8	215.8***	352.8	88.37***	91.96	87.52***
A×B	1	6.878	3.740	2.147	1.073	29.13	10.64	52.67	3.190	3.923	3.733
Error	66	1.839		2.001		2.737		3.992		1.051	

P_1 = Lifting of empty bucket, P_2 = Placing of bucket on ground, P_3 = Milking, P_4 = Lifting of bucket containing milk and P_5 = Carrying bucket containing milk.

Table 12. Adjusted means of groups of dairy workers for angle of body deviation in lumber region during different activities of milking (complete cycle).

Activities	Angle of body deviation (Activities of milking) Groups of dairy workers (adjusted means)			
	A_1	A_2	B_1	B_2
P_1	7.006	9.241	9.744	5.415
P_2	7.996	9.608	10.39	6.443
P_3	14.33	16.59	17.17	12.63
P_4	11.51	14.22	15.14	9.263
P_5	4.005	6.018	5.681	3.350

P_1 = Lifting of empty bucket, P_2 = Placing of bucket on ground, P_3 = Milking, P_4 = Lifting of bucket containing milk, P_5 = Carrying bucket containing milk, A_1 = Lower age group (30-40), A_2 = Higher age group (40-50), B_1 = Female and B_2 = Male.

two groups of dairy workers taken at a time in all the activities adopted by dairy workers during milking. Moreover, from the findings of Table 11, it is observed that main effect of age (A) and sex (B) of dairy workers on angle of body deviation in lumber region was significant and their interaction effect was non-significant for all the activities of milking. Non-significant interaction effect implies that impact of sex of dairy workers on angle of body deviation in lumber region during different activities has not changed along with the age of dairy workers. Except that, mean value (adjusted) of angle of body deviation in lumber region in different activities (P_1, P_2, P_3, P_4 and P_5) of milking was maximum in female (B_1) and minimum in males (B_2) (Table 12).

Table 13 shows that mean value (adjusted) of angle of body deviation in lumber region in the activities of milking was significantly higher in dairy workers of higher age group (A_2) than the dairy workers of lower age group (A_1) as well as, also significantly higher in female dairy workers (B_1) as compared to male dairy workers (B_2).

In nutshell, it can be said that all the work posture of milking requires deviation of backbone from its natural alignment. Except, the maximum angle of body deviation in all the activities was

Table 13. Comparison of groups of dairy workers on the basis of angle of body deviation in lumber region during different activities of milking (complete cycle).

Group	Angle of body deviation (Activities of milking)									
	P_1		P_2		P_3		P_4		P_5	
	$S.E_D$	't'$_{66}$	$S.E_D$	't'$_{66}$	$S.E_D$	't'$_{66}$	$S.E_D$	't'$_{66}$	$S.E_D$	't'$_{66}$
A_1 vs A_2	0.3709	-6.025***	0.387	-4.167***	0.453	-5.978***	0.547	-4.127***	0.280	-7.178***
B_1 vs B_2	0.328	13.22***	0.342	11.55***	0.400	14.69***	0.483	9.400***	0.248	9.356***

P_1 = Lifting of empty bucket, P_2 = Placing of bucket on ground, P_3 = Milking, P_4 = Lifting of bucket containing milk, P_5 = Carrying bucket containing milk, A_1 = Lower age group (30-40), A_2 = Higher age group (40-50), B_1 = Females and B_2 = Males.

recorded in females of the higher age group which indicates that age and sex of dairy workers significantly affect the angle of body deviation in lumber region during work however, effect of sex of dairy workers does not change along with their age. Effect of age on postural deviation may be because of decreased human body capacity to maintain stable body posture during work against to the pull of gravity due to decreased muscle's flexibility, reduced muscles mass and due to increased bone demineralization which reduces bone mass and renders the bone fragile and prone to fractures with the increase of age of dairy workers. Furthermore, on an average, upper body strength is 40 to 75% less in females than in males while lower body strength is 5 to 30% less in females (Falkel et al., 1986). Hence, female's body capacity to maintain stable posture during work is lesser than male's body capacity. It may be a reason behind greater degree of angle of body deviation among females than males during various activities of milking. In Punjab, Oberoi et al. (1999) also observed greater percentage deviation of angle in female of higher age group as compared to lower age group performing fetching water, collecting and bringing fodder.

Furthermore, maximum body deviation from normal body curve was in Stage 2 (milking) performed in squatting posture. Verma (2001) also found that the percent deviation of lumber region of rural women was maximum for working in sitting type kitchen in squatting posture.

Conflict of Interest

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

REFERENCES

Abbot NC (2003). Painful experiences : why do women and men feel pain differently? Health pain and gender. Pathways the Novartis J. 44:37-41.

Ahuja V, George PS, Ray S, McConell KE, Kurup MPG, Gandhi V, Umail-Deininger D, De Haan C (2000). Agricultural services and the poor : case of livestock health and breeding services in India. Indian Institute of Management, Ahmedabad, India.

Alagh YK (2002). Key note address. Indian Dairyman, 54(2):21-24.

Anonymous (1999). Occupational injuries and illness : Counts, rates and characteristic. Washington D.C. U.S. Department of Labour.

Anonymous (2001). Home and farm resource management in rural areas. Report, All India Coordinated Research Project in Home Science, Department of Family Resource Management, Haryana Agricultural University, Hisar, India.

Anonymous (2003-2004). The Hindu Survey of Indian Agriculture, pp. 5-9.

Boyle D, Gerberich SG, Gibson RW, Maldonado G, Robinson RA, Martin F, Renier C, Amandus H (1997). Injury from dairy cattle activities. Epidemiol. 8:37-41.

Carruth AK, Sharke L, Moffett B, Prestholdt C (2001). Women in agriculture : risk and injury experiences on family farms. J. Medical Women's Assoc. 56(1):1-4.

Chowdhury N (2005). Key note address delivered at National Seminar on Implementation of National Project on cattle and buffalo breeding at National Institute of Industrial Engineering, Mumbai, organized by Department of Animal Husbandry and Dairying, Ministry of Agriculture, Govt. of India and NABARD Consultancy Services, Mumbai, India.

Engberg L (1993). Woman and agricultural work. Occupational Medicine, 8:869-883.

Falkel JE, Sauka MN, Levine L, Pandolk KB (1986). Upper to lower body muscular strength and endurance ratios for woman and men. Ergonomics 28:1661-1670.

Federor WT (1955). Experimental design.Macmillan Co.,NEW York.

Guo H, Tanaka S, Halperin W, Cameron L (1994). Back pain prevalence in U.S. industry and estimates of lost work days. Am. J. Public Health. 89:1029-1035.

Gustafsson B, Pinzke S, Isberg PE (1994). Musculo-skeletal symptoms in Swedish dairy farmers. Swedish J. Agri. Res. 24:177-188.

Hildebrandt VH (1995b). Musculo-skeletal symptoms and workload in 12 branches of Dutch agriculture. Ergonomics 38:2576-2587.

Jain V, Verma SK (1995). Nature and extent of involvement of men and women in animal husbandry operations. Indian Dairyman 44(7):332-337.

McCoy CA (2000). Risks for occupational injury in farm women. Ph.D. Dissertation, University of Kentucky, Lexington.

Meyers JM, Bloomberg L, faucet J, Janowitz I, Miles A (1995). Using ergonomics in the prevention of musculoskeletal cumulative trauma injuries in agriculture: Learning from

mistakes of others. J. Agro. Med. 2(3):11-24.
Nordstrom D, Layde P, Olson K, Stuelond D, Follen M (1995). Incidences of farm-work-related acute injury in a defined population. Amer. J. Indust. Med. 28:551-564.
Nordstrom D, Layde P, Olson K, Stueland D, Follen M, Brand I (1996). Fall – related occupational injuries on farms. American J. Indust. Med. 29:509-515.
Padmanabhan BS (2001). Women empowerment in farm sector. Yojana 45:47-52.
Pickett W, Brison RJ, Niezgocles H, Chipmen ML (1995). Non-fatal farm injuries in Ontario; A population based survey. Accident Anal. Prev. 27:425-433.
Patel RK, Mehta RK (1988). Appropriate livestock production technologies for farm women. International Conference on Appropriate Agriculture Technology for farm women, New Delhi, India.
Reed DB, Westneat SC, Browning SR, Skarke L (1999). The hidden work of the farm homemaker. J. Agric. Safety Health 5:317-327.
Snedecor GW, Cocharan WG (1967). Two way classification with unequal numbers and proportion. Statistical Method ed (6th). pp. 484-489.
Stal M, Moritz U, Gustafsson B, Johansson B (1996). Milking is a high risk job for young females. Scand J. Rehab. Med. 28:95-104.
Stueland D, Lee B, Nordstrom D, Layde P, Wittman L, Gunderson P (1997). Case control study of agricultural injuries to women in central Wisconsin. Women Health, 25(4):91-103.
Upadhyay B (2003). Gender roles and multiple uses of water in north Gujarat. International Water Management Institute, working paper 70.
Verma S (2001). Ergonomic study of existing kitchen designs of rural and urban homes of Ludhiana district. Ph.D. dissertation, Punjab Agricultural University Ludhiana.

academicJournals

Vol. 10(5), pp. 394-398, 29 January, 2015
DOI: 10.5897/AJAR2013.7549
Article Number: 0AB6AA549881
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Initial growth of *Moringa oleifera* Lam. under different planting densities in autumn/winter in south Brazil

Poliana Ferreira da Costa*, Paulo Sérgio Rabello de Oliveira, Augustinho Borsoi, Edmar Soares de Vasconcelos, Loreno Egídio Taffarel, Jeferson Tiago Piano and Marcos Vinícius Mansano Sarto

Universidade Estadual do Oeste do Paraná/Centro de Ciências Agrárias/ Programa de Pós Graduação em Agronomia. Rua Pernambuco, 1777, CEP: 85960-000. Marechal Cândido Rondon, Paraná, Brazil.

Received 25 June, 2013; Accepted 22 January, 2015

Plant densities that decrease interplant competition can improve *Moringa oleifera* growth and yield by better use of resources and information about its cultivation in the autumn/winter season is necessary. An experiment was conducted to investigate the viability for the cultivation under the edafoclimatic conditions of the southern Brazil, region of subtropical climate. In addition, it was determined effect of planting densities on the initial growth of moringa (*M. oleifera* Lam.) plants. The experiment was carried out from April to July 2012, autumn/winter season, on a clayey Rhodic Hapludox in Marechal Cândido Rondon, Paraná State, Brazil. Treatments were arranged in a randomized block design in a 2 × 3 factorial: two evaluation periods (30 and 60 days after plant emergence) and three plant densities (14,815; 22,222 and 44,444 plant ha^{-1}), with four replications. When grown at lower population densities, the initial growth of moringa plants is not affected. The initial growth of moringa plants in the southern region of Brazil, on autumn/winter season was unsatisfactory due the occurrence of low temperatures. The moringa showed a high mortality rate under low temperature and does not seem to be recommended, in principle, to compose an agroforest system with edafoclimatic conditions similar to those of the studied region.

Key words: Plant population, vegetative growth, adaptation.

INTRODUCTION

Moringa oleifera Lam. (Synonym: *Moringa pterygosperma* Gaertner) belongs to a onogeneric family of shrubs and tree, Moringaceae. It is a native species from northwest region of India and now widely distributed throughout the tropics (Foidl et al., 2001). Moringa is a multipurpose tree and it has a great potential to become one of the most economically important crops for the tropics and subtropics considering its use in many fields as a medicine (Peixoto et al., 2011; Anwar et al., 2007), food (Pontual et al., 2012) and fodder plant (Reyes-Sánchez et al., 2006a). This great potential is due to the many valuable properties that the plant possesses include high protein content of leaves twigs and stems, the high protein and oil contents of seeds, large number

*Corresponding author. E-mail: poliferreiradacosta@hotmail.com

Table 1. Soil chemical properties at 0.0-0.10, 0.10-0.20, and 0.20-0.40 m depths, before the establishment of the experiment.

Depth (m)	pH	O.M.	$P_{Mehlich-1}$	H+Al	Al	K	Ca	Mg	CEC	V	m
		g kg^{-1}	mg kg^{-1}	------------------- cmol$_c$ kg^{-1} --------------------						----- % -----	
0.0–0.10	4.5	26.0	45.9	8.36	0.25	0.48	4.32	1.77	14.93	44.0	3.7
0.10–0.20	4.5	35.5	33.9	8.36	0.40	0.21	4.47	1.73	14.77	43.4	5.9
0.20–0.40	4.7	23.2	15.5	6.29	0.20	0.13	4.44	1.77	12.63	50.2	3.1

pH in $CaCl_2$ 0.01M. O.M.: organic matter. CEC: cation exchange capacity. V: soil base saturation. m: aluminum saturation.

of unique polypeptides in seeds that can bind to many moieties, the presence of growth factors in the leaves, and high sugar and starch content of the entire plant (Foidl et al., 2001).

This tree can grow in environments with constraints such as reduced rainfall, high temperatures, poor soil conditions, where most of the agriculturally important plant species are not able to grow satisfactorily (Morton, 1991). However, to achieve high production levels, plant requires fertile soils and good physical conditions (Mendieta-Araica et al., 2013; Asante et al., 2012). In addition, prolonged dry periods result in loss of leaves. It was introduced in Brazil in 1985 and its excellent adaptation to soils and climate of Brazilian northeast Semi-Arid region has motivated the researchers to study their growth in other regions of the country (Reyes-Sánchez et al., 2006b). However, the initial growths of moringa plants in the southern region of Brazil, on autumn/winter season, with occurrence probability of low temperatures are scarce.

The plant population, row spacing, and fertilization are major management decisions that moringa farmers must consider. As moringa continues to grow between cuttings the number of plants per hectare is dramatically reduced owing to the different growth rates among the plants. As they compete for sunlight, the larger plants shade out the slower growing or smaller plants. However, few studies have been carried out to discover optimum density at which moringa should be planted to produce a maximum amount of dry matter (DM). Therefore, studies on lower densities more adapted to the practical needs of small and medium-sized farms are still needed (Foidl et al., 2001).

Despite very interesting properties and many potential applications of the moringa outlined previously, this plant is practically unknown in western region of Paraná State, Brazil. The present study was carried out to investigate the effect of plant densities on the initial growth of moringa (*M. oleifera* Lam.), in order to determine the viability of its cultivation in southern Brazil, region of subtropical climate, with occurrence probability of low temperatures.

MATERIALS AND METHODS

Study site description

The experiment was carried out at the Agronomic Experimental Station, Universidade Estadual do Oeste do Paraná (State University of West Paraná), in Marechal Cândido Rondon Municipality, Paraná State, Brazil (24°31' S, 54°01' W and 390 m asl), during the months of April and July of 2012. The soil was a clayey Rhodic Hapludox (Eutroferric Red Latosol in the Brazilian classification) with 620, 270 and 110 g kg^{-1} of clay, silt and sand, respectively. Before starting the experiment, soil samples were collected at depths of 0.0–0.10; 0.10–0.20 and 0.20–0.40 m. The results of chemical analysis are shown in Table 1.

The southern region of Brazil is characterized by a humid subtropical climate. The average annual temperature is 20.9°C. The month of January is the hottest of the year (average 23.8°C) and the coldest month is June (average 16.6°C). The average annual rainfall is about 1600 mm, with rainfall during the summer (December = 230 mm) is about two times higher than in winter (August = 51 mm), featuring two stations well defined (Bianchini et al., 2001). The State of Paraná is located in a climatic transition zone, from the subtropical to temperate conditions prevail in which, in general, three types of climate. These are defined by the location, temperature and rainfall cycles. In western Paraná, predominates mesothermal humid subtropical climate with hot summers, no dry season with occasional periods of frost (Carvalho and Queiroz, 2002). In the state, there are few locations without risk of severe frost or under frost every 10 years (Wrege et al., 2004). The regional climate is relatively warm and wet with low temperatures in the winter. Rainfall and temperature data gathered during the experiment are shown in Figure 1.

Experimental design and treatments

The experimental design was a 2 × 3 factorial in randomized complete blocks with four replications. Treatments consisted of two evaluation periods (30 and 60 days after plant emergence) and three plant densities (14,815; 22,222 and 44,444 plants ha^{-1}). Uniform spacing between rows (0.90 m) was used in all plots. With the aim of obtaining three different planting densities (14,815; 22,222 and 44,444 plants ha^{-1}), 0.75; 0.50 and 0.25 m spacing's between plants were used within rows. The individual plot size was 18 m^2 (3.6 m wide × 5.0 m long) and the net area used for harvest was 7.2 m^2 to eliminate edge effects.

Field management and measurements

Moringa (*M. oleifera* Lam., Syn. *Moringa pterygosperma* Gaertner) seeds were sown on 03 April 2012, in 0.90 m spaced rows at densities studied. Untreated seeds of moringa were used for propagation. Seeds were sown in 2.0 cm deep holes at the study site (two seeds per hole). After two weeks of growth, the stand was thinned and only one healthy plant was kept. Mineral fertilization was carried out by applying 200 kg ha^{-1} of a commercial formulated 08-20-20 (N, P_2O_5 e K_2O, respectively), at sowing, and 90 kg ha^{-1} N top dressing in the form of urea at the beginning of plant's tillering. Irrigation was not applied. Weeds were controlled manually three weeks after germination and every second month throughout the

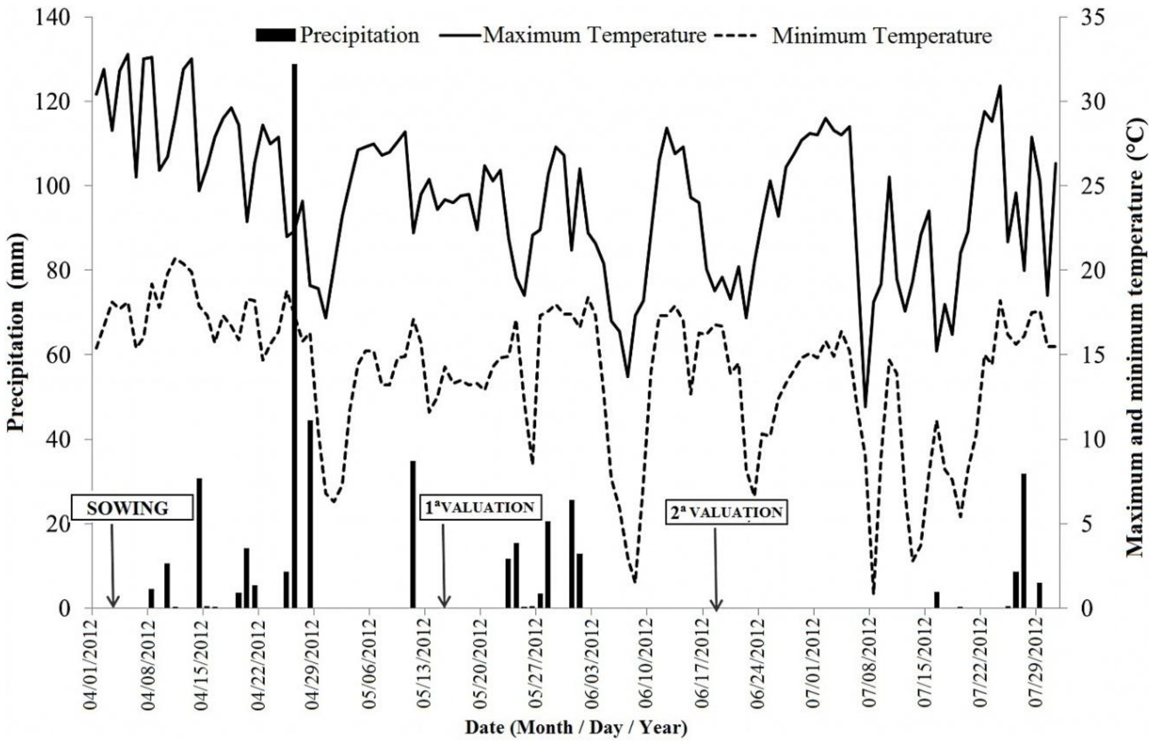

Figure 1. Total daily rainfall (mm) and maximum and minimum temperature (ºC) during the experiment. Sm – moringa sowing, 1st and 2nd – first and second evaluation, respectively.

Table 2. Summary of the analysis of variance for effects of evaluation periods and planting densities on plant height and stem diameter of moringa (*Moringa oleifera* Lam.) plants.

Sources of variation	Mean Square	
	Plant height	Stem diameter
Period (P)	48.40*	1.79*
Density (D)	4.45^{ns}	0.03^{ns}
Interaction (P × D)	1.92^{ns}	0.26^{ns}
C.V. (%)	15.5	8.4

ns: not significant. *: statistical significance at 5% by F test. C.V.: coefficient of variation.

experiment. The following parameters were used for data collection: plant height measurements and stem diameter at 15 cm base height were taken at 30 and 60 days after plant emergence (DAPE).

Statistical analysis

Original data were analyzed by ANOVA, and means of plant density were compared by the Tukey test at the 0.05 level of confidence. All analysis was performed using Sisvar 5.1 software for Windows (Statistical Analysis Software, UFLA, Lavras, MG, BRA).

RESULTS AND DISCUSSION

A summary of the analysis of variance for plant height and stem diameter is shown in Table 2. Period effect on plant height and stem diameter of moringa was significant ($P < 0.05$). Planting density had no significant effect on plant height and stem diameter of moringa plants. There was no significant interaction between the effects of evaluation periods and planting density on the plant height and stem diameter (Table 2).

The effect of evaluation periods on plant height and stem diameter of moringa is shown in Table 3. The plants evaluated at 60 days showed greater plant height and stem diameter compared plants evaluated at 30 days (Table 3). Indicating that there was plant growth although there has been only a small growth rate (1.4 cm in height and 0.3 mm in diameter). The small plant growth occurred in the second evaluation (60 days after

Table 3. Effect of evaluation periods on plant height and stem diameter of *Moringa oleifera* Lam. plants grown.

Evaluation period	Plant height (cm)	Stem diameter (mm)
30 days after emergence	7.3[b]	2.4[b]
60 days after emergence	8.7[a]	2.7[a]
SE	0.22	0.03
Number of observations	48	48

Values represented by the different letters, for the evaluation period show significant differences (F test, $p < 0.05$). Standard error (SE).

Table 4. Effect of planting density on plant height and stem diameter of *Moringa oleifera* Lam. plants grown.

Planting density (plant ha^{-1})	Plant height (cm)	Stem diameter (mm)
14,815	7.7	2.5
22,222	7.9	2.6
44,444	8.4	2.6
SE	0.22	0.04
Number of observations	48	48

Standard error (SE).

emergence) compared to the first evaluation (30 days after emergence) was due to the low temperatures recorded in the period of plant development (Figure 1). There were no reports of moringa cultivation under low temperature conditions. The younger the plant, the greater the damage to the leaves, stems and branches by frosts, due to the higher sensitivity of the vegetative material due to the proximity to the ground, where the temperature inversion is more pronounced (Caramori et al., 2000).

The effect of the three planting densities on plant height and stem diameter of moringa is shown in Table 4. The plant height and stem diameter of moringa were not significantly different between plant densities (Table 4). Similar finding was reported by Reyes-Sánchez et al. (2006b) when they evaluated the planting densities of 250,000; 500,000; and 750,000 plants ha^{-1} and the DM yield of moringa was not affected. Manh et al. (2005) also reported no effect of density on DM yield when densities of 125,000 plants ha^{-1} or lower were used. Goss (2012) found that population density reduced the stem diameter of moringa plants at high populations while increasing them at low densities. Studies done on other multipurpose trees indicate that increases in plant population density results in an increase in the plant growth with resources being utilized when roots and stems entangle and when each plant competes with its neighbor (Squire, 1990). In production systems suitable plant densities are used, the plants efficiently utilize soil and environmental conditions, and the inter-or-intra-specific competition is reduced (Sadeghi et al., 2009). A positive relationship between planting density and DM yield in tropical tree legumes such as *M. oleifera* has been reported (Mendieta-Araica et al., 2013; Sadeghi et al., 2009; Foidl et al., 2001).

Foidl et al. (2001) reported increasing DM production from 3.3 to 44 Mg ha^{-1} at 95,000 and 16,000,000 plants ha^{-1}, respectively. However, due to the high mortality at very high planting densities, those authors recommended 0.10 × 0.10 m or 1,000,000 plants ha^{-1} as the optimum. In another study, Mendieta-Araica et al. (2013) found that the planting densities of 167,000 plants ha^{-1} was best compared to density 100,000 plants ha^{-1}, due to the possibility of achieving very high dry matter yield (19 Mg ha^{-1}) with a high proportion of fine fraction yield. Although, high densities are positively correlated with high DM yields, the spatial arrangement in the field, the high amount of labour needed and difficulties during harvesting make high densities impractical for small and medium-scale farmers (Mendieta-Araica et al., 2013).

The initial growth of moringa plants was impaired by the occurrence of low temperatures, which triggered an increase plant mortality rate. The average mortality rate of moringa plants was 60% (data not shown). At occurrence of low temperatures around 1.5°C (Figure 1) in the period in which the plants found 45 days affected the survival of moringa plants, compromising the crop development. Based on results presented here, we infer that the moringa genotype used in this study is sensitive to low temperature conditions. Therefore, the moringa cultivation in the Paraná State, Brazil, on autumn/winter season, should not be recommended because at low temperatures negatively affects the crop establishment.

The susceptibility of the crop to low temperatures varies greatly according to the species and phenological stage of the plants (Camargo et al., 1993). With the aim of verify, the adaptability of native tree species submitted to extreme frost stress under an agroforestry system in southern Brazil, Vieira et al. (2003) found that species such as Brazilian coral tree (*Erythrina falcata* Benth), guanandi (*Calophyllum brasiliense* Cambess.) and licurana (*Hieronyma alchorneoides* Allemão) showed a high mortality rate under frost, and did not show a good potential to compose an agroforest system in a region of low temperatures like in southern Brazil.

Conclusion

When grown at lower population densities, the initial growth of moringa plants is not affected. The moringa plant has a slow initial growth rate under low temperature conditions in the autumn/winter season. The moringa showed a high mortality rate under low temperature and does not seem to be recommended, in principle, to compose a system with edafoclimatic conditions similar to those of the studied region.

Conflict of Interest

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

REFERENCES

Anwar F, Latif S, Ashraf M, Gilani A (2007). *Moringa oleifera*: a food plant with multiple medicinal uses. Phytother. Res. 21:17-25.

Asante WJ, Ochire-Boadu K, Baatuuwie NB (2012). Initial growth response of *Moringa oleifera* seedlings to different soil amendments. Afr. J. Agric. Res. 7(45):6082-6086.

Bianchini E. Pimenta JA, Santos FAM (2001). Spatial and temporal variation in the canopy cover in a tropical semi-deciduous forest. Braz. Arch. Biol. Technol. 44(3):269-276.

Camargo MBP, Pedro Júnior MJ, Alfonsi RR, Ortolani AA, Brunini O (1993). Probabilidade de ocorrência de temperaturas mínimas absolutas mensais e anuais no Estado de São Paulo. Bragantia 52(2):161-168.

Caramori PH, Manetti Filho J, Morais H, Leal AC (2000). GEADA - Técnicas para proteção dos cafezais. Londrina, IAPAR 35 pp. (IAPAR, Circular, 112).

Carvalho JR, de Queiroz PE (2002). Uso da cokrigagem colocalizada na determinação da distribuição espacial de precipitação. Campinas: Embrapa Informática Agropecuária 4 pp. (Embrapa Informática Agropecuária, Comunicado técnico, 21).

Foidl N, Makkar HPS, Becker K (2001). The potential of *Moringa oleifera* for agricultural and industrial uses. What development potential for Moringa products? Dar Es Salaam.

Goss M (2012). A study of the initial establishment of multi-purpose moringa (*Moringa oleifera* Lam) at various plant densities, their effect on biomass accumulation and leaf yield when grown as vegetable. Afr. J. Plant Sci. 6(3):125-129.

Mahn LH, Dung NNX, Ngoi PT (2005). Introduction and evaluation of *Moringa oleifera* for biomass production and as feed for goats in the Mekong Delta. Cantho University Cantho, Vietnam.

Mendieta-Araica B, Spörndly E, Reyes-Sánchez N, Salmerón-Miranda F, Halling M (2013). Biomass production and chemical composition of *Moringa oleifera* under different planting densities and levels of nitrogen fertilization. Agroforest. Syst. 87:81-92.

Morton J (1991). The horseradish tree, *Moringa pterygosperma* (Moringaceae) - a boon to arid lands? Econ. Bot. 45(3):318-333.

Peixoto JR, Silva GC, Costa RA, Sousa Fontenelle JR, Vieira GH, Filho AA, Vieira RHF (2011). *In vitro* antibacterial effect of aqueous and ethanolic moringa leaf extracts. Asian Pac. J. Trop. Med. 4(3):201-204.

Pontual VE, Belany EAC, Bezerra SR, Coelho CBBL, Napoleão HT, Paiva MGP (2012). Caseinolytic and milk-clotting activities from *Moringa oleifera* flowers. Food Chem. 135:1848-1854.

Reyes-Sánchez N, Ledin S, Ledin I (2006b). Biomass production and chemical composition of *Moringa oleifera* under different management regimes in Nicaragua. Agrofor. Syst. 66:231-242.

Reyes-Sánchez N, Spörndly E, Ledin I (2006a). Effect of feeding different levels of foliage of *Moringa oleifera* to creole dairy cows on intake, digestibility, milk production and composition. Livest. Sci. 1001:24-31.

Sadeghi S, Rahnavard A, Ashraf ZY (2009). Study importance of sowing date and plant density effect on black cumin (*Cuminum carvi*) yield. Bot. Res. Int. 2(2):94-98.

Squire GR (1990). The physiology of tropical crop production. CAB International Wallingford, UK.

Vieira ARR, Feistauer D, Silva VP (2003). Adaptação de espécies arbóreas nativas em um sistema agrossilvicultural, submetidas a extremos climáticos de geada na região de Florianópolis. Rev. Árvore 27(5):627-634.

Wrege MS, Caramori PH, Gonçalves ACA, Bertonha A, Caviglione JH, Faria RT, Ferreira RC, Freitas PSL, Gonçalves SL (2004). Ocorrência da primeira geada de outono e última de primavera no Estado do Paraná. Revista Brasileira de Agrometeorologia, Santa Maria 12(1):143-150.

academicJournals

Vol. 10(5), pp. 399-403, 29 January, 2015
DOI: 10.5897/AJAR2013.8448
Article Number: 959C39349883
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Study on biochemical constituents of *Sclerotium rolfsii*, a causal agent of stem rot of groundnut (*Arachis hypogaea* L.)

Saraswathi Maddu* and Jaya Madhuri Ravuri

Department of Applied Microbiology, Sri Padmavati Mahila VisvaVidyalayam, Tirupati-517502, A.P. India.

Received 27 December, 2013; Accepted 17 December, 2014

***Sclerotium rolfsii* is a ubiquitous soil-borne fungal pathogen known to cause disease on worldwide range of agricultural and horticultural crops. In spite of economic loss caused by this pathogen, very few reports were available on this aspect, biochemical characterization of the *S. rolfsii*; hence the present study was under taken to study the biochemical characterization of *S. rolfsii*. Qualitative and quantitative analysis of free and protein-bound amino acids was carried out in mycelial mats and culture filtrate of *S. rolfsii.* Five amino acids were identified and were common both in free and protein-bound amino acids. Methionine was the most abundantly occurring amino acid in the protein-bound amino acids, whereas asparagine in case of free amino acids. Eleven amino acids were detected in the culture filtrate, but methionine, phenylalanine and leucine/*iso*leucine were more abundant. Phenolic acids both in culture filtrate and mycelia mat were analyzed by 2-dimensional paper chromatography; seven were detected both in culture filtrate and mycelial mat. Gallic, ferulic, chlorogenic and cinnamic acids were common both in mycelium and culture filtrate of the *S. rolfsii*. The other biochemical constituents like carbohydrate fractions, phenolic compounds and nitrogen fractions present in both mycelia mat and culture filtrate were also studied.**

Key words: *Sclerotium rolfsii*, stem rot, biochemical constituents, amino acids, phenolic acids.

INTRODUCTION

Sclerotium rolfsii is a ubiquitous soil-borne fungal pathogen known to cause disease on worldwide range of agricultural and horticultural crops (Buensanteai et al., 2012). It infects more than 500 plant species in 100 families throughout the world (Adandonon et al., 2005; Ganesan et al., 2007). Most *S. rolfsii* diseases have been reported on dicotyledonous hosts and monocotyledonous species are also being infected, indicating the wide host range of parasitism of *S. rolfsii*. Secondary hosts are numerous, most of them are economically important like food crops and ornamental crops.

Sclerotium rolfsii is a facultative parasite that survives in the soil mainly as sclerotia which function as the main source of inoculums and remain viable for several years (Cilliers et al., 2000; Okereke and Wokocha, 2007). *S. rolfsii* causes severe damage during any stage of crop

*Corresponding author. E-mail: saraswathiphd@gmail.com

growth (Ganesan et al., 2007) and attacks all parts of the plant but stem infection is the most common and serious. The first symptom is sudden wilting of the branch with the stem near the soil level is the most point of attack and a white coating of mycelium appears. Sclerotia of mustard seed size appear on the infected area at later stages. About 85% of yield loss due to the *S. rolfsii* has been reported from India. Keeping in view the losses caused by this fungus, the aim of the present investigation therefore was to evaluate the biochemical characterization of the *S. rolfsii.*

MATERIALS AND METHODS

Isolation of pathogen

Cultured *S. rolfsii* strain was isolated on PDA from the plants showing stem rot or southern blight symptoms of groundnut from the area of Sadhanavaripalem, Chittoor District in Kharif season on PDA. The pure culture of the fungus was obtained and maintained on PDA for further study. The stock culture was maintained on PDA slants in a refrigerator and subcultured every two months.

Biochemical analysis of pathogen

Collection of mycelium and culture filtrate of S. rolfsii

The fungus was grown in 1 liter Roux bottles containing 200 ml of basal medium, under stationary conditions at 29±2°C. After 10 days of incubation period, the cultures were harvested by filtration through a Whatman No. 1 filter paper and fungal mat was blotted dry in four folds of a filter paper. The culture filtrate was collected separately. Both the mycelial mat and culture filtrate were analyzed for free and protein-bound amino acids.

Estimation of carbohydrate fractions

For analysis of various biochemical constituents in the mycelium and culture filtrate of *S. rolfsii*, the extracts were prepared according to the method of Mahadevan et al. (1965):

(i) Estimation of reducing sugars: Reducing sugars in the ethanol extract were determined by Nelson-Somogy's method (Ram et al., 1979),
(ii) Estimation of non-reducing sugars: Non-reducing sugars present in the ethanol extract were first hydrolyzed to reducing sugars as described by Inman (1965). Total sugars in the hydrolysed sample were estimated by Nelson-Somogy's method (Nelson, 1944). The quantity of reducing sugars was calculated by subtracting the reducing sugar content from total sugars and expressed as glucose equivalent,
(iii) Estimation of starch: The residue left behind after ethanol extraction of the original material was used for starch extraction and estimated according to the method of Mc Cready et al. (1950) and McAnelly (1959).

Phenolic compounds

(i) Estimation of *ortho*-dihydric phenols: *Ortho*-dihydric phenols (OD) were estimated by employing Arnow's reagent, which is specific to *ortho* groups (Johnson and Schaal, 1957).
(ii) Estimation of total phenols: Total phenols were estimated by employing the Folin-Ciocalteau reagent method (Sadasivam and Manickam, 1996).
(iii) Phenolic acids: Phenolic acids were extracted according to the method of Bate-Smith (1954) adopted by Das and Rao (1964). The extract was subjected to 2-dimensional ascending paper chromatoghaphy technique on Whatman No. 1 chromatography paper. The solvents employed were benzene-acetic acid-water (60:70:30) in the first direction and the sodium formate-formic acid-water (10:1:200) in the second direction (Ibrahim and Towers, 1960). The dried chromatograms were observed under ultraviolet light, first without and then with ammonia vapors, all the fluorescent spots were marked. The sheets were then sprayed with diazotized p-nitraniline (Smith, 1960) or diazotized sulphanilic acid (Ames and Mitchell, 1952) or 1% ferric chloride in order to identify the phenolic acids present in the fungal mycelium.

Nitrogen fractions

Total nitrogen and protein nitrogen were estimated in the mycelial mat of *S. rolfsii*:

(i) Total nitrogen: It was estimated according to the method of Markam (1942). The amount of nitrogen present in mycelium was calculated as follows: One ml 0.01 N HCl (=0.14 mg of nitrogen). The results are expressed in mg per gram fresh weight of host tissue or fungal mycelium,
(ii) Protein nitrogen: Protein nitrogen was estimated by the method of Thimann and Loos (1957),
(iii) Soluble nitrogen: Soluble nitrogen fraction was calculated by subtracting insoluble nitrogen (protein nitrogen) from total nitrogen content. The results are expressed as mg of nitrogen per gram fresh weight,
(iv) Total proteins: The proteins were extracted according to the method of Lowry et al. (1951).
(v) Amino acids

Free amino acids

Amino acids were extracted from mycelium and culture filtrate of *S. rolfsii* according to the method Reddy and Rao (1975). The quantitative and qualitative determinations of amino acids were carried out by 2-dimensional ascending paper chromatographic technique using Whatman No. 1 paper. Solvents employed were sec-butanol-formic acid-water (75:13:12 v/v/v) and citrate buffer saturated phenol (was prepared by dissolving 6.3 g of sodium citrate and 3.7 g of potassium dehydrogenize phosphate in 100 ml of distilled water, to which 200 ml distilled phenol was added, shaken thoroughly, kept aside for a few hours and the supernatant taken up for use.) as the first and second solvent systems, respectively. The dried chromatograms were sprayed with 0.2% ninhydrin and developed at 60-65°C for 5 min to increase the intensity of the spots. The identity of the spots was established by co-chromatography along with the mixture of known amino acids and also comparing the R_f values of the amino acids in a known mixture with those in the extracts.

Protein bound amino acids

The residue left over after ethanolic extraction was hydrolyzed with 6 N HCl for 30 min at 1 bar pressure in the presence of a pinch of stannous chloride (added to the residue prior to autoclaving) to prevent humin formation (Reddy and Rao, 1975). After hydrolysis, the acid was removed by evaporation. The residue of the hydrolysate was then taken in 1 ml 80% ethanol and an aliquot was stopped and analyzed for amino acids as described earlier for free amino acids.

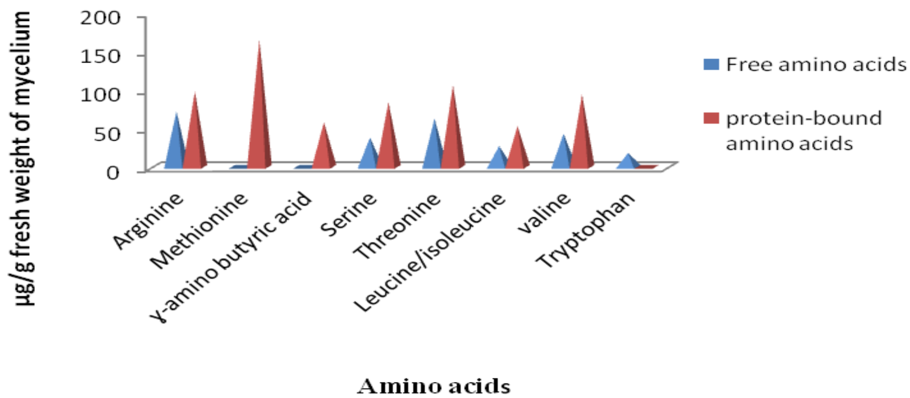

Figure 1. Amino acids in ethanol extract and ethanol insoluble fraction of mycelium of *S. rolfsii*.

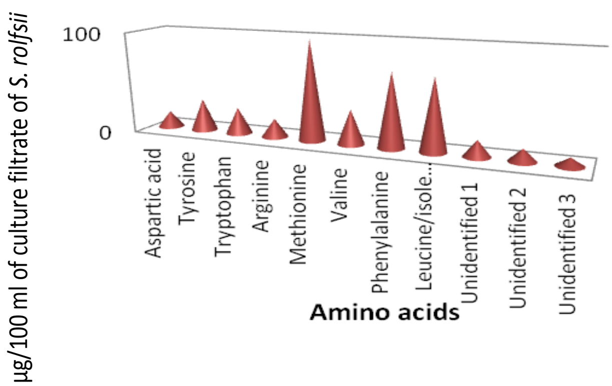

Figure 2. Amino Acids in culture filtrate of *S. rolfsii*

RESULTS AND DISCUSSION

A greater knowledge of the biochemistry of fungi pathogenic to plants is expected to aid in understanding the physiological relations between the host and parasite (Mc Combs and Winstead, 1964). Several investigators have used qualitative and quantitative differences in biochemical composition of fungi to bring out taxonomic differences. Studies on the metabolic chemistry of *S. rolfsii* are quite a few (Mathur and Sarbhoy, 1977; Ram et al., 1979; Sarma et al., 2002; Singh et al., 2002) and such studies are needed to help in understanding why this fungus is a pathogen on many host plants and also in understanding the host-pathogen interaction.

Qualitative and quantitative analysis of free and protein-bound amino acids carried out in mycelial mats as well as culture filtrates of *S. rolfsii* resulted in the detection of six amino acids in ethanol extract of the mycelium and seven in ethanol insoluble fraction. The amino acids aspargine, serine, threonine, leucine/isoleucine and valine were common in free and protein-bound amino acids. Methionine was the most abundantly occurring amino acid in the protein-bound amino acid, whereas aspargine in case of free amino acids (Figure 1).

The isolate showed variation in its ability to release amino acids into the culture medium. Eleven amino acids were present in culture filtrate, where 8 identified as aspartic acid, tyrosine, tryptophan, arginine, methionine, valine, phenylalanine, leucine/*iso*leucine and 3 were unidentified. Methionine, phenylalanine and leucine/*iso*leucine were abundant in culture filtrate. Valine, tyrosine and tryptophan were present in moderate amounts while the other amino acids were present only, in small quantities (Figure 2).

The phenolic compounds in the culture filtrate and mycelial mat of *S. rolfsii* were analyzed by 2-dimensional paper chromatography. Seven phenolic compounds were detected in the culture filtrate, four of which were identified as gallic, ferulic, chlorogenic and cinnamic

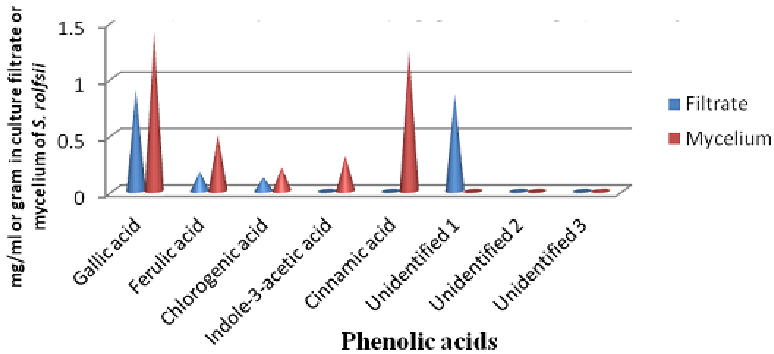

Figure 3. Phenolic acids in culture filtrate (mg/ml of culture filtrate) and mycelial mat (mg/g fresh weight) of *S. rolfsii*.

Table 1. Biochemical constituents of the mycelium and culture filtrate (mg/g) fresh weight)* of *S. rolfsii*.

S/N	Biochemical constituents	Culture filtrate	Mycelium
1	Total phenols*	0.10	0.28
2	*Ortho*-dihydric phenols*	0.13	0.045
3	Reducing sugars**	0.437	0.372
4	Non-reducing sugars**	2.185	1.86
5	Starch**	-	45.0
6	Total nitrogen***	-	0.138
7	Soluble nitrogen***	-	0.034
8	Protein nitrogen***	-	0.935
9	Total protein****	-	2.060

*Each value is an average of three replicate samples, * Expressed as catechol equivalents, ** Expressed as glucose equivalents,*** Expressed as glutamic acid equivalents, **** Expressed as Bovine Serum Albumin equivalent.

acids and remaining three were unidentified. In the mycelial mat, seven compounds were detected, five of which were identified as gallic, ferulic, chlorogenic, indole-3-acetic acid and cinnamic acids and remaining two were unidentified (Figure 3). Phenolic substances are commonly encountered as microbial metabolites. They are widely distributed in fungi (Miller, 1961). The synthesis of aromatic amino acids, tyrosine and phenylalanine by this pathogen may indicate that the shikimic acid pathway is operative and synthesized mostly through this pathway. These two aromatic amino acids have an important role in phenol metabolism. A great deal of information has accumulated in recent years concerning the degradation of aromatic amino acids by fungi to form phenolics (Moore and Towers, 1967; Moore et al., 1968; Reddy et al., 1975; Prasad and Reddy, 1987). The activities of phenylalanine ammonia-lyase and tyrosine ammonia-lyase were also detected in fungi. It is capable of releasing large number of phenolic compounds when grown on a simple synthetic medium. Pathogenic nature of *S. rolfsii* may partly be due to its capacity to release a large number of phenolics into the external medium, some of which may be phytotoxic and exert their effect on plants resulting in disease production.

The other biochemical constituents like carbohydrate fractions, phenolic compounds, nitrogen fractions present in both mucelial mat and culture filtrate of the *S. rolfsii* are presented in Table 1. Knowledge on major biochemical constituents of the pathogen is of immense importance in understanding the host-pathogen interaction. This may give an idea of the contribution of the pathogen in the deranged metabolism of the host due to parasitic invasion. It is well understood that the processes and mechanisms associated with disease development are a function of both the host and pathogen, and disease may be considered as the sum of their interactions. Therefore, in order to understand the host-parasite relationship one ought to know the conditions congenial for successful disease development, the biochemical nature of the pathogen, the details of host metabolites available for the parasite and the subsequent metabolic disturbances in the host due to parasitic invasion. Infected plants naturally include both the host tissues and the fungus associated with it. Hence, the interpretation of chemical changes during disease development must take into account the additive effects of the pathogen present in the host as also pointed out by Mc Combs and Winstead (1964).

Conflict of Interest

The authors have not declared any conflict of interest.

REFERENCES

Adandonon A, Theresa ASA, Nicolaas GS (2005). Genetic variation among *Sclerotium* isolates from Benin and South Africa, determined using mycelial compatibility and ITS rDNA sequence data. Aust. Plant Path. 34:19-25.

Ames BN, Mitchell HK (1952). The paper chromatography of imidazoles. J. Am. Chem. Soc. 74:252-253.

Bate-Smith EC (1954). Leuco anthocyanins. I. Detection and identification of anthocyanidines formed from leuco anthocyanins in plant tissues. Biochem. J. 58:122-125.

Buensanteai N, Kanjana T, Kooboran K, Athinuwat D, Prathuangwong S (2012). Biochemical adaptation of phytopathogenic fungi, *Sclerotium rolfsii*, in response to temperature stress. Afr. J. Biotech. 11(84): 15082-15090.

Cilliers AJ, Herselman L, Pretorius ZA (2000). Genetic viability within and among mycelial compatibility groups of *Sclerotium rolfsii* in South Africa. Phytopathology 90(9):1026-1031.

Das VSR, Rao JVS (1964). Phenolic acids of onion plant (*Allium cepa).*Curr. Sci. 33:471-472.

Ganesan S, Ganesh KR, Sekar R (2007). Integrated management of stem rot disease (*Sclerotium rolfsii*) of groundnut (*Arachis hypogaea* L*.)* using *Rhizobium* and *Trichoderma harzianum* (ITCC-4572). Turk. J. Agric. For. 31:103-108.

Ibrahim RK, Towers CHN (1960). The identification by paper chromatography of phenolic acids. Arch. Biochem. Biophys. 87:125-128.

Inman RE (1965). Qualitative sugar changes in barely infected with a facultative parasite. Phytopathology 55:341-345.

Johnson G, Schaal LA (1957). Chlorogenic acid and other *ortho*-dihydric phenols in scab resistant Russet Burbank and scab susceptible Trium potato tubers of different nutrients. Phytopathology 47:253-258.

Lowry OH, Rosebrough NJ, Farr AL, Randall RJ (1951). Protein measurement with the Folin phenol reagent. J. Biol. Chem. 193:265-275.

Mahadevan A, Kuc J, Williams EB (1965). Biochemistry of resistance in cucumber against *Cladosporium cucumerinum* 1. Presence of pectinase inhibitor in resistant plant. Phytopathology 55:1000-1003.

Markam R (1942). A stem distillation apparatus suitable for micro-Kjeldahl analysis. Biochem. J. 36:760-791.

Mathur SB, Sarbhoy AK (1977). Chemical analysis of the sclerotia of the fungus *Sclerotium rolfsii* causing root rot of sugar beet. Indian Phytopathol. 30:294-295.

McAnelly CW (1959). Free amino acids in the culture media and cells of *Fusarium* solani f.phaseoli. Phytopathology 49:734-737.

Mc Combs CL, Winstead NN (1964). Changes in sugars and amino acids of cucumber fruits infected with *Pythium aphanidermatum*. Phytopathology 54:233-234.

Mc Cready RK, Goggloz J, Silvieta V, Owens HS (1950). Determination of starch and amylase in vegetables. Application to Peas. Anal. Chem. 29:1156-1158.

Miller MW (1961). The Pfizer Hand Book of Microbial Metabolites. Page 185.McGraw Bill. New York P. 772.

Moore K, Subba Rao PV, Towers GHN (1968). Degradation of phenylalanine and tyrosine by *Sporobolomyces reseus*. J. Biochem. 106:507-514.

Moore K, Towers GHN (1967). Degradation of aromatic amino acids by fungi. I. Fate of L-Phenylalanine in *Schizophyllum*. Can. J. Biochem. 45:1659-1665.

Nelson N (1944). A photometric adaptation of the Somogyi method for the determination of glucose. J. Biol. Chem. 153:375-380

Okereke VC, Wokocha RC (2007). *In vitro* growth of four isolates of *Sclerotium rolfsii* Sacc in the humid tropics. Afr. J. Biotech. 6(16):1879-1881.

Prasad P, Reddy MN (1987). Estimation of amino acids, phenols, sugars and nitrogen from the mycelium of *A.alternata*. Indian Phytopath. 40:416-418.

Ram RP, Lal BB, Prasad M (1979) Fluctuation in amino acid constituents of a developing culture of *Sclerotium rolfsii* Sacc. and its relation to growth. Zentralbl Bakteriol Naturwiss 134(2):175-178.

Reddy MN, Rao AS (1975). Amino acids in mycelium of culture filtrates of *Rhizoctonia solani*. Trans. Br. Mycol. Soc. 64:527-528.

Reddy MN, Rao AS, Rao KN (1975). Production of phenolic compounds by *Rhizoctonia solani*. Trans. Brit. Mycol. Soc. 64:146-148.

Sadasivam S, Manickam A (1996). Biochemical methods, Second Edition. pp. 193-194

Sarma BK, Singh UP, Singh KP (2002). Variability in Indian isolates of *Sclerotium rolfsii*. Mycologia 94(6):1051-1058.

Singh UP, Sarma BK, Singh DP, Bahadur A (2002). Studies on exudates-depleted sclerotial development in *Sclerotium rolfsii* and the effect of oxalic acid, sclerotial exudates, and culture filtrate on phenolic acid induction in chickpea (*Cicer arietinum*). Can. J. Microbiol. 48(5):443-448.

Smith I (1960). Chromatographic and electrophoretic techniques. Inter Science Publication, New York.

Thimann KV, Loos GM (1957). Protein synthesis during water uptake by tuber tissues. Plant Physiol. 32:274.

academicJournals

Vol. 10(5), pp. 404-407, 29 January, 2015
DOI: 10.5897/AJAR2013.7386
Article Number: E286FEF49886
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Cultivation of soybean varieties under cross-seeding system

Reginaldo Ferreira Santos[1], Doglas Bassegio[1]*, Bruno Boareto[1], Fabíola Tomassoni[1], Deonir Secco[1], Samuel Nelson Melegari de Souza[1] and Tiago Roque Benetoli da Silva[2]

[1]State University of the West of Paraná – Master's Degree in Energy Applied to Agriculture Program, Rua Universitária,. 2069, CEP: 85.819-130, Bairro Faculdade, Cascavel-PR, Brazil.
[2]Departamento de Ciências Agronômicas, Campus Avançado de Umuarama, Universidade Estadual de Maringá - Av. Colombo, 5790, 87020-900, Maringá, PR, Brazil.

Received 29 May, 2013; Accepted 9 January, 2015

The aim of this study was to evaluate the productivity of four varieties of soybean grown under both cross-seeding and conventional systems. The experiment was conducted in Campina da Lagoa, in the state of Paraná, Brazil during the period from October to February 2012/2013 in a completely randomized factorial scheme (4x2) with five replications. Treatments consisted of four soybean varieties: 4990 Nidera RR, VMAX Syngenta RR, BMX MAGNA RR and 5909 Nidera RR, with two planting systems: crossed and uncrossed. The following components of growth and yield were evaluated: Fresh and dry mass, pod number, plant height and yield in kg^{-1}. Variety VMAX stood out in terms of productivity, regardless of the planting system. The cross-seeding system provided increment of 9.25% in grain yield.

Key words: *Glycine max*, Cross-seeding system, densification.

INTRODUCTION

Soybean occupies a prominent position in Brazilian agriculture, with 68,688 million tons of grains produced in 23,468 million hectares in crop year 2010/2011 (Conab, 2012). This large increase is due to the productive potential of new genotypes and high technological level of the producer. Cross-seeding is a practice which uses the same technologies already existing for soybean production, but including a variation in the planting scheme. The productive results of cross-seeding have led many researchers to consider that even though the current system of soybean production in Brazil have evolved, there is still room for significant increases in productivity, without interfering in the Amazon, Pantanal, Cerrado, Caatinga or even in the current existing area (Balbinot Junior et al., 2012)

New varieties have smaller leaflets, more vertical slope and less branching when compared to traditional cultivars. According to Board (2000), the amount of light reaching the plants through photoreceptors can effectively affect the growth pattern of plants. By considering these two points it is necessary to develop further adjustments in the current system of sowing

*Corresponding author. E-mail: doglas14@hotmail.com.

density and spatial arrangement of these new plant varieties (Souza et al., 2010).

The standard population recommended for soybean crops until the 80's was approximately 400,000 plants ha^{-1}. Bulletin 15 with recommendations for the soybean harvest 2012/13 states that variations between 200 and 500 thousand plants ha^{-1} do not usually affect grain yield (Embrapa, 2011). Populations above the recommended level lead to expenses with seeds and lodging, besides not providing increases in productivity. Populations below the recommendation favor the development of weed and increase loss at harvest (Vazquez et al., 2008).

Balbinot Junior et al. (2012) in studies performed in Londrina - PR, by Embrapa - Brazilian Agricultural Research Corporation, found that grain growth and yield of cultivar BRS 294 RR were not affected by the cross-seeding system, and also that the spacing of 0.6 m between rows contributed to higher grain yield when compared to the spacing of 0.4 m.

Several works must be conducted to better understand this new planting technique, not only in its aspect of grain production, but also in what concerns to the sustainability of the production system. The aim of this study was to evaluate the growth and grain yield of soybean varieties cultivated under cross-seeding and conventional systems.

MATERIALS AND METHODS

The experiment was conducted under field conditions on a commercial farm in the agricultural year 2012/2013, during the period from October to February in Campina da Lagoa - PR, Brazil, Latitude: 24° 35' 21" South and Longitude: 52° 49' 34" West, with humid subtropical climate (Köppen-Geiger climate Rating: Cfa) with an average annual rainfall of 1955 mm, annual average evaporation of 1003 mm, average temperature of 21.1°C, 2433 h of insolation per year (IAPAR, 2013) and 561 m (1,841 ft) from the sea.

The soil of the experimental area was identified as distroferric Oxisol (Embrapa, 2006). Before the experiment, soil sampling was conducted to determine the chemical and physical characteristics, at the depth of 0-20 cm; results were: 22.48 g dm^{-3} of organic carbon, pH ($CaCl_2$) 5.10; 6.80 mg dm^{-3} of P, 0.37 cmolc dm^{-3} of K^+; 4.91 cmolc dm^{-3} of Ca^{2+}; 1.97 $cmol_c$ dm^{-3} of Mg^{2+}; 5.35 $cmol_c$ dm^{-3} H + Al; CTC 12.60 $cmol_c$ dm^{-3} and 57.54% of base saturation. Physical characteristics at the same depth were: 700 g kg^{-1} of clay, 200 g kg^{-1} of silt and 100 g kg^{-1} of sand fraction.

The factorial design (4×2) was completely randomized with five replications. The treatments were formed by the combination of four varieties and two planting systems (crossed and uncrossed). The plots were 7 m long and 3.42 m wide (9 lines of 0.38 m) totaling 23.94 m^2. Sowing was held on 04/10/2012 under direct-drilling system under AG9010 corn residues, with soybean varieties: 4990 Nidera RR, VMAX Syngenta RR, BMX MAGNA RR and 5909 Nidera RR, using a seed-fertilizer (Semeato PS8/9L). Basic fertilization consisted of applying 24 kg ha^{-1} of nitrogen, 180 kg ha^{-1} of K_2O and 60 kg ha^{-1} of P_2O_5 with formula 4-30-10 NPK. 657,000 and 497,000 seeds ha^{-1} were used in cross-seeding and conventional systems, respectively. In coverage, 180 kg ha^{-1} of potassium chloride were applied 20 days after sowing. The control of pests, diseases and weeds was performed according to the technical indications for the crop.

Due to the harvest it was necessary to determine plant height in function of the distance from the ground up to the apical meristem of the main stem of 10 soybean seedlings chosen randomly within each plot. Soybean yield was estimated by collecting existing plants in one square meter in the center of the plot, with values corrected to moisture of 13% and expressed in kg ha^{-1}.

The fresh and dry mass of plants were also determined, by cutting the plants at ground level in each plot, which were placed in plastic bags to prevent moisture loss and, soon after, weighed. The material was dried in an oven with forced air circulation at 65°C until it reached constant weight and then weighed in order to determine its dry mass.

The results for yield and production components were subjected to analysis of variance and the averages compared by Tukey's test at 5% probability, using the statistical package Assistat® version 7.5 beta (Silva and Azevedo, 2002).

RESULTS AND DISCUSSION

The behavior of the analysis of variance is presented in Table 1. Yield components were significantly affected ($p \leq 0.01$) in function of varieties and planting systems. There was significant interaction between the factors "variety" and "planting system" for all production components.

Due to the interaction between variety and planting system it is necessary to analyze the unfolding (Table 2) for fresh and dry mass, pod number, plant height and yield.

The fresh and dry mass was influenced by varieties and planting system, as well as by the interaction between factors. All varieties showed an increase of fresh and dry mass in the cross-seeding planting system. Variety VMAX, which presents an upright set and indeterminate growth habit stood out in the accumulation of fresh and dry mass, with 9.26 and 8.92%, respectively, in the cross-seeding system in comparison to the conventional method. Rodrigues et al. (2007) observed higher production of dry mass for denser spacings for the same population of plants.

Balbinot Junior et al. (2012) obtained contradictory results working with crossed soybean spacing system in Paraná; the largest accumulation of dry leaves, branches and pods per plant was in one with 375,000 seeds ha-1 compared to 562,500 seeds ha^{-1}, namely conventional and cross-seeding systems, respectively.

According to Bruin and Pedersen (2009) genotypes of modern growing habits have higher grain yield due to higher yield per plant and higher tolerance to high densities, and can be explained by the higher dry mass accumulation in the vegetative stage, which promotes the setting of many vegetables and grains with consequent maintenance of the active drain and photosynthetic activity for more time. Kahlon et al. (2011) point out that modern genotypes have a greater number of reproductive nodes and grains per area due to increased radiation interception.

By analyzing the results in the unfolding against the component "number of pods per plant", one can note that the conventional planting system (no cross) stood out,

Table 1. Aerial fresh matter (FM), aerial dry matter (DM), number of pods/plant (NP), plant height (PH) and yield.

Treatments	FM (g)	DM (g)	NP (n^o)	PH (cm)	Yield (kg ha^{-1})
Varieties					
4990 Nidera	0.93^d	0.32^d	26.48^c	61.90^d	2151.4^d
VMAX	1.80^a	0.52^a	25.97^d	79.00^b	4172.2^a
MAGNA	1.18^c	0.38^c	28.38^b	75.50^c	2733.3^c
5909 Nidera	1.28^b	0.42^b	31.67^a	82.40^a	2979.4^b
Planting system					
Crossed	1.36^a	0.43^a	21.35^b	76.20^a	3144.4^a
Uncrossed	1.24^b	0.39^b	34.90^a	73.20^b	2873.7^b
CV(%)	1.54	3.74	1.31	1.27	1.54
Varieties (A)	**	**	**	**	**
Planting system (B)	**	**	**	**	**
AxB	**	**	**	**	**

** Significant at 1 % of probability.

Table 2. Unfolding of the interaction varieties/planting system for aerial fresh matter, aerial dry matter, number of pods/plant, plant height e yield.

Varieties	Planting system	
	Crossed	Uncrossed
Aerial fresh matter (g)		
4990 Nidera	0.9858^{dA}	0.8760^{dB}
VMAX	1.8930^{aA}	1.7176^{aB}
MAGNA	1.2166^{cA}	1.1488^{cB}
5909 Nidera	1.3470^{bA}	1.2314^{bB}
Aerial dry matter (g)		
4990 Nidera	0.3234^{dA}	0.3192^{dA}
VMAX	0.5492^{aA}	0.5000^{aB}
MAGNA	0.4136^{cA}	0.3540^{cB}
5909 Nidera	0.4630^{bA}	0.3926^{bB}
Number of pods/plant		
4990 Nidera	21.34^{bB}	31.62^{cA}
VMAX	14.48^{cB}	37.45^{aA}
MAGNA	21.68^{bB}	35.08^{bA}
5909 Nidera	27.91^{aB}	35.08^{bA}
Plant height (cm)		
4990 Nidera	70.20^{cA}	53.60^{dB}
VMAX	60.60^{dB}	97.40^{aA}
MAGNA	82.20^{bA}	68.80^{cB}
5909 Nidera	91.80^{aA}	73.00^{bB}
Yield (kg ha^{-1})		
4990 Nidera	2278.29^{dA}	2024.53^{dB}
VMAX	4374.93^{aA}	3969.56^{aB}
MAGNA	2811.69^{cA}	2655.00^{cB}
5909 Nidera	3113.06^{bA}	2845.90^{bB}

Means with different small letters in the columns are statistically different at (**) 1% and (*) 5% of probability or no significant (n.s.) Tukey test.

with variety VMAX getting the highest averages. In the cross-seeding system, variety semi erect 5909 Nidera presented more pods per plant. Chaves (2012) observed a linear decrease in the number of pods per reproductive node with densification of population in the variety Nidera 5909. The reduction of pods per plant when the culture is subjected to densification and increase of population is also reported by Kuss et al. (2008).

Plant height was changed depending on the varieties and planting system. One may observe in Table 2 that in the cross-seeding system, variety 5909 Nidera stood out for showing taller plants. The cross-seeding system between rows and plant densification did not result in increased plant height compared to the conventional system, what disagrees with Balbinot Junior et al. (2012) who observed an increase in plant height in the cross-seeding system, which according to the author possibly happened due to the lower quality of light. Hicks et al. (1969) point out that the increase in plant height with reduced spacing is more significant in varieties of low stature.

Under low light quality soybean plants tend to exhibit high development in height in order to trap these features, besides emitting fewer branches (Board, 2000). The results of this experiment are possibly due to the fact that all varieties in this study present upright growth habit, which means that they are resistant to densification and lodging.

As for grain yield, one can observe that variety VMAX stood out in terms of productivity, regardless of the planting system. It is observed (Table 2) that in the conditions of this study there was an increase of 9.25% in grain yield of the variety compared to the conventional system. Balbinot Junior et al. (2012) verified no effect of the cross-seeding system for variety BRS 294 RR with determined growth habit in grain yield.

Conflict of Interest

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

Conclusion

Variety VMAX stood out in terms of productivity, regardless of the planting system. The cross-seeding system provided an increase of 9.25% in grain yield.

REFERENCES

Balbinot Jr AA, Procópio SO, Franchini JC, Debiasi H, Panison F (2012). Avaliação do sistema de plantio cruzado da soja- cultivar de hábito indeterminado. 6º congresso Brasileiro de Soja pp. 1-4.

Board J (2000). Light interception efficiency and light quality affect yield compensation of soybean at low plant population. Crop Sci. 40:1285-1294. http://dx.doi.org/10.2135/cropsci2000.4051285x

Bruin JL de, Pedersen P (2009). New and old soybean genótipo responses to plant density and intercepted light. Crop Sci. 49:2225-2232. http://dx.doi.org/10.2135/cropsci2009.02.0063

Chaves A (2012). Formação do rendimento de grãos de soja em função de arranjos de plantas, genótipos e épocas de semeadura. Tese de Doutorado em Universidade Universidade de passo fundo P. 227.

Conab-Companhia Nacional de Abastecimento (2012). Acompanhamento da safra brasileira de grãos (safra 2011/12) – 8º levantamento, maio, 2012. Disponível em: <http://www.conab.gov.br/OlalaCMS/uploads/arquivos/11_06_09_08_50_47_graos_-_boletim_maio-2012.pdf>. Acesso em 19/03/2013.

Embrapa (2011). Empresa Brasileira de Pesquisa Agropecuária. Tecnologias de produção de soja – região central do Brasil 2012 e 2013. Embrapa Soja, P. 261.

Embrapa (2006). Empresa Brasileira de Pesquisa Agropecuária. Serviço Nacional de Levantamento e Conservação de Solos. Sistema brasileiro de classificação de solos. 2nd ed. Rio de Janeiro: Embrapa Solos P. 306.

Hicks DR, Pendleton JW, Bernard RL, Johnston TJ (1969). Response of soybean plant types to planting patterns. Agron. J. 61:290-293. http://dx.doi.org/10.2134/agronj1969.00021962006100020034x

IAPAR (2013). Instituto Agronômico do Paraná. Médias históricas em estações do IAPAR. Disponívelem: http://www.iapar.br/arquivos/Image/monitoramento/Medias_Historicas/Cascav-el.html Acesso em: 11 mar. 2013.

Kahlon CS, Board JE, Kang MS (2011). An analysis of yield component changes for new vs. old soybean Genótipos. Agron. J. 103:13-22.http://dx.doi.org/10.2134/agronj2010.0300

Kuss RCR, Könnig O, Dutra LMC, Bellé RA, Roggia S, Sturmer GR (2008). População de plantas e estratégias de manejo de irrigação na cultura da soja. Ciênc. Rural 38:1133-1137. http://dx.doi.org/10.1590/S0103-84782008000400036

Rodrigues O, Teixeira MC, Costenaro ER, Bertagnolli PF (2007). Avaliação de cultivares de soja transgênica (BRS-RR) em sistema precoce de semeadura (SPS). Passo Fundo: Embrapa Trigo, P. 30.

Silva FAZ, Azevedo CAV (2002). Versão do programa computacional Assistat para o sistema operacional Windows. Rev. Bras. Prod. Agroind. 4:71-78.

Souza CA, Gava F, Casa RT, Bolzan JM, Kuhnem PRJ (2010). Relação entre densidade de plantas e genótipos de soja Roundup Ready TM. Planta Daninha 28:887-896. http://dx.doi.org/10.1590/S0100-83582010000400022

Vazquez GH, Carvalho NM, Zocoller MB (2008). Redução na população de plantas sobre a produtividade e a qualidade fisiológica da semente de soja. Rev. Bras. Sementes 30:01-11.

academicJournals

Vol. 10(5), pp. 408-415, 29 January, 2015
DOI: 10.5897/AJAR2013.8000
Article Number: FAF220649890
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Diagnostic of the use and management of factors of production used in dairy farming in the nothwest region of Paraná, Brazil

Jéssica da Silva Santos Gonçalves[1], Jailson de Oliveira Arieira[1]*, Claudia Regina Dias-Arieira[1], Rita de Cassia Menchon Tramontini[2], Mariana Zampar Toledo[3] and Andressa Gomes Brandão[1]

[1]Departamento de Ciências Agronômicas, Universidade Estadual de Maringá. Estrada da Paca, s/n, CEP: 87507-190, Bairro São Cristóvão, Umuarama, PR, Brazil.
[2]Campus Regional de Umuarama, Universidade Estadual de Maringá Estrada da Paca, s/n, CEP: 87507-190, Bairro São Cristóvão, Umuarama, PR, Brazil.
[3]Centro Universitário da Grande Dourados. Rua Balbina de Matos, 2121 - Jd. Universitário, CEP 79.824-900 - Dourados/MS, Brazil.

Received 29 September, 2013; Accepted 25 March, 2014

The aim of this study was to carry out a diagnostic of the use and management of factors of production used in dairy farming in the Northwest region of Paraná, Brazil. Interviews using a semi-structured questionnaire were held with 19 of the region's milk producers chosen at random. To evaluate the profiles of the producers and their farms in terms of characteristics of management and use, the data obtained was submitted to descriptive statistics analysis to characterize the region's dairy industry and its rural producers. The results show that farmers exploit dairy farming in the traditional way (semi-extractive and familiar), few producers see the activity as a business, despite having higher productive results to the national average. It also appears that prices received are low and there is high dependence of the dairy industry and poor cooperation among producers. Thus, producers are not specialized and dairy farming is not really a business.

Key words: Production, management, milk.

INTRODUCTION

Dairy farming was introduced in Brazil at the beginning of the 16th century when expeditions led by the Portuguese brought the first animals to Vila São Francisco. This activity did not undergo any significant changes until the 1950s, when dairy farming in Brazil entered its modern phase (Oliveira, 2008). However, it was only after a series of economic changes took place during the 1980s that a cycle of change could be observed to which the

*Corresponding author. E-mail: jarieira@attaconsultores.com.br

sector had to adapt itself (Reis et al., 2001).

These changes were the result of factors such as the end of controls over milk prices, open-trade policy, the country's economic stabilization plan, the deregulation of the market and an increase in consumer awareness (Vilela et al., 2002). Within this context, the entire production chain realized the need to adopt new strategies in order to optimize the use and management of factors of production, leading to a subsequent increase in revenues and the production of higher quality products. According to Rubez (2003) and Oliveira and Silva (2012), few sectors of the Brazilian economy went through such structural change in such a short space of time.

The production chain of the dairy industry holds an important position in Brazil's agro-industrial sector. According to IBGE (2006), the net value of milk production has reached around 10 million USD. The highest percentage of dairy farms out of the total number of rural establishments is concentrated in the Southern part of the country (41%) and Central-West (39%) regions. Family farming has a significant role in the generation of employment and income within this sector, and in 2006 it was responsible for 59% of the GDP (Gross Domestic Product) generated by dairy farming (Guilhoto et al., 2007).

Given the importance of this activity and the transformation of the relationships within its production chain, the dairy market became competitive and demanding. According to Lopes et al. (2007), dairy farming in Brazil, has become a structure typical market oligopsony, with a large number of sellers (farmers) and a small number of buyers (industries) that have great bargaining power over producers. Rural producers were therefore the most significantly affected part in the dairy production chain. As they work within a traditionalist industry that has always operated on a low technology level that is still restricted in terms of the technological and managerial support which hinder them to keep up with the changes that have taken place in Brazilian dairy sector (Alencar et al., 2001).

A producer's success within this activity is associated with their knowledge and efficient management of factors of production, as it is only through using tools for planning and cost control that they can increase their revenues. According to Bressan (1998), the union of small production units into credit or production cooperatives with their own niches in the market can allow an economy of scale to be improved, principally through cost reduction. According to Carvalho et al. (2009), scale of production is one of the fundamental success factors in dairy farming, as it tends to reduce the average costs associated with this activity.

Reducing production costs is the first strategy that must be adopted in order to increase the viability of this activity (Carvalho et al., 2009). This requires technological innovation and higher levels of technical and managerial expertise, however, which leads to a significant percentage of producers abandoning their activities due to their inability to make further investments. Therefore, if this activity is not carried out with cooperation between small producers, advances in technology, reductions in cost and increases in bargaining power are hindered and producers tend be held hostage to the market (Pfau, 2002).

Taking into account these changes and the needs of the sector, which are often more pronounced in small municipalities where there is usually a lack of technical support, it is important to understand how rural producers manage their farms and the resources available for them.

Therefore, the general objective of this study was to carry out a diagnostic of the use and management of factors of production used in dairy farming in the Northwest of Paraná. More specifically, the intention was to: (a) evaluate the management and organizational profile of the region's milk producers; (b) characterize the region's dairy industry in terms of its technological and management profile; (c) evaluate the production and financial results obtained by these producers.

MATERIALS AND METHODS

Description of the study area

The study was carried out in the Northwest region of Paraná, which has a predominantly Humid Subtropical mesothermic climate with hot summer and occasional frost, rainfall is concentrated in the summer months (IAPAR, 2012).

The predominant soil type in the region is sandy Red-Yellow Argisol (EMBRAPA, 2006). The most common agricultural and animal raising activities in the region are beef and dairy cattle breeding, poultry farming, cultivation of cassava, sugarcane and horticulture. The dairy farming occupies 22.5% of the municipal area and is the activity with the highest number of producers (EMATER, 2012).

Data collection and analysis

Data was collected from October through December 2012. Farmers were interviewed using a semi-structured questionnaire. The questioner designed to contains necessary information that can be used to evaluate the factors of production management.

Five dimensions for analysis were considered, these dimensions were then used to evaluate producers' farming profiles and their use of factors of production. The dimensions of analysis used were: (a) personal and social factors (of the producers); (b) herd factors; (c) market factors (commercialization); (d) knowledge factors (information and technology) and (e) land use factors. Within these dimensions, the specific variables used to evaluate the main difficulties uncovered and the strong and weak profiles of the producers were analyzed. The questionnaire contained the following variables for each dimension:

Dimension 1: Personal and social factors: It illustrate the producer's socio-cultural profile, which affects decisions in seeking and adoption of new technology and management strategies. The main variables in this dimension were: Age; level of education; marital status; time spent on farm to produce milk) as well as of-farm activities.
Dimension 2: Herd factors: It illustrate the dairy cows management

in terms of nutritional status, vaccination and the management style adopted and productivity. The collected variables were: Total number of animals –number of lactating animals; daily milk production – average milk production per animal; monthly milk production – average monthly production; the predominant breed within the herd; feed supplementation; vaccination; differences in management systems between dry and rainy seasons.

Dimension 3: Market factors: These include the management of financial resources and sales and purchases. The variables adopted were: Income, percentage of income out of dairy farming; product delivery, who is it delivered to, quantities and prices; inputs, where were they obtained and at what percentage; animals' categories, calves, heifers, and young bulls.

Dimension 4: Knowledge factors: It illustrates the sources of technical and management information available to producers that maximize the use of factors of production. The variables adopted were: Support, where does technical and management support come from; relationships, participation in associations, cooperatives or syndicates; information, if they research technical and market information.

Dimension 5: Land factors: These include the farm and the carried out activities. The variables adopted were: size, the size of the farm; soil, soil fertility, fertilization and analysis conditions; pastures, predominant pasture type; activities, activities carried out prior to dairy farming, other activities carried out on the farm; improvements, the improvements and machinery available on the farm; industrialization, industrialization products on the farm; storage, how are the inputs stored on the farm; labors, are they belongs to family members or hired labors.

Field data collection was carried out through individual interviews with 19 producers chosen at random. To define the number of producers interviewed, standard deviations were obtained from the production variable (daily milk production values obtained from the local dairy) according to the method proposed by Milone (2004).

$$N = \left(\frac{Z * \sigma}{e}\right)^2$$

Where, N = sample size to be interviewed; z = desired degree of confidence; e = permitted error, and σ = estimated standard deviation of the sample;

To define the sample size, it was considered that: Z = desired degree of confidence (95% = 1.96); e = permitted error (20% of the average production (0.20 × 271.55 L)), giving an error of 5431 L; σ = estimated standard deviation of the sample (181.04 L). This resulted in a sample size (N) of 19 dairy farmers.

The data obtained was submitted to descriptive statistics analysis to characterize the region's dairy farming and the profile of its rural producers and their farms, with respect to the characteristics and use of factors of production.

RESULTS AND DISCUSSION

In the studied region, dairy farming is mainly carried out through family farming on farms that range in size from five to fifteen hectares. The majority of dairy farmers were involved in this activity for a period of five to fifteen years, they are married, have not fully completed either primary or secondary education and do not have any other off-farm activities, Table 1 shows the producer profile, personal and social factors of milk producers in the Northwest region of Paraná.

Upon analyzing the resources available to farmers and the way in which they use and manage it (Tables 2 and 3), a lack of information and support was observed. There is no form of technical support available to 63.5% of farmers, and the 36.5% that do have access to support do not obtain it through farming cooperatives despite 100% of them being associated with some form of entity. This could be related to the fact that the regional cooperatives are mainly concentrated, its activity on grain production and do not have the technical ability to support their associates in dairy farm management.

From Table 2, it can be observed that 63.16 and 89.48% of the interviewed farmers do not seek out production or market information respectively, resulting in the alienation of the farmers and reaffirming their position as actors with little bargaining power in the production chain. However, it worth noting that EMATER is the only organization pointed out by the farmers as a source of production information.

In their study, which was carried out in the west of Santa Catarina State, Oliveira and Silva (2012) have emphasized the importance of rural extension in the distribution of technology and information in that region. However, this agent's activities have been hindered in recent years due to a lack of investment (Arieira, 2010).

The municipal government and EMATER were mentioned again by the producers when questioned about technical support. However, this assistance only reaches 36.84% of producers, in other words, a representative number of these do not have access to technical support or updated information.This situation compromises farmers productivity, as information is one of the main inputs for the development of dairy farming and operational and financial results are compromised without it (Lopes et al., 2009). It has previously been established that small producers do not often have access to trustworthy sources of information, resulting in decisions being made based on: experience, tradition, the potential of the region, a lack of other options and the availability of financial resources and labors (Oliveira et al., 2001).

This lack of access to information is reflected in the situation of dependence of the producer in relation to the other stakeholders in the production chain. This can be observed in the question on product delivery, in which 100% of farmers marketed their products to local dairies and 100% obtained their inputs through the cooperatives operating in the region (Table 3). This impedes the producer's negotiating power along the production chain, giving them little capacity to influence the price of their product or the terms of purchase for their inputs. This situation confirms the statement made by Lopes et al. (2007) that the Brazilian dairy industry is a market structure that most closely resembles the oligopsony which to perfect competition, being composed of many small producers and few large industries.

It was observed that despite limited access to information, lack of control over cost and low levels of

Table 1. Dimension 1: Producer profile, personal and social factors of milk producers in the Northwest region of Paraná.

Variable	Percentage (%) of producers for each range of observation					
Age (years)	< 20	20 – 30	30 – 40	40 – 50	50 – 60	> 60
	0	0	15.8	47.4	31.6	5.3
Marital status	Single	Married	Divorced	Widowed		
	10.5	73.7	10.5	5.3		
Time in activity (years)	< 5	5 – 10	10 – 15	15 – 20	20 – 25	
	0	36.8	47.4	10.5	5.3	
Level of education	Primary education incomplete	Primary education complete	Secondary education incomplete	Secondary education complete	Higher education incomplete	Higher education complete
	26.3	26.3	31.6	15.8	0	0
Other occupations (off-farm activities)	Yes	No				
	21.1	78.9				

Table 2. Dimension 4: Knowledge factors, the sources of technical and management information available to producers.

Variable	Percentage (%) of producers for each range of observation				
Participation in an association, syndicate or cooperative	Yes	No			
	100	0			
Which association	Cooperative	Rural society	Syndicate	Other	
	100	31.58	0	0	
Receives technical support	Yes	No			
	36.84	63.16			
From where	EMATER*	Municipal government	Cooperative	Other	
	52.63	47.37	0	0	
Seeks production information	Workshops	EMATER	Technical support	Other	No
	0	36.84	0	0	63.16
Seeks market information	Internet	TV programs	Workshops	Other	No
	5.26	5.26	0	0	89.48

*EMATER: The Paraná Institute for Technical Assistance and Rural Extension.

technology, the majority of farmers did not have off-farm activities (Table 3). This information shows that dairy farming within the region is deeply rooted and many producers remain within this activity because of the monthly income which guarantees the survival and subsistent for their families, this fact was also proven by Oliveira and Silva (2012).

Operating in a competitive and demanding market, family farming faces a variety of difficulties, as has already been observed, and is dependent on the actions of other actors (principally agribusiness) to maintain their position within the market (Reis et al., 2001). Conversely, family farming allows small producers to sustain their families and provides them with a sufficient income to cover their monthly expenditures (Oliveira et al., 2001).

According to Paraná State dairy farming association, Conseleite PR (2013), the value of milk in March and April of 2013 varied between USD $0.38 and USD $0.39. It was observed that 10.53% of the farmers interviewed received USD $ 0.40 L^{-1}, which is a value above the average price paid in the period. Moreover, most farmers receive a maximum of USD $ 0.36, that is, the lower limit of the range of rates. This shows that there is great disparity between the prices received for products by the

Table 3. Dimension 3: Market factors, management of financial resources, purchase and sales relations.

Variable	Percentage (%) of producers for each range of observation				
Product delivery	Dairy	Cooperative	Market	Other	
	100	0	0	0	
Acquisition of inputs	Cooperative	Commercial stores	Vendors	Industry	
	100	0	0	0	
Sale of calves, heifers and young bulls	Yes	No			
	64.82	31.58			
Family Income from dairy farming (%)	< 25	25 – 50	50 – 75	75 – 100	100
	0	5.26	15.79	5.26	73.68
Average price of product in USD $ (%)	0.36	0.37	0.38	0.40	
	21.05	10.53	57.89	10.53	

Table 4. Dimension 5: Factors associated with land use, infrastructure and activities carried out on farms.

Variable	Percentage (%) of producers for each range of observation				
Dedicated to other activities	Yes	No			
	42.12	57.89			
Which activity	Vegetable crops	Grains	Meat cattle breeding	Other	
	21.05	5.26	0	15.79	
Use of family labor	Yes	No			
	42.11	57.89			
Use of contracted labor	Day-workers	Salaried/CLT*	Salaried	None	
	5.26	0	21.05	73.68	
Farm size (ha)	6 - 7	8 - 9	10 - 11	12 - 13	14 - 15
	10.53	26.32	5.26	15.79	10.53
Land ownership (%)	0	25	50	75	100
	0	0	0	0	100
Soil management	Carried out analysis	Analysis and fertilization	carried out fertilization	None	
	0	21.05	36.84	42.11	
Other activities	Vegetable crops	Grains	Meat cattle breeding	Other	None
	0	5.26	0	31.58	63.16
Predominant grasslands	Brachiaria	Panicum	African grass	Other	
	31.58	47.37	15.79	5.26	
Improvements on the farm	Corral	House	Shed		
	21.05	100	21.05		
Equipment and machinery	Milking equipment	Milk cooler	Grinder	Tractor	
	36.84	10.5	31.58	68.42	
Manufacture of products	Yes	No			
	0	100			
Storage of products and inputs	Yes	No			
	10.52	89.47			

* CLT: Consolidation of Brazilian Labor Laws.

lack of homogeneity between the production processes, production volume and product quality. This shows that the majority of farmers have received low payments for their products. This situation is aggravated by production scale producers because the farms have between seven to nine hectares, and none are larger than 15 ha, which indicates a typical household production (Table 4). According to Carvalho et al. (2009), one of the factors that boosts milk production activity the most is scale of production, which is a limiting factor within the farms studied.

Table 5. Dimension 2: Herd factors, herd characteristics, feeding and vaccination.

Variable	Range of observation				
Predominant phenotype (%)	Holstein Friesian 73.68	Girolando 10.53	Jersey 5.26	Other 10.53	
Dietary supplementation	Silage 26.32	Milk Whey 15.79	Concentrate 73.68	Other 5.26	None 21.05
Vaccination (%)	Brucellosis 94.73	Foot and Mouth 100	IBR 47.37	Other 52.63	None 0
Number of animals (%)	10 - 15 15.79	16 - 20 42.11	21 - 25 21.05	26 - 30 21.05	
Average production (L/cow) (%)	10 - 13 L 10.53	14 - 16 L 15.79	17 - 19 Liters 31.58	20 - 22 L 10.53	23 - 25 L 31.58
Different management for dry/wet season (%)	Yes 42.11	No 57.89			

The producers that obtain the highest prices are those that invest in technology and seek out information. These producers store inputs on their farms and own milk coolers, demonstrating that investment in equipment and improvements on farms has a direct impact on final revenues (Table 4).

The current lack of support, information and investment is also reflected in the use of factors of production. In this study, basic management techniques such as soil analysis and fertilization are practiced by only 21% of the producers, while 36.84% of the farmers have applied fertilization and the majority (42.11%) did not use any forms of maintenance on their pastures (Table 4).

Sant'Ana and Tarsiato (2009) discussed the important of soil management as a fundamental factors of technological modernization, and according to their analysis, dairy farming in the Northwest region of Paraná is not an activity that uses modern technology because it is small the use of technological inputs in this region. It is possible that the lack of knowledge among farmers about the importance of analysis and correction of soil is responsible for the low use of these techniques and the consequent technological delay.

In terms of fertilization, only 21.05% of the farmers admitted applying after soil analysis. This situation demonstrates that extractive and traditional farming methods still exist in the region's dairy industry.

Use of family labor is predominant (42.11%), and just 21.05% of farms employ salaried workers (Table 4).

It worth to note that a minority of farmers use modern dairy farming machinery such as milking equipment (36.84%) or milk coolers (10.5%) (Table 4). When analyzing dairy farming in Minas Gerais, Lemos et al. (2003) noted that the use of this type of equipment (milking equipment and milk coolers) was a factor indicative for specialization within the dairy sector. In addition, the low level of value added to the product within the farm and the small proportion of farmers prepared to store inputs and products emphasizes rural producers' position as the weak link in the milk production chain, as they depend on other actors to carry out these activities.

The data presented in Table 5 shows satisfactory values for nutrition and vaccination, since only 21.05% of producers did not use dietary supplementation and 73.68% of them used concentrated. Practically all producers carried out the main recommended vaccinations (foot and mouth, 100% and Brucellosis, 94.73%) (Table 5). This is necessary for the development of activity in Brazil, because according to Lucena et al. (2010), for the dairy farming to expand into new markets, it is necessary to control the health condition of the herd, preventing infectious diseases that decrease production, milk quality and the return of the producer, and that can be contained using vaccines, assertion ratified by Valente et al. (2012).

The predominant herd phenotype is Holstein Friesian (Table 5). However, in the region there is no ascertained genetic control of animals, which could ensure their blood purity, and most animals is mixed between Holstein Friesian and other races. Interbreeding is often necessary and is used as a production strategy, as it combines the resistance the zebu cattle has to the region's tough climate with the high productivity of European breeds, mainly Holstein Friesian and Jersey (Perotto et al., 2010), strengthening the herd's genotype-environment interaction, as described by Paula et al. (2009).

In terms of herd productivity, 73% of farms presented good results (above 16 kg/cow/day) compared to results obtained in a study carried out in high-technology farms using confinement and semi-confinement production systems (15.62 and 22.25 kg/cow/day) respectively (Lopes et al., 2012).

The majority of farmers (57.89%) did not change their management during the dry season, which can result in a reduction in production per animal as nutritional demands and pasture conditions greatly vary due to the climatic changes that occur during dry period. Inadequate diet may affect the quality of the milk produced and the health of the animals (Marques et al., 2010). It can also cause significant oscillations in the production volume obtained by farmers between these two periods (dry and wet), and subsequently affects revenues and profitability. This situation has also been verified by Lopes et al. (2010). While studying the technical characteristics of 16 low-scale production farms, it was observed that all of these presented a high seasonal variations and a fall in production during the dry season.

Even so, the average production per animal observed among the region's producers varied between 10 and 25 L/cow/day (Table 5), while the national average oscillates from 4 L to over 17 L/cow/day (EMBRAPA, 2007). This data shows that the region is well suited to dairy farming and that larger investments into management and technology may generate significant increases in production and revenues.

In contrast to current practice on the majority of the farms reviewed in this study, lactating cows should be managed on high quality pasture in sufficient quantity to ensure enough for each animal, and good quality roughage should be supplied in adequate concentrations and with the appropriate mixture of minerals (Barbosa et al., 2002).

Barbosa et al. (2002) indicate that dietary supplementation given to lactating cows should vary along the production cycle and highlight that the stage of lactation that the cows are in should influence the type of supplement to be used, as this affects both the composition of the milk and the cows production level.

The situation observed in this region can be observed throughout Brazil. A study by Gomes (2000) shows that dairy farming is made up of a large number of small producers with low production rates, and a small number of large producers that achieve higher production rates. Despite their low production rates, small farms are highly important within the production chain. Guilhoto et al. (2007) emphasize the extent and importance of family farming in Brazil's dairy industry, which was responsible for 59% of the total national production in 2006.

Conclusions

It was concluded that the producers of northwestern Paraná still have traditional managerial profile, with little use of techniques for planning, management and control of activity, exploring the business of amateur and familiar way. Regarding the technological profile of the farm, still verified the predominance of semi-intensive farming, with little use of modern production inputs, such as equipment, soil improvement techniques and specialized animals. Moreover, the region has productivity above the national average and some actions in order to specialize the activity being effective. With regard to economic aspects, the producer has a low bargaining power in the supply chain, the price received for milk is low and it has no influence on the formation of the same, being totally at the mercy of dairy. Thus, dairy farming in the region is in a state of transition between the traditional model found in most Brazilian regions, and a modern system of milk production, that characterizes the major producing countries and some of the leading and most advanced dairy regions in Brazil.

Conflict of Interest

The authors have not declared any conflict of interest.

REFERENCES

Alencar E, Grandi DS, Andrade DM, Andrade MP (2001). Agribusiness complex, cooperatives and management. Org. Rurais Agroind. 3(2):30-44.

Arieira JO (2010). Evaluation of relationships in business networks: a study of agribusiness in the region of the AMERIOS – PR. São Paulo: Unip. P. 191.

Barbosa PF, Pedroso AF, Novo ALM, Rodrigues AA, Camargo AC, Pott EB, Schiffer EA, Afonso E, Oliveira MCS, Tupy O, Barbosa RT, Lima VMB (2002). Alimentation. Embrapa Gado de Leite. Production System 4.

Bressan M (1998) Alternatives for small milk production in Brazil. Research Interest Group for Family Farming. Brasília: Embrapa.

Carvalho FM, Ramos EO, Lopes MA (2009). Comparative analysis of production cost of two dairy farm, in the city of Unaí - MG, in the period of 2003 and 2004. Ciênc. Agrotecnol. 33:1705-1711.

Conseleite (2013). Resolução nº 04/2013. Curitiba: Conseleite.

Emater (2012). Paraná Institute of Technical Assistance and Rural Extension. Alto Piquiri - PR. Workplan 2012. Summary of the Municipal Plan. Curitiba: Emater, 2012.

Embrapa (2006). Brazilian system of soil classification. Rio de Janeiro: National Center of Soil Research, 2006.

Embrapa (2007). Grass fertilization. Embrapa Cattle Southeast.

Gomes ST (2000) Diagnosis and perspectives of milk production in Brazil.

Guilhoto J, Ichiara S, Silveira FG, Diniz BC, Azzoni C (2007). The importance of family farming in Brazil and its states. Brasília: NEAD.

IAPAR (2012). Agronomic Institute of Paraná State. Climate Classification.

IBGE (Brazilian Institute of Geography and Statistics) (2006). IBGE Automatic Recovery System – SINDRA. Brasília: IBGE.

Lemos MB, Galinari R, Campos B, Biasi E, Santos F (2003). Technology, regional specialization and productivity: a study of dairy cattle in Minas Gerais State. Braz. J. Rural Econ. Sociol. 41(3):117-138.

Lopes AD, Oliveira MDS, Fonseca MI (2010). The technical features of the properties of low milk level observed in the catchment area of the office of rural development Jaboticabal - SP. Sci. Magaz. Ext. 6(2):32-45.

Lopes MA, Dias AS, Carvalho FM, Lima ALR, Cardoso MG, Carmo EA (2009). Economical results of milk production systems with different technological levels in the area of Lavras, Minas Gerais, Brazil in the years 2004 and 2005. Sci. Agrotechnol. 33(1):252-260.

Lopes MA, Santos G, Carvalho FM (2012). Comparative economic

indicators of milk production systems with high daily volume in Minas Gerais State. Rev. Ceres 59(4):458-465.
Lopes PF, Reis RP, Yamaguchi LCT (2007). Costs and scale of production in dairy cattle: study in the major producing states of Brazil. Braz. J. Rural Econ. Sociol. 45(3):567-590.
Lucena RB, Pierezan F, Kommersg D, Irigoyen LF, Fighera RA, Barros CSL (2010). Diseases of cattle in southern Brazil: 6.706 cases. Braz. Vet. Res. 30(5):428-434.
Marques LT, Fischer V, Zanela MB, Ribeiro MER, Jr WSM, Manzke N (2010). Supply of supplements with different levels of energy and protein to Jersey cows and their effects on milk instabilty. J. Anim. Sci. 39(12):2724-2730.
Milone G (2004). Applied and general statistics. São Paulo: Pioneira Thomson.
Oliveira LFT (2008) Institutional environment and milk production: A case study in western Santa Catarina region from the introduction of IN51. Santa Maria: Santa Maria University P. 143.
Oliveira LFT, Silva SP (2012). Institutional changes and family farming in milk production chain in Western Santa Catarina State. Braz. J. Rural Econ. Sociol. 50(4):705:720.
Oliveira TBA, Figueiredo RS, Oliveira MW, Nascif C (2001). Technical indices and profitability of the dairy industry. Sci. Agríc. 58(4):687–692.
Paula MC, Martins EM, Silva LOC, Oliveira, CAL, Valotto AA, Ribas NP (2009). Genotype × environment interaction for milk yield of Holstein cows among dairy production units in the state of Paraná. J. Anim. Sci. 38(3):467-473.
Perotto D, Kroetz IA, Rocha JL (2010). Milk production of crossbred Holstein × Zebu cows in the northeastern region of Paraná State. J. Anim. Sci. 39(4):758-764.
Pfau LA (2002). Milk production in regional development. In: South - Milk Symposium on Sustainability of Dairy Cattle in Southern Brazil. Proceedings, Maringá: UEM/CCA/DZO – NUPEL. Maringá: UEM.
Reis RP, Medeiros AL, Monteiro LA (2001). Production costs of dairy farming in the southern region of Minas Gerais State. Org. Rurais Agroind. 3(2):45–54.
Rubez J (2003) The milk in the last 10 years. Brazil. Brazilian Association of Milk Producers.
Sant'ana AL, Tarsitano MAA (2009). Typification of the families of eight rural settlements of the region Andradina (SP), based on different strategies for production and commercialization. Braz. J. Rural Econ. Sociol. 47(3):615-636.
Valente LCM, Souza EC, Vale SMLR, Braga, MJ (2012). Relationship between preventive and treatment expenditures: evaluation of the situation of dairy farms in Minas Gerais, Brazil. J. Anim. Sci. 41(1):212-220.
Vilela D, Leite JLB, Resende JC (2002) Policies for milk in Brazil: Past, present and future. In: South - Milk Symposium on Sustainability of Dairy Cattle in Southern Brazil. Proceedings, Maringá: UEM/CCA/DZO – NUPEL.

academicJournals

Vol. 10(5), pp. 416-422, 29 January, 2015
DOI: 10.5897/AJAR2014.9287
Article Number: AD42BFA49892
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Review

Use of micronutrients in tropical and sub-tropical fruit crops: A review

M. K. Yadav[1]* and V. K. Solanki[2]

[1]Department of Horticulture and Farm Forestry Ministry of Horticulture and Food Processing, Satna 485001, India.
[2]Formerly at Navsari Agricultural University, Navsari 396450, India.

Received 29 October, 2014; Accepted 9 January, 2015

Soil is the reservoir of macro and micro nutrients with the inception of commercial farming the emphasis is given to production without taking care of soil health and eventually soil health deteriorates and production falls. One of the very important components of soil health remained neglected and now reached to the threatening level. Management of balanced nutrients has become of vital importance. Without minimizing the importance of macronutrients in quadrupling the fruit production in the world during the last 50 years, it can be stated that micronutrients are going to play a major productive and qualitative role in bringing stability and sustainability in the production system during the next few decades, particularly in respect of tropical and sub-tropical fruit crops.

Key words: Micronutrient, tropical, sub-tropical.

INTRODUCTION

India is one of the horticultural rich countries of the world, produces large varieties of fruits, and banana is one of them. Since the last 50 years a considerable research work has been done in the country on various aspects such as varieties, irrigation, weed management, spacing, post harvest etc. for increase in yield and quality of banana. It would therefore be worthwhile to improve the growth, yield and quality of banana with basal feedings on nutrients. Moreover, elements like nitrogen, phosphorus and potash play a vital role in promoting the plant vigour and production and the micronutrients like Fe, Zn, Mn, Cu and B are not only essential but they are equally important like other macro nutrients, in spite of their requirement in micro quantities. Micronutrients are key elements in plants growth and development. These elements play very important role in various enzymatic activities and synthesis. Their acute deficiencies some time poses the problem of incurable nature (Kumar, 2002). These micronutrients also help in the uptake of major nutrients and play an active role in the plant metabolism process starting from cell wall development to respiration, photosynthesis, chlorophyll formation, enzyme activity hormone synthesis, nitrogen fixation and reduction (Das, 2003).

Soil is the reservoir of macro and micro nutrients with the inception of commercial farming, the emphasis is given to production without taking care of soil health and eventually soil health deteriorates and production falls. One of the very important components, that is, micronutrients of soil health remained neglected and now reached to the threatening level. Management of balanced nutrients has become of vital importance.

Without minimizing the importance of macronutrients in quadrupling the fruit production in the country during the last 50 years, it can be stated that micronutrients are going to play a major productive and qualitative role in

*Corresponding author. E-mail: manoj_bioversity@hotmail.com

bringing stability and sustainability in the production system during the next few decades, particularly in respect of tropical fruits. The micronutrients are available in non-chelated (sulphate) and chelated form. The chelates are the complex compound in which certain cations are complexed or bound to an organic molecule in complex form. The cations are protected from reactions with inorganic soil constituents that would make them unavailable for uptake by plants. Chelates also provide a continuous supply of nutrient without any danger of toxicity (Tisdale et al., 1985). The role of major nutrients in fruit crops have been intensively investigated on experimental farms as well as on the farmers' field, but less attention has been paid in the past to the requirements of micronutrients for tropical fruits. It is generally believed that micronutrients are present in adequate quantities in Indian soils for optimum production. It is however, now recognized that with the adoption of improved agronomic practices for increasing production, use of high yielding varieties, adoption of intensive farming and cropping systems, the demands for micronutrients will also increase. The shortage of organic manure for large scale application and higher use of NPK fertilizers, micronutrients are essential for efficient use and balance soil status of major nutrients, hence application of micronutrients is obvious. An attempt is being made here to present a brief Account of some previous studies related to the present investigation in banana and other fruit crops.

EFFECT OF MICRONUTRIENTS ON GROWTH PARAMETERS

Banana

Micronutrients such as Zn and Cu had been reported to be essential for the growth and development of banana plants (Srivastava, 1964a and b). He further stated when Zn at 2-4 ppm was applied to the roots or as a foliar spray, all the applications of Zn greatly improved both top and roots growth of the plants compared to control plants. Various levels of Cu, Zn, Mo, B and Mn when applied as the substrate and as foliar sprays, Zn and Cu proved essential for growth and development, favorable responses were also obtained to B and Mo and there was a slight response to Mn (Srivastava, 1964). Das and Mohan (1993) reported that application of micronutrients with combination of B + Zn + Cu + Mn, induced marked improvement in plant height, girth, leaf area and number of functional leaves. Ghanta and Mitra (1993) found that the combined application of Zn (0.3%), Cu (0.1%) and B (0.2%) showed the best response in plant growth at flowering in terms of height, girth of pseudostem and number of leaves per plant and maximum days required for flowering from planting. The number of suckers produced per plant at flowering reduced considerably over control. The combined application of 25 kg Farm Yard Manure (FYM) + 0.5 kg Neem cake per plant and 25 kg $ZnSO_4$ per hectare had improved the plant height, plant girth and total functional leaves after 60 days of application (Subramanian and Pillai, 1997). Yadav et al. (2010) recorded maximum plant growth and minimum crop duration with recommended dose of fertilizers (200+90+200 NPK g/plant) + 40 g Zn EDTA + 20 g $MnSO_4$ + 5 g $CuSO_4$ + 10 g Borax/plant.

Mango

Singh and Rajput (1976) reported that the various levels of $ZnSO_4$, increased the length of terminal shoot, number of leaves and leaf area per shoot of mango tree. An experiment on the foliar applications of Zn (0.1, 0.2 and 0.4%), Fe (0.1, 0.2 and 0.4%) and B (0.1, 0.2 and 0.4%) indicated that both Zinc and Boron promoted vegetative growth in terms of plant height, trunk girth and spread of young plants.

Guava

Sharma and Bhattacharyya (1994) obtained the highest number of leaves and total number of flowers when plants treated with non-chelated and chelated Zinc at the concentrations of 0.4%. Copper at 0.4% significantly increased terminal shoot length, number of leaves and leaf area (Singh and Singh, 2002).

Papaya

The monthly spray of $FeSO_4$, $ZnSO_4$ and borax @ 0.1% with or without combination were effective in increasing the plant height and girth compared to control. The $FeSO_4$ sprays were most effective in the plant height and girth (Veena and Lavania, 1998).

Grape

Aggarwal et al. (1975) noted that micronutrient applications increased the shoot growth over control with or without combinations of Zn, Cu and Fe. The 0.2% concentration of $ZnSO_4$ was found to be more effective out of different concentration tried for improving berry (fruit) set and reducing panicle drying over control (Kumar et al., 1988). Singaram and Prabu (2001) reported that the foliar application of $ZnSO_4$, 0.5% + borax 0.2% increased the shoot length, number of internodes per shoot and number of leaves per shoot compared to other combination of Zn and Boron.

Litchi

Foliar application of Zinc (0.6%), Copper (0.3%) and

Boron (0.3%) was found to accelerate the growth and vigour of the plant (Babu and Singh, 2002).

Citrus fruits

The spray with Zinc or Zinc + Iron increased the leaf area of citrus fruit (Bhambota et al., 1962). Supriya and Bhattacharyya (1993) reported that the highest number of leaves per terminal shoot and highest leaf area of Assam lemon (*Citrus limon*) with 0.4% Zinc treatment. Ram and Bose (2000) observed that the application of Mg and micronutrients (Cu, Zn, Fe and B) had significant effect on plant height, stem girth and spread of canopy. The combinations of Mg + Cu + Zn showed the maximum increase in height, stem girth and canopy of the Mandarin orange (*C. reticulata*). Haque et al. (2000) reported that the foliar spray of $ZnSO_4$ (0.5%) and phosphoric acid (0.1%) either alone or in combination with other nutrients (Mg and Cu) on Mandarin showed effective in increasing the plant height and plant spread. However, the significant maximum increase in plant height and spread was found with combined application of Mg, Cu and Zn.

Pineapple

An experiment was conducted on the effect of five concentration of Zinc (that is, 0, 1, 2, 3 and 4 ppm) as foliar spray on pineapple. Significant improvement in leaf area and plant height were noted with 2 ppm Zinc (Shrivastava, 1969). Shrivastava (1970) concluded that the application of Boron increased the growth characters such as, height of plant, total leaf area per plant, fresh and dry weight of plant and shortening the total period of cropping.

EFFECT OF MICRONUTRIENT ON YIELD AND YIELD PARAMETERS

Banana

The combined application of Zn (0.3%), Cu (0.1%) and B (0.2%) resulted in maximum number of hands per bunch, number of fingers per bunch, bunch weight and yield per hectare (Ghanta and Mitra, 1993). The study conducted by Subramanina and Pillai (1997) revealed that the maximum number of hands per bunch, number of fingers per hand, bunch length and bunch yield per hectare recorded when 25 kg $ZnSO_4$/ha + FYM @ 25 kg/plant + neem cake @ 0.5 kg/plant were applied. Suresh and Savithri (2001) observed that the soil application of N, P, K and foliar spray of nutrients (1% DAP + 1% MOP + 0.5% $ZnSO_4$+ $CuSO_4$ + 0.2% Borex) in addition to liming caused substantial increase in the yield of bunch per hectare.

Mango

Singh and Rajput (1976) found that in different levels significantly increased the fruit yield as compared to control. The size of the fruit (length and diameter) and fresh weight were increased greatly when boric acid and Zinc sulphate were sprayed at the rate of 0.8% concentration (Rath et al., 1980). Banik et al. (1997a) reported that the plants treated with Zinc at the highest level (0.4%) in combination with Iron and Boron at the lowest level (0.1%) produced maximum number of fruits and yield per plants as against the control. Banik and Sen (1997) observed that the application of Zinc, Iron and Boron was found to increase the number of fruit, individual fruit weight and fruit yield. Spraying of Zinc, Magnese and iron each at 0.1 and 0.2% improved the fruit weight, size, number of fruits per plant and yield per plant in mango irrespective of the stages of application and the effect of Zn was more marked in improving fruit yield when applied at higher concentration twice (at flowering + pea stage) as compared to Mn and Fe (Dutta and Dhua, 2002).

Guava

Zinc chelated at 0.4% increased percent fruit set per plant, total number of fruits per plant and reduced flowering-harvesting interval (Sharma and Bhattacharyya, 1994). Pandey et al. (1998) reported that the fruits of bigger size were obtained with the application of urea + $ZnSO_4$ + etherel + NAA. However, the spraying of borax also proved equally effective. Foliar spray of Zn @ 4 g/plant/year and Mn at same rate/plant/year significantly increased the fruit yield (Lal et al., 2000). Singh and Singh (2002) concluded that foliar application of Copper at 0.4% significantly increased number of flower buds, fruit set, fruit retention and yield per tree.

Papaya

Veena and Lavania (1998) reported that foliar sprays of $FeSo_4$, $ZnSo_4$ and Borex singly or $ZnSo_4$ in combination with $FeSO_4$ or borax gave remarkable increase in the fruit diameter and yield over the control. It was noted that the foliar sprays of Zn 0.5% + B 0.1% at 4^{th}, 8^{th}, 12^{th} and 16^{th} month after planting improved the total number of fruits per tree, fruit characters, fruit and latex yield (Kavitha et al., 2000a).

Grape

Daulta et al. (1983) reported that all the concentrations of $ZnSO_4$ (0.2, 0.4 and 0.6%) and two concentrations of $FeSO_4$ (0.1 and 0.2%) significantly improved berry size and berry weigh over the control. An experiment conducted by Kumar et al. (1988) noted that the application of $ZnSO_4$ was found to be more effective for increasing weight, length and breadth of bunch and berry over the control. The spray of Boron (0.4% and $ZnSO_4$ (0.2%) proved to be better in increasing the size and weight of bunches (Kumar and Pathak, 1992). Prabu and Singaram (2001) found that the applications of $ZnSO_4$ and borax single or in combination at different levels, increased the yield than the control. The treatment $ZnSO_4$ 0.5% + borax 0.2% foliar spray produced the maximum yield.

Litchi

Awasthi et al. (1975) reported that the foliar sprays of $ZnSO_4$ @ 0.5, 1.0 and 1.5% on litchi considerably increased the fruit yield and reduced fruit drop. Misra and Khan (1981) found maximum length and diameter of fruit in $ZnSO_4$ at 0.4% spray whereas the weight of fruit was obtained highest in $ZnSO_4$ at 0.2% and 0.4% during the study. Foliar applications of Zn, Cu, B and K in different concentrations increased the length and diameter of fruit, weight of fruit and reduced fruit drop (Sarkar et al., 1984). Dutta et al. (2000) reported that the foliar application of B as boric acid improved fruit set and fruit weight over control. The fruit size and weight of fruit were increased greatly with borax applied at 0.4% and $ZnSO_4$ at 1.0% through foliar spray (Rani and Brahmachari, 2001).

Citrus fruits

Bhambota et al. (1962) noted that the application of Zinc (0.6%) + Iron (0.4%), significantly increased the number of fruits, mean weight of fruit, diameter and volume of each fruits of citrus plant. The foliar applications of $ZnSO_4$ (0.5, 0.75 and 1.0%) and $FeSO_4$ (0.5, 0.75 and 1.0%) in Kinnow mandarin, improved the fruit yield. Among their respective concentrations 1.0% $ZnSO_4$ and 0.5% $FeSO_4$ were most effective (Dixit et al., 1977). The foliar application of Zinc had considerably increased the number of fruit per plant and yield and reduced fruit fall and flowering harvesting interval of Assam Lemons (Supriya and Bhattaacharyya, 1993). Durgadevi et al. (1997) reported that the highest fruit yield of Sathgudi orange was recorded in trees treated with soil application @ 50 g/plant combined with foliar spray of 0.5% each of $ZnSO_4$, $FeSO_4$ and $MnSO_4$. Spraying of micronutrients (Cu, Zn and B) alone and their combinations significantly increased the number of fruits per plant, total fruit weight per plant, fruit diameter and yield of Mandarin orange (Haque et al., 2000).

Pineapple

Shirvastava (1969) reported that the fresh and dry weight of fruits and percent edible portion were improved with 2 ppm Zinc spray but higher doses were unfavorable.

Other minor fruit crops

Foliar applications of $ZnSO_4$ at 0.4%, $FeSO_4$ at 0.4% boric acid at 0.2% in ber gave best results on fruit weight and yield (Kamble et al., 1994). Afria et al. (1999) reported that the foliar spray of $ZnSO_4$ + $FeSO_4$ + Borex in pomegranate produced the maximum number of fruits per plant, average fruit weight and yield per plant compared to other combinations of treatments.

EFFECT OF MICRONUTRIENTS ON QUALITY PARAMETERS

Banana

Pulp: peel ratio and fruit quality in terms of Total Soluble Salts, total sugars, reducing sugars, sugar acid and ascorbic acid content were highest with foliar application of 0.3% Zn + 0.1% Cu + 0.2% B at 3 and 5 months after planting (Ghanta and Mitra, 1993). Suresh and Savithri (2001) found that the soil application of N, P and K and foliar spray on nutrients (1% DAP + 1% MDP + 0.05% $ZnSO_4$ + 0.2% $CuSO_4$, 0.2% Borex) in addition to liming had increased the TSS, sugar acid ratio and decreased the titrable acidity. Yadav et al. (2011) recorded maximum TSS and other quality parameters with RDF (200+90+200 NPK g/plant) + 40 g Zn EDTA + 20 g $MnSO_4$ + 5 g $CuSO_4$ + 10 g Borax/plant.

Mango

The Zinc application (0.8%) significantly increased the reducing and non-reducing sugars, ascorbic acid and TSS (Singh and Rajput, 1976). Rath et al. (1980) reported that the total sugars, ascorbic acid content, acidity and TSS of the fruit pulp were increased greatly by the higher (0.8%) concentrations of boric acid and Zinc sulphate. The quality of mango fruit was improved by the application of 0.6 and 0.8% $ZnSO_4$ and 500 ppm CCC (Daulta et al., 1981; Banik et al., 1997a). An experiment was conducted by Banik et al. (1997b) to assess the quality of mango fruit under the influence of three levels of Zinc, Iron and Boron. The size of the fruit and fresh weight increased greatly when Zinc sulphate and borax were sprayed. Fruit quality as evident by TSS and sugar content was enhanced markedly by the application of Zn and B in young mango plants. Application of Zn, Fe and Mn at 0.1 and 0.2% showed a considerable improvement in TSS, sugars and ascorbic acid contents in fruit at harvest as well as on ripening as compared to control (Dutta and Dhua, 2002).

Guava

Foliar spray of Zn, B, and Mo at the rate of 0.2% $ZnSO_4$, 0.4% boric acid and 0.05% ammonium molybdate, singly and in various combinations revealed that Zinc gave maximum TSS, reducing and non reducing sugars. Maximum ascorbic acid was noted with the treatment of Boron (Singh and Chonkar, 1983). Pandey et al. (1998) reported higher TSS, sugars and ascorbic acid content in fruits than control when plants treated with Borex and $ZnSO_4$. The size of fruits and fruit quality as evident by TSS and sugars content were enhanced markedly by the application of Boron and Zinc (Singh and Brahmachari, 1999).

Papaya

Veena and Lavania (1989) observed that TSS, sugars, acidity and sugar: acid ratio increased remarkably, when $FeSO_4$, $ZnSO_4$ and borax applied at monthly interval as foliar spray singly or in combinations over control. The foliar spray of Zn, 0.5% + B 0.1 at 4th, 8th, 12th and 16th months after planting increased total sugars, reducing sugars, non-reducing sugars, ascorbic acid and sugar acid ratio, in association with bio-chemical traits (Kavitha et al., 2000b).

Grape

The foliar spray of $ZnSO_4$ (0.2, 0.4 and 0.6%) $FeSO_4$ (0.1, 0.2 and 0.6 %) and Boron (0.50 and 0.75%) improved TSS, however, the acidity of berries was not affected by different chemicals except $FeSO_4$ (0.2 and 0.4%) which significantly increased the acid content of the grape berries (Daulta et al., 1983). Kumar et al. (1988) reported that among the different concentrations of $ZnSO_4$ (0.2, 0.3 and 0.4%), concentration of 0.2% gave the maximum juice, TSS and acidity percent. All concentrations of $ZnSO_4$ were found better than control. The maximum TSS, total sugars as well as reducing and non-reducing sugars were found with the spray of 0.2% $ZnSO_4$ followed by its higher concentration 0.4% (Kumar and Pathak, 1992). Prabu and Singaram (2001) reported that the application of $ZnSO_4$ at 0.5% + borax at 0.2% through foliage increased the TSS, reducing sugars, many reducing sugars, total sugars and sugar acid ratio and reduced acidity.

Litchi

Foliar sprays of $ZnSO_4$ at 0.5, 1.0 and 1.5% concentrations on litchi considerably increased the pulp weight and TSS and decreased total acidity (Awasthi et al., 1975). Sarkar et al. (1984) studied that the foliar application of Zn, Cu, B and K in different concentrations increased the pulp weight, total sugars and TSS over control. The foliar application of $ZnSO_4$ at 1.0% and potassium chloride at 2.0% found to be the most effective treatments for improving i TSS, sugar: acid ratio and ascorbic acid of the fruit. The total sugar and sugar: acid ratio were recorded higher with $ZnSO_4$ at 0.1% spray (Kumar et al., 1995). Dutta et al. (2000) found that the foliar application of B as boric acid improved TSS, total sugars, non-reducing sugars, TSS: acid ratio and ascorbic acid, while the acid content of fruits decreased with higher doses of Boron. The spray of various concentrations of $ZnSO_4$ and borax increased the pulp weight, pulp: peel ratio, TSS and sugar: acid ratio and significantly decreased the acidity (Rani and Brahmachari, 2001).

Citrus fruits

Studies conducted by Dixit et al. (1977) revealed that the sprays of $ZnSO_4$ and $FeSO_4$ on Kinnow mandarin, improved the juice content, TSS, total and reducing sugar, sugar acid ratio and ascorbic acid content. Foliar application of micronutrients were made for fruit quality improvement in orange. Borax at 0.6% and Zn and Cu as combined treatments increased the fruit TSS, sugar contents, sugar acid ratio and ascorbic acid content (Rai et al., 1988). Haque et al. (2000) found the maximum total sugar content, reducing sugar content, non-reducing sugar content and ascorbic acid content in fruit juice with spraying of $ZnSO_4$ 0.5% in Mandarin orange.

Pineapple and Ber

Shrivastava (1969) found that the reducing sugars, total sugars and sugar: acid ratio were improved with 2 ppm Zinc but non-reducing sugars and acidity were more with 4 ppm Zinc concentration. Shrivastava (1970) reported that the application of Boron at 1.0 ppm concentration increased the reducing, non-reducing and total sugars TSS and sugar: acid ratio, over control. Yadav et al. (2008) recorded maximum ber fruit quality parameters when trees feed with 40 g FeEDTA /plant.

EFFECT OF MICRONUTRIENTS ON NUTRIENTS CONTENT IN LEAF

Banana

Spraying with different micronutrients (Zn 0.3%, Cu 0.1%, B 0.2% and Mn 0.05%) with or without combinations significantly increased the leaf nitrogen, phosphorus and potassium content before flowering compared with control. Single application of Boron showed the highest amount of N (3.11%), P (0.175%) and K (3.13%) in leaf

(Ghanta and Mitra, 1993). Yadav et al. (2010) recorded Zn content in leaf with RDF (200+90+200 NPK g/plant) + 40 g Zn EDTA + 20 g $MnSO_4$ + 5 g $CuSO_4$ + 10 g Borax/plant. While maximum Fe content in leaf noted from RDF + 25 g $FeSO_4$ + 2 g $MnSO_4$ + 5 g $CuSO_4$ + 10 g Borax and RDF + 25 g Fe EDTA + 20 g $MnSO_4$ + 5 g $CuSO_4$ + 10 g Borax/plant, respectively (Yadav et al. 2009).

Mango

Dutta and Dhua (2002) reported that the leaf nutrient status of mango increased with application of Zn (0.1 and 0.2%), Mn (0.1 and 0.2%) and Fe (0.1 and 0.2%). Application of Zn improved the leaf N and Zn content while Fe improved P and Fe and Mn improved the Mn and K contents.

Guava

Lal et al. (2000) found that the basal application of N, Zn and (2 and 4 g/plant) and Mn (2 and 4 g/plant), significantly increased the Zn and Mn content individually in guava leaves.

Grape

Aggarwal et al. (1975) observed that different combination of $ZnSO_4$ (0.54), $CuSO_4$ (0.25) and $FeSO_4$ (0.25%) increased the Zn, Cu and Fe contents in leaf tissues over the control.

Litchi

Foliar sprays of Zinc sulphate of 0.5, 1.0 and 1.5% concentrations on litchi considerably increased the Zinc content of the leaves (Awasthi et al., 1975).

Citrus fruits

Durgadevi et al. (1997) reported that the application of $ZnSO_4$, $FeSO_4$ and $MnSO_4$ as foliar spray or soil application or combination of both, significantly increased the N, P, K, Ca and Mg contents in the Sathgudi orange leaves. Ram and Bose (2000) found that the foliar spray of $MnSO_4$. (2%), $CuSO_4$ (0.4%), $ZnSO_4$ (0.5%), boric acid (0.1%) and $FeSO_4$ (0.25%) either singly or in various combinations significantly increased the N, P and K content of the Mandarin orange leaf.

Pomegranate

Afria et al. (1999) reported that the foliar application of $FeSO_4$ (0.4%), $ZnSO_4$ (0.25%) and borax (0.2%) increased the Fe, Zn and B content in leaves individually or in combination.

CONCLUSIONS

It is recognized that with the adoption of improved agronomic practices for increasing production, use of high yielding varieties, adoption of intensive farming and cropping systems, the demands for micronutrients will also increase. The shortage of organic manure for large scale application and higher use of NPK fertilizers, micronutrients are essential for efficient use and balance soil status of major nutrients, hence application of micronutrients is obvious.

Conflict of Interest

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

REFERENCES

Afria BS, Pareek CS, Garg DK, Singh K (1999). Effect of foliar spray of micronutrients and their combinations on yield of Pomegranate. Ann. Arid Zone 38(2):189-190.

Aggarwal RK, Panday SKN, Pareek OP (1975). Foliar application of micronutrients on Thompson seedless grape. Ann. Arid Zone 14(2):191-193.

Awasthi RP, Tripathi BR, Singh A (1975). Effect of foliar sprays of zinc on fruit drop and quality of litchi. Punjab Hortic. J. 15:14-16.

Babu N, Singh AR (2002). Effect of micronutrients spray on fruit cracking of litchi fruits. Haryana J. Hortic. Sci. 13(1-2):18-21.

Banik BC, Sen SK (1997). Effect of three levels of zinc, iron, boron and their interactions on growth, flowering and yield of mango cv. Fazli. Hortic. J. 10(1):23-29.

Banik BC, Mitra SK, Sen SK, Bose TK (1997b). Effect of zinc and boron sprays on the physico-chemical composition of mango fruits cv. Fazli. Orissa J. Hortic. 25(1):5-9.

Banik BC, Mitra SK, Sen SK, Bose TK (1997a). Interaction effects of zinc, iron and boron sprays on flowering and fruiting of mango cv. Fazli. Indian Agric. 41(3):187-192.

Bhambota JR, Azad KC, Kanwar JS, Dhingra DR (1962). Study of the effect of sprays with micronutrients of the chlorosis of citrus. Hortic. Adv. 6:168-172.

Das DK (2003). ‘Micronutrients: Their behaviors in soils and plants' Kalyani publ., Ludhiana pp. 1-2.

Das PK, Mohan NK (1993). Effect of micronutrient on growth and development of banana cvs. Chenichampa,Jahaji and Barjahaji. South Indian Hortic. 41(4):192-197.

Daulta BS, Kumar R, Ahlawat VP (1983). A note on the effect of micronutrients spray on quality of Beauty seedless grapes. Haryana J. Hortic. Sci. 12(3-4):198-199.

Daulta BS, Singh HK, Chauhan KS (1981). Effect of zinc and CCC sprays on flowering, fruiting and physico-chemical composition of fruit in mango cv. Dashehari. Haryana J. Hortic. Sci. 10(3-4):161-165.

Dixit CK, Yamdagni R, Jindal PC (1977). A note on the effect of micronutrients spray on quality of kinnow- A Mandarin hybrid. Haryana. J. Hortic. Sci. 6 (3-4):153-154.

Durgadevi D, Srinivasan PS, Balakrishna K (1997). Leaf nutrient composition, chlorosis and yield of Sathgudi orange as affected by micronutrient applications. South Indian Hortic. 45(1-2):16-29.

Dutta P, Dhua RS (2002). Improvement on fruit quality of Himsagar mango through application of zinc, iron and manganese. Hortic. J. 15(2):1-9.

Dutta P, Banik A, Dhua RS (2000). Effect of boron on fruit set, fruit retention and fruit quality of litchi cv. Bombai. Indian J. Hortic. 57(4):287-290.

Ghanta PK, Mitra SK (1993). Effect of micronutrients on growth, flowering, leaf nutrient content and yield of banana cv. Giant Governor. Crop Res. 6(2):284-287.
Haque R, Roy A, Pramanic M (2000). Response of foliar application of Mg, Zn, Cu and B on improvement of growth, yield and trial quality of Mandarin orange in Darjeeling Hills of West Bengal. Hortic. J. 13(2):15-20.
Kamble AB, Desai UT, Choudhari SM (1994). Effect of micronutrients on fruit set, fruit retention and yield of ber. Ann. Arid Zone 33(1):53-55.
Kavitha M, Kumar N, Jeyakumar P (2000a). Effect of zink and boron on biochemical and quality characters of papaya cv. Co.5. South Indian Hortic. 48(1-6):1-5.
Kavitha M, Kumar N, Jeyakumar P (2000b). Role of zinc and boron on fruit yield and associated characters in papaya cv. Co.5. South Indian Hortic. 48(1-6):6-10.
Kumar R, Chauhan KS, Sharma S (1988). A not on the effect of zinc sulphate on berry set, panicale drying and quality of grapes cv. Gold. Haryana J. Hortic. Sci. 17(3-4):213-215.
Kumar S, Pathak RA (1992). Effect of foliar application of micronutrients on the yield and quality of grapes cv. Perlette. Prog. Hortic. 22(1-2):13-16.
Kumar S Sharma RK, Choudhary R (1995). Effect of potassium, zinc and molybdenum spray on chemical composition of litchi. Hortic. J. 8(1):33-37.
Kumar P (2002). Managing micronutrient deficiency in ornamental crops. Indian Horticult. 46(4):30-31.
Lal G, Sen NL, Jat RG (2000). Yield and leaf nutrient composition of guava as influenced by nutrients. Indian J. Hortic. 57(2):130-132.
Misra RS, Khan I (1981). Effect of 2, 4, 5-Trichlorophenoyacetic acid and micronutrients on fruit size cracking, maturity and quality of litchi cv. Rose scented. Prog. Hortcult. 13(3-4):87-90.
Pandey DK, Pathak RA, Pathak RK (1998). Studies on the foliar application of nutrients and plant growth Regulators in Sardar Guava I-Effect on yield and fruit quality. Indian J. Hortic. 45(3-4):197-202.
Prabu PC, Singaram P (2001). Effect of foliar and soil application of zinc and boron on yield and quality of grapes cv. Muscat. Madras Agric. J. 88(7-9):505-507.
Rai RM, Tewari JD, Pant N, Pathak CP (1988). Effect of micronutrient sprays on fruit quality of orange. Prog. Hortic. 20(1-2):133-135.
Ram RA, Bose TK (2000). Effect of foliar application of magnesium and micronutrients on growth, yield and fruit quality of mandarin orange, Indian J. Hortic. 57(3):215-220.
Rani R, Brahmachari VS (2001). Effect of foliar application of calcium, zinc and boron and cracking and physico-chemical composition of litchi. Orissa. J. Hortic. 29(1):50-57.
Rath S, Singh RL, Singh B, Singh DB (1980). Effect of boron and zinc sprays on the physico-chemical composition of mango fruits. Panjab Hortic. J. 20(1-2):23-35.
Sarkar GK, Singh MM, Misra RS, Srivastava RP (1984). Effect of foliar application of mineral elements on cracking of litchi fruits. Haryana J. Hortic. Sci. 13(1-2):18-21.
Sharma R, Bhattacharyya RK (1994). Effect of foliar application of zinc on vegetative growth and reproductive characters of guava. South Indian Hortic. 42(3):200-203.
Shrivastava SS (1969). Effect of foliar application of zinc on growth, fruiting behaviours and quality of pineapple. Indian J. Hortic. 26(1-2): 146-150.
Shrivastava SS (1970). Foliar application of boron on Pineapple: Its Effect on growth, yield and fruit quality. Madras Agric. J. Sci. 57:146-151.
Singaram P, Prabu PC (2001). Effect of zinc and boron on growth and quality of grapes cv. Muscat. Madras Agri. J. 88(4-6):233-236.
Singh RR, Rajput CBS (1976). Effect of various concentrations of zinc on vegetative growth characters, flowering, fruiting and physico-chemical composition of fruits in mango cv. Chausa, Haryana J. Hortic. Sci. 5(1-2):10-14.
Singh SP, Singh A (2002). Effect of foliar nutrition of copper on growth and yield of guava cv. Allahabad safeda. Hortic. J. 15(1):55-61.
Singh UP, Brahmachari VS (1999). Effect of potassium, zinc, boron and molybdenum on the physico-chemical composition of Guava cv. Allahabad Safeda. Orissa J. Hortic. 27(2):62-61.
Singh PN, Chonkar VS (1983). Effect of zinc, boron and molybdenum as foliar spray on chemical composition on Guava fruit. Punjab Hortic. J. 23:34-37.
Srivastava RP (1964). Effect of micro elements (Cu, Zn, Mn, B and Mo) on the growth characteristics of banana. Sci. Cult. 30:352-355.
Srivatava RP (1964b). Effect of micronutrient on growth characteristics of banana II-Zinc. Fertilizer News 9(6):26-32.
Srivatava RP (1964a). Effect of micronutrient on growth characteristics of banana I-copper. Fertilizer News 9(2):13-26.
Subramanian V, Pillai AA (1997). Studies on the zinc deficiency in banana growing soils of Tamil Nadu. Indian J. Agric. Res. 31(3):105-188.
Supriya L, Bhattacharyya RK (1993). Effect of foliar application of chelated and non-chelated zinc on growth and yield of Assam lemon. Hortic. J. 6(1):35-38.
Suresh S, Savithri P (2001). Yield and quality of wetland banana as influenced by liming and nutrients application in an acid soil. Haryana J. Hortic. Sci. 30(122):12-13.
Tisdale SL, Nelson WL, Beaton JD (1985). Soil fertility and fertilizers. Macmillan Publishing Company, New York P. 754.
Veena P, Lavania ML (1989). Effect of foliar application of iron, zinc and boron on quality of papaya fruits. Prog. Hortic. 21(1-2):165-167.
Veena P, Lavania ML (1998). Effect of foliar sprays of iron, zinc and boron on growth and yield of papaya. South Indian Hortic. 46 (1-2):1-5.
Yadav MK, Patel NL, Hazarika A, Parmveer S (2011). Fruit quality and shelf life of Banana cv. Grand Naine influenced by chelated and non-chelated micronutrient. Andhara Agric. J. 58(3):352-354.
Yadav MK, Patel NL, Parmar BR, Kirtibardhan, Paramver S (2010). Effect of micronutrients on growth and crop duration of banana cv. Grand Nain. Prog. Hortic. 42(2):162-165.
Yadav MK, Patel NL, Patel SR, Kirtibardhan (2009). Response of banana to micronutrients. Ann. Plant Physiol. 23(1):71-73.
Yadav MK, Patel NL, Singh P, Choudhary M, Nayak D (2008). Influence of micronutrients on Fruit quality of ber. Andhara Agric. J. 55(4):515-517.

academicJournals

Vol. 10(5), pp. 423-433, 29 January, 2015
DOI: 10.5897/AJAR2014.9037
Article Number: 33673F449893
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Determinants of change and household responses to food insecurity: Empirical evidence from Nigeria

Hyacinth Onuorah Edeh* and Kwabena Gyimah-Brempong

International Food Policy Research Institute – Nigeria Strategy Support Program (NSSP), Abuja, Nigeria.

Received 31 July, 2014; Accepted 9 January, 2015

Limited economic and physical capacities as well as environmental and economic shocks have constrained the ability of many Nigerian households to feed themselves adequately. This has resulted in food shortages; and they had to adopt various consumption-related strategies to mitigate the effect of the shortfalls. Using the 2010/2011 Nigeria Living Standards Measurement Study-Integrated Surveys on Agriculture data and the reduced consumption coping strategy index (RCCSI), this paper examined the determinants of change in food (in)security of Nigerian households in the two major farming periods. Results showed that there were significant differences in the food insecurity status of households in the two periods. The likelihood of change in the food security status were determined by sex of the household head, farmland holdings, nature of livelihood, shocks associated with land loss, and climate change events. Coping strategies in the two periods were dietary change and rationing strategies. However, the frequency of use of these strategies was higher in the post-planting period and more among female-headed households. The use of high-yielding climate-resistant crops and reduction in post-harvest losses through processing and improved storage facilities were advocated.

Key words: Food security, food consumption score, reduced consumption coping strategy index, post-harvest, post-planting.

INTRODUCTION

Food security is defined as access by all people *at all times* to have enough food for an active, healthy life (World Bank, 1986). Elaborating on the World Bank's definition of food security, FAO (1996) noted that in addition to have access to enough food, food security must encompass access to preferred food. This definition thus indicates that an individual or household is food secure if only such entity is able to acquire and consume in a sustainable manner nutritionally adequate, safe and preferred food through socially acceptable means to guarantee wellbeing. When an individual or population lacks, or is potentially vulnerable due to the absence of one or more factors outlined in these definitions, the individual or population is said to be food insecure (John et al., 2013). The literature suggests that households particularly those in developing countries, are vulnerable or food insecure due to limited economic and physical capacities as well as environmental and economic shocks. Because households are vulnerable, a presently food secure household is not guaranteed the same status

*Corresponding author. E-mail: h.edeh@cgiar.org

in the future. As such, Jeronim et al. (2010) argue that the notion of food security is a dynamic rather than a static phenomenon.

Household food insecurity has been classified as either chronic or transitory. Chronic food insecurity signifies persistent food crisis caused by the continual inability of households to acquire needed food, either through market purchases or through own production (Khatri-Chatri and Maharjan, 2006). On the other hand, transitory food insecurity is a temporary decline in a household's access to needed food due to instability in food prices, production or income. It signifies a short time inadequacy in households' food access, which obligates the vulnerable households to cope in order to bridge their food consumption gap. Whether chronic or transitory, food crisis remains a great concern to developing countries particularly, in sub-Saharan Africa which has a significant share in the World's population. According to the Population Reference Bureau report (2010), out of the World's population of 7.137 billion, 1.030 billion (15%) are in Africa. FAO (2010) indicates that out of about 925 million people worldwide still suffering from chronic hunger, 235 million of them (25%) are from sub-Sahara Africa. This trend is also shown by the Global Hunger Index (GHI) report of 2013 (von Grebmer et al., 2013) which indicates that hunger level in Africa generally is alarming with sub-Saharan Africa recording the second highest regional GHI after South Asia. Because of the global concern to curb this crisis, global resolution in the form of the Millennium Development Goal (MDG) has been targeted to reduce by half, the amount of people who suffer from acute starvation and who earn less than $1 per day by the year 2015 (FAO, 2006).

In Nigeria, significant gains have been made in the reduction of hunger as indicated by the drop in the country's GHI from 16.3 in 2005 to 15 in 2013 (von Grebmer et al., 2013). However, this is still far above the safe and comfortable level of below 5 indicating that food insecurity is still prevalent in the country. As noted by Abimbola and Kayode (2013), a large proportion of Nigeria households are still food insecure despite the several efforts by successive governments to achieve food security through setting up of various agricultural development institutions, programmes and projects. Low household agricultural productivity and associated low income have resulted in persistent food insecurity particularly in the rural and low income urban households. From the foregoing, it is evident that Nigeria households are far from being food secure.

It is a common believe that households may be more food secure during the harvest period than in the planting season. This is because after harvest, most farming households have enough food from their own production and commodity prices are generally low. Abimbola and Kayode (2013) however noted that due to inadequate processing and storage facilities, and the challenge of meeting other household needs, these households usually end up selling their excess produce at low price during the harvest period. Immediately after this farming period, food stocks are depleted and most households rely on market purchases since they do not have enough to subsist on the year round. For non-farming households, their food purchasing power is very high during the harvest period and continuously declines as the lean period sets in. This leads to inconsistent food availability in the household thus contributes to food insecurity during the periods.

Several studies on Nigeria household food insecurity (Dare et al., 2013; Abimbola and Kayode, 2013; Adebayo, 2012; Olagunji et al., 2012; Victoria and Benjamin, 2012; Orewa and Iyangbe, 2010; Idrisa et al., 2008; Babatunde et al., 2007; Aromolaran, 2004), focus on case studies and mainly on various indicators of food security which FAO (2003) grouped as undernourishment (per capita dietary food energy supply), food intake (actual household food consumption), nutritional status (anthropometric measures) and access proxied by wealth status (total consumption, expenditure or income). A major shortcoming of these indicators is the non-inclusion of the vulnerability aspect of food security, which Maxwell (1996) notes is the most important element of the definition of food security. Dare et al. (2013) opine that though several studies on household food security have been conducted in Nigeria, more detailed analyses at the household level are still needed especially those that provide an understanding of the types of coping strategies adopted by households to tackle the problems of food shortages. Because of the need to shed more light on the implications of food insecurity on households' welfare and ways of promoting household food security, Abimbola and Kayode (2013) stated that changes in the food security status of households over time should be closely monitored with explanation given for the change.

This study contributes to the growing literature on household food insecurity by addressing these knowledge gaps through the assessment of the determinants of change in food insecurity of Nigerian households between two (post-planting and post-harvest) farming periods. The households' food insecurity status is captured by a reduced consumption coping strategy index for each farming period, and the difference in the index between the two periods represents the change in the level of household's food insecurity. It also assesses the nature of consumption coping strategies used by households in the two farming periods with a view to providing suggestions for increased sustainability of household food supply and better targeting policies.

CONCEPT OF VULNERABILITY TO FOOD INSECURITY

The widely recognized definition of food security as given by the World Bank (1986) recognizes that all must have access to sufficient food for active, healthy life". This provides a standard for further definitions from individuals and organizations. However, these many definitions all agree that the key defining characteristic of household food security is secure access at all time to sufficient food. As a working definition in this study, food security is "a situation in which all people, *at all times*, have physical, social, and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (F. A. O., 2002). This definition identifies the pillars of food security as availability, accessibility, stability of accessibility and utilization. As Webb et al. (2006) noted, these dimensions are inherently hierarchical, with availability necessary but not sufficient to ensure access and access, necessary but not sufficient for effective utilization. The availability of food therefore does not translate to food security of households except when they become accessible to individuals in sufficient and sustained quantity, nutritionally acceptable standards, and in good sanitary conditions to guarantee their general wellbeing. Anything short of this signifies food insecurity. At the household level, Phillips and Taylor (1990) state that food insecurity exists when members of a household have inadequate diet for part or all of the year or face the possibility of an inadequate diet in the future.

Food availability at household level is achieved when sufficient quantities of food are consistently available to all individuals within the household. The availability of such food can be achieved through household production, market purchases, or food assistance. Food accessibility is guaranteed when households and all individuals within them have adequate resources to obtain appropriate foods for nutritious diet. Accessibility can be through physical means to reach the food, economic means (buy the food) or social means (socially acceptable standing). Access depends on household income, distribution of income within the household, and on the price of food.

Stability of accessibility (or secure access to enough food) is ensured when households and all individuals within have adequate and preferred food *at all times* to maintain a healthy living. It affects the availability, access and utilization dimensions of food security. Households should not risk losing access to food as a consequence of sudden shocks (e.g an economic or climatic crisis) or cyclical events (e.g. seasonal food insecurity).

Food utilization measures whether a person will be able to derive sufficient daily nutrition from the available and accessible food. It entails the proper biological use of food, requiring a diet providing sufficient energy and essential nutrients, potable water, and adequate sanitation. It depends to a great extent on knowledge within the household of food storage and processing techniques, basic principles of nutrition and proper child care, and illness management.

The stability of access dimension of food security is reflected in the "*at all times*" language which denotes that at no time should a household or its members face food inadequacy situation. According to Babatunde et al. (2008), stability dimension of food security shows that there is need to understand both the current and future food security status at different point in time; and any adopted framework must capture the temporal dynamics of food security. The vulnerability framework has been widely accepted in literature to capture this dynamics.

Vulnerability is a function of exposure to risks/shocks and the non-resilience or poor coping capacity to these risks which threaten household's food security (availability, accessibility and utilization) (Babatunde et al., 2008). Besides natural disasters that can alter the food security status of households and usually make them vulnerable to food insecurity, socio-economic characteristics of households can also influence the food security status of households (John et al., 2013). They further argue that since human beings have less control over natural occurrences, focusing on socio economic characteristics of households will provide better alternative in addressing food security challenges. However, Khatri-Chetri and Maharjan (2006) maintain that a high level of exposure to risk of natural disasters and lack of ability or means to cope with them affect to a very great extent the food security status of households. These are indications that both factors (risks and households' socio-economic characteristics) are important determinants of vulnerability to food insecurity.

Vulnerability is determined by accumulation of events through time. The probability of households becoming food insecure in the future is a function of their present socioeconomic conditions, the risk factors prevalent within the given period and their capacity to manage the risks (Babatunde et al., 2008). The present household food situation is also a function of past events and conditions. What happened yesterday is reflected in today's status and what happened today influences tomorrow's status. This implies that the observed food insecurity status of the households during the post-planting period is a reflection of the various events during the preceding post-harvest period, and their status in post-harvest period is a reflection of the preceding post-planting events. This is what Jeronim et al. (2010) describe as recursive process. The post-planting and the post-harvest food insecurity status both determine the overall food insecurity situation over the period of time, given that household status in each period is mutually independent. The dynamic and forward-looking characteristics of the vulnerability to food insecurity is captured by the assessment of households' food security status at the present with the expectation of the future.

In this vulnerability framework, households have two-period lifetime consisting of the past, t_o (post-planting period) and the present, t_1 (post-harvest period). Between the past and the present ($t_1 - t_0$) are a number of events or risk factors which manifest themselves and determine, depending on the households' coping strategies, the present (post-harvest) food security status. During the post planting period, the food insecurity status of the households as measured by their consumption coping strategy index is determine by the prevailing socioeconomic characteristics of the households at that period, and the previous risk events the households experienced. Over time, this status improves or deteriorates depending on the nature and level of the shocks (natural, economic, political, and social) the household is exposed to, and the responses or coping strategies (consumption, expenditure, income and migration) the household is able to adopt to ameliorate the impacts of the shocks.

Migotto et al. (2006) identify five groups of measures of food insecurity to include measures of undernourishment, food intake, nutritional status, wealth status (total consumption, expenditures or income), and vulnerability (share of income spent on food and various coping strategy indices). The measure of undernourishment is estimated by the per capita dietary food energy supply. This estimate is derived from aggregate food supply and measures household food availability concept of food security. The food intake measures account for the food actually consumed at the individual or household level; and the measures of nutritional status are the anthropometric measures that assess food utilization. The wealth status measures account for the accessibility concept of food security and are measured by total consumption, expenditures or income. The last measures capture the vulnerability concept of food security through qualitative or "self-assessment" indicators of food security. Notable indicators of vulnerability measures are the share of income spent on food and the various coping strategy indices.

DATA, ANALYTICAL TECHNIQUES, MODEL SPECIFICATION, AND DATA ANALYSIS

Data

This study used data from the World Bank sponsored Living Standards Measurement Study-Integrated Surveys Agriculture (LSMS-ISA), which is a national survey on household welfare in Nigeria. The data represents 5000 households panels across the 36 states in Nigeria and the Federal Capital Territory (FCT), which were surveyed twice, first in 2010 to collect post-planting (lean season) data and in 2011 to collect postharvest data. The data, collected by the National Bureau of Statistics (NBS), is representative at the national level and provides information on of key socio-economic, food-related consumption coping strategies, economic shocks variables across the six zones in the country.

Analytical techniques

Reduced consumption coping strategy index (RCCSI)

The coping strategy index (CSI) measures frequency and severity of a household's coping strategies for dealing with shortfalls in food supply. Its uniqueness as a measure of household food insecurity lies in its ability to query household behaviours directly and factor in the severity of different behaviours (Maxwell et al., 2008a). It is calculated by combining the means of scoring the relative frequency with the severity of the various coping strategies used by households during food deficiency period. The relative frequency is measured by determining how many days per week a household had to rely on various coping strategies and the perceived severity of behaviour is usually determined by community members in focus groups. Weighted scores are combined into an index that reflects current and perceived future food security status (CARE/WFP, 2003; Maxwell et al., 1999).

Several studies have shown that there are set of behavioural responses to food insecurity that can be employed by any household, anywhere and this reflects accurately the food insecurity status of the households. These responses have universal severity weighting that can be applied across different context to establish the reduced coping strategy index, which Maxwell et al. (2008b) note reflects the food security situation accurately as the full index. The reduced consumption coping strategy index (RCCSI) is a variant of the coping strategy index calculated based on the five standard consumption coping strategies: eating less preferred food, borrowing food/money from friends and relatives, limiting portions at meal time, limiting adult intake, and reducing the number of meals per day, with their universal severity weighting. This index facilitates the comparison of food insecurity across various strata by normalizing the behaviours and severity scores that are used to create the index. The RCCSI score denotes that the higher the value of the RCCSI score is, the higher the level of food insecurity, and vice versa.

Using responses to the question on seven day recall of household behavioural consumption responses to food shortages, a reduced consumption coping index (RCCSI) was constructed for each household in each farming period. Based on the change in the index between the two periods, three categories of households were identified namely; those whose food security status improved (lower RCCSI in post-harvest), those whose food security status worsened (higher RCCSI in post-harvest), and those with no change in their food security status (RCCSI neither increased nor decreased). Thus, giving multiple discrete outcomes of food (in) security status of the households.

Model specification

In order to estimate a model with multiple discrete outcomes and explanatory variables that are attributes of individuals, a multinomial probit analysis was adopted. This model assumes that the outcomes with a cumulative normal distribution, are not independently and identically distributed; and allows for analysis of multiple, unordered outcomes. It also enables the estimation of the model without the Independence of Irrelevant Alternatives assumption usually associated with the logit model (McFadden, 1984); and appropriate for the estimation of probability that a certain characteristic is present or absent in the data, for instance, occurrence of food insecurity (Scaramozzino, 2006). In the model proposed here, the dependent variable is the change in the reduced consumption coping strategy index (ΔRCCSI), which represents the change in the food insecurity status of the households between the periods of post-planting and post-harvest. The dependent variable is grouped based on the nature of change of the index at the post-harvest period and it is assumed to be dependent on the households' observable characteristics and incidence of shocks (covariate and idiosyncratic).

To account for any heteroscedastic and normality problems that may arise, this study specifies the Huber-White sandwich estimator. Before the empirical estimation of the multinomial probit model, the independent variables were scrutinized for possible presence of

Table 1. Frequency of use of coping strategies by households disaggregated by season.

FCCS used	Number of days per week							
	Post-planting				Post-harvest			
	Never	1 – 2	3 – 6	7	Never	1 – 2	3 – 6	7
lesspreffood	62.47	21.07	13.60	2.86	70.81	17.48	9.37	2.34
limsizeatmealtimes	69.72	20.28	8.72	1.28	81.37	12.56	5.31	0.76
rednomealseatenday	71.70	18.38	7.87	2.05	83.59	11.25	4.36	0.80
resconsumptionbyadults	82.67	12.12	4.75	0.46	91.30	6.00	2.30	0.40
borrowfoodorrelyhelp	90.74	6.73	2.41	0.13	97.41	1.85	0.64	0.11
limitvarietyfoodeaten	62.86	24.29	11.17	1.69	73.08	17.76	7.79	1.37
havenofoodanykind	91.98	6.33	1.61	0.08	96.69	2.61	0.64	0.06
gosleepatnighthungry	91.61	6.71	1.66	0.02	97.03	2.46	0.49	0.02
gowholedaynight	96.09	3.21	0.67	0.02	98.71	1.04	0.23	0.02

Source: Authors calculation from the World Bank 2010/2011 LSMS-ISA data.Figures in percentages.

multicollinearity which is a common problem with cross-section datasets. Variables found to be correlated were excluded from the analysis.

Consider a household, *y* whose food insecurity outcome, *i* may fall within any of the defined set, k=1, 2, 3 of categories or outcomes, namely those whose food security status improved (lower RCCSI in post-harvest=1), those whose food security status worsened (higher RCCSI in post-harvest=2), and those with no change in their food security status (RCCSI neither increased nor decreased=3). Let $\Delta RCCSI_{iy}$ indicate the category of the change in the household's food insecurity status, which we assume depends on a vector of fixed household characteristics, X_h, as depicted in the socio-economic characteristics of the household, and on a vector of shocks: covariate, X_c and idiosyncratic, X_s experienced by the household. Assuming a simple linear dependence, the change in each household's food insecurity status can be expressed as a random variable consisting of the sum of an observable or systematic part, V_{ij} plus an error term ε_{ij} with zero mean and a certain distribution:

$$\Delta RCCSI_{iy} = V_{iy} + \varepsilon_{iy} \quad (1)$$

The error term, ε_{iy}, represents other factors such as measurement errors, differences between individuals, the individuals' erroneous perceptions of food insecurity, and the randomness inherent in human nature (Munizaga et al., 2000). The deterministic part, V_{iy} represents the vectors of fixed household characteristics, X_{iyh} and the covariate, X_{iyc} and idiosyncratic, X_{iys} shocks experienced by the households in the years before the post-harvest period. Equation (1) can then be explicitly written as:

$$\Delta RCCSI_{iy} = V_{iy} + \varepsilon_{iy} = \alpha + \beta_i \sum X_{jyh} + \delta_i \sum X_{iyc} + \gamma_i \sum X_{iys} + \varepsilon_{iy} \quad (2)$$

Because the multinomial probit model assumes the errors are distributed multivariate normal, with mean zero (0) and Covariance matrix $\Sigma = \begin{bmatrix} \sigma_1^2 & \sigma_{12} & \cdot & \sigma_{1n} \\ \sigma_{12} & \sigma_2^2 & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \sigma_{1n} & \cdot & \cdot & \sigma_1^2 \end{bmatrix}$, the probability of household being in category k=1 can be written as:

$$\Pr(k=1|\beta_i, \delta_i, \gamma_i, X_{jyh}, X_{iyc}, X_{iys}, \Sigma^*) = \int_{-\infty}^{\beta_1^* X_1^* + \delta_1^* X_{1_c}^* + \gamma_1^* X_1^*} \dots \int_{-\infty}^{\beta_1^* X_{k+1_h}^* + \delta_1^* X_{k+1c}^* + \gamma_1^* X_{k+1s}^*} f(\varepsilon_{i1}^*, \dots, \varepsilon_{ik+1}^*) \partial_{i1}^*, \dots \partial_{ik+1}^*$$

Where *f*(.) is the probability density function of the multivariate normal distribution.

RESULTS AND DISCUSSION

Results of the data analysis are presented in this here. We utilized household level information to investigate food-related coping strategies, gender and seasonal responses to food shortages, food consumption score and nature of food (in) security changes, and the determinants of change in the households' food (in) security level.

Food-related consumption coping strategies

The frequency of use of each strategy in each season is presented in Table 1. The post-planting season refers to the period after cultivation season which is generally characterized by few food baskets in the households, low income especially for households who are not seriously involved in non-farm income generating activities, and increase in expenditures occasioned by a rise in labour demand for farm activities. The post-harvest season, which is the off season, that directly follows the period after harvesting time is usually marked by increased household food basket, selling of farm produce and consequently, improved income earnings, and low farm labour demand. From Table 1, it is clear that variations exist in the frequency of use of each coping strategy in both seasons. In the post-planting period, most households depend on such coping strategies as limiting the variety of food eaten (24.29%), relying on less preferred food (21.07%), limiting portion size at meal times (20.28%), and reducing number of meals eaten in a day (18.38%), which they use 1 - 2 days per week. On the whole, 37.53, 37.14, 30.28, and 28.30% of the respondents predominantly rely on less preferred food, limit the variety of food eaten, limit portion size at meal times, and reduce number of meals eaten in a day

Table 2. Nature of food consumption coping strategies disaggregated by household type and season.

Consumption coping strategies used/food security dimension	Household type/Season					
	Female-headed			Male-headed		
	Total	PP	PH	**Total**	PP	PH
Rely on less preferred food *(acceptability)*	0.043 (0.059)	1.037 (0.061)	0.994 (0.061)	0.221* (0.025)	0.779 (0.023)	0.557 (0.020)
Limit portion size at meal times *(quantity)*	0.225* (0.055)	0.832 (0.054)	0.606 (0.048)	0.212* (0.018)	0.504 (0.017)	0.292 (0.135)
Reduce number of meals eaten in a day *(quantity)*	0.249* (0.059)	0.801 (0.056)	0.553 (0.045)	0.266* (0.020)	0.522 (0.019)	0.256 (0.013)
Restrict consumption by adults in order for small children to eat *(quantity)*	0.060 (0.038)	0.322 (0.032)	0.262 (0.032)	0.152* (0.014)	0.291 (0.013)	0.139 (0.01)
Borrow food, or rely on help from friend or relative *(quantity)*	0.027 (0.024)	0.131 (0.018)	0.103 (0.022)	0.120* (0.009)	0.154 (0.009)	0.033 (0.005)
Limit the variety of food eaten *(quality/diversity)*	0.092 (0.058)	1.010 (0.060)	0.919 (0.058)	0.208* (0.020)	0.643 (0.019)	0.434 (0.017)
Have no food of any kind in your household *(quantity)*	0.063** (0.026)	0.174 (0.021)	0.111 (0.020)	0.068* (0.007)	0.109 (0.008)	0.039 (0.005)
Go to sleep at night hungry because there is not enough food *(sufficiency)*	0.096* (0.023)	0.169 (0.023)	0.072 (0.013)	0.078* (0.007)	0.113 (0.007)	0.035 (0.004)
Go whole day and night without eating anything *(quantity)*	0.052* (0.013)	0.067 (0.013)	0.015 (0.005)	0.033* (0.006)	0.053 (0.005)	0.020 (0.003)

Source: Author's calculation from the World Bank 2010/2011 LSMS-ISA data. * significant at 1%; ** significant at 5%; food security dimension in italics; and Standard errors in parentheses.

respectively for at least once in a week during the post-planting period. Although the trend is similar in the post-harvest period, the proportion of households that use these strategies is lower. For instance, 29.19, 26.91, 18.63 and 16.41% of the respondents rely on less preferred food, limit the variety of food eaten, limit portion size at meal times, and reduce number of meals eaten in a day respectively for at least once per week during the post-harvest period. There were also similar reductions in the use of the other coping strategies. The reduction in the number of households using these strategies justifies better food condition during this period.

However, the record of less than 50% change (reduction) in the use of most of the strategies, especially the less severe strategies in the post-harvest period implies that mild to moderate food insecurity still exist in households during the post-harvest period. Very few (less than 10%) households use the most severe strategies such as borrow food, or rely on help from friend or relative; have no food of any kind in your household; go to sleep at night hungry because there is not enough food; and go whole day and night without eating anything in both seasons. Interestingly, the percentage reduction in these strategies during the post-harvest period is greater than 50%, which is a reflection of almost non severe food insecurity cases.

Household type and season differentiated household consumption coping strategies

The matrix in Table 2 is used to examine the food-based consumption coping strategies adopted by different households in different agricultural seasons. As expected, the result indicates that fewer households use the coping strategies in the post-harvest than in the post-planting period. However, male-headed households showed significance difference in the use of these strategies in both seasons than female-headed households. For instance, while there is a significant reduction in the number of male-headed households that use these strategies during post-harvest period, the proportion of female-headed households who had significant reduction in the use of the coping strategies were observed for few strategies. These strategies are limiting portion size at meal times; reducing the number of meals eaten in a day; having no food of any kind in the household; going to sleep at night hungry because there is not enough food; and going whole day and night without eating anything (quantity). Thus for female-headed households, there is no notable change (decrease) in such strategies as relying on less preferred food;

Table 3. Household food security changes from post-planting to postharvest by food consumption score and household type.

Food consumption score category	Household type/Nature of change					
	Female-headed household			Male-headed household		
	Increased	Decreased	Unchanged	Increased	Decreased	Unchanged
Poor	28.57	42.86	28.57	31.01	8.86	60.13
Borderline	45.19	13.46	41.35	33.46	13.77	52.77
Acceptable	36.12	23.95	39.92	35.18	14.15	50.68
Total	**37.23**	**23.10**	**39.67**	**34.77**	**13.87**	**51.36**

Source: Authors calculation from the World Bank 2010/2011 LSMS-ISA data. Figures are percentages.

restricting consumption by adults in order for small children to eat; borrowing food, or relying on help from friends or relatives; and limiting the variety of food eaten in both seasons.

Generally, it is evident that food insecurity exists in all households in both seasons, but higher frequency of use of the coping strategies and the non-significant seasonal difference among female-headed households in the use of some of the coping strategies like borrowing food and restricting consumption is an indication that they are more likely to be vulnerable and food insecure even in post-harvest periods than the male-headed households. If this category of household is food insecure in the harvest period when they are expected to rely on household production or purchases at lower prices, it points not only to probable poor harvest but also to their low income position. Thus, they may be chronically food insecure and may not be able to improve on their situation without external assistance.

Household seasonal food security changes

The nature of the relationship between food consumption score and changes in the reduced food consumption coping strategy index of households was determined using the Pearson's correlation matrix. The relationship though weak (-0.0340) is negatively signed as expected and statistically significant at p=0.05 level. Similar result was obtained by Maxwell et al. (2011). The weak correlation may be attributed to the nature of consumption coping strategies adopted to construct the index. These strategies are considered less severe coping behaviours. The negative correlation as expected is based on the inverse relationship between the food consumption score (FCS) and the reduced consumption coping strategy index (RCCSI). Higher FCS indicates greater food security while high RCCSI implies greater food insecurity. The use of the food consumption score and the change in the consumption coping strategy index in the determination of the proportion of households' net food (in) security change is based on vast literature which advocate for proper identification of households using multiple indicators.

The result of the cross tabulation of household's FCS and RCCSI is presented in Table 3. The nature of change and food consumption score (FCS) of households indicates the food (in) security position of the household in the post-harvest period. The FCS is based on dietary diversity, food frequency and the relative nutritional importance of different food groups, and serves as proxy for current food security while the reduced CCSI is based on frequency and severity of the strategies adopted. Though female-headed households (37%) recorded a slight increase in food security than the males (35%) during the post-harvest period, it is evident from Table 3 that more (23.10%) of female-headed households experienced a decrease in food security in the post-harvest period compared to about 14% of the male-headed households. Based on individual food consumption score category, Table 3 also shows that about 29 and 31% of the female-headed and male-headed households respectively though still have poor diet (low dietary diversity and food frequency), had an improvement in its food security status in the post-harvest period. Still in that category, those female-headed households whose status worsened in post-harvest were about 43% as compared to male-headed households with only about 9%. About 45% of the female-headed households within the borderline of food consumption improved in their food security as compared to the male-headed households (33.46%) in the same category. Another result of concern is those in the acceptable diet category. Twenty-four percent of female-headed households who had a decrease in their food security status in post-harvest still remained in the acceptable food consumption score category compared to 14% male-headed households. This trend indicates that the female-headed households are highly vulnerable to factors that predispose them to change in food security status than their male counterparts.

Determinants of change in food security status

For the purpose of this study, the nature of food (in) security change in the post-harvest period: increased, decreased and unchanged food security was used as the

Table 4. Summary statistics and the expected hypothetical sign of the explanatory variables used in the multinomial probit model.

Variable	Code	Mean	Min	Max
Nature of food (in) security change	RCCSIchange	2.1442 (0.9094)	1	3
Post-harvest reduced coping strategy index	phRCCSI	2.2506	0	46
Post-planting reduced coping strategy index	ppRCCSI	3.8384	0	52
Household experienced climate-related (flood and drought) shocks (-)	climdf_shock (dummy)	0.1667 (0.3728)	0	1
Household experience illness of income earning member (-)	illness_shock (dummy)	0.0820 (0.2745)	0	1
Household experience loss of farm land (-)	land_shock (dummy)	0.0144 (0.1193)	0	1
Sex of household head (-/+)	hhsex (dummy)	0.8513 (0.3558)	0	1
Household head literacy status (+)	hhwr (dummy)	0.6276 (0.4835)	0	1
Number of farm plots own by household (+)	lnplotown (continuous)	2.0462 (1.2620)	1	10
Household head livelihood category (Agric or Non-agric) (+)	livelihood (dummy)	0.4454 (0.4971)	0	1

Values in brackets below the mean values are standard deviation.

Table 5. Multinomial Probit Regression Results for Determinants of Households' Food (in) Security Change.

Variables	Coefficient estimates		Marginal effects of coefficient estimates	
	Category 1	Category 2	Pr(RCCSIchange == category 1)	Pr(RCCSIchange == category 2)
climdf_shock	-0.234 (0.151)	0.200 (0.166)	-0.087 (0.038)**	0.065 (0.033)***
land_shock	-1.401 (0.725)***	0.152 (0.566)	-0.313 (0.084)*	0.143 (0.143)
illness_shock	0.170 (0.255)	0.379 (0.278)	0.009 (0.067)	0.064 (0.058)
hhsex	-0.504 (0.184)*	-0.763 (0.200)*	-0.061 (0.048)	-0.112 (0.042)*
hhwr	-0.113 (0.125)	-0.046 (0.143)	-0.029 (0.033)	0.002 (0.026)
lnplotown	0.289 (0.113)*	0.345 (0.128)*	0.052 (0.030)***	0.041 (0.023)***
livelihood	0.043 (0.126)	0.320 (0.147)**	-0.017 (0.034)	0.058 (0.025)**
Constant	0.254 (0.206)	-0.499 (0.228)**	-	-

Category 1: Household food security increased in post-harvest period, Category 2: Household food security decreased in post-harvest period, Base category: Household had no change in food security level in both seasons. Values in bracket are the robust standard errors, Number of households: 932, Wald chi2 (14) = 43.22, Prob > chi2 =0.000*, Log pseudolikelihood = -941.685, ***sig at 10%; **sig at 5%; *sig at 1%.

dependent variable. The included independent variables used in the model are presented in Table 4.

The result of the multinomial probit regression are presented in Table 5. Columns 2 and 3 presents the coefficient estimates while columns 4 and 5 show the marginal effects of the change equation. In this case, the base category is no change in food security status in both seasons from which to compare all other food security groups.

The result above shows that the model fits the data relatively well as indicated by the regression statistics. Though the included independent variables show different levels of significance in the different outcomes, the discussions below are based on the marginal effect estimates that significantly determine the change in the food (in) security status of the households. As expected, climate change variables (drought and flood) have negative impact on the probability of household experiencing increased food security status in the post-harvest period. The estimate indicates that as the incidence of climate change factors (drought and flood) increases by a unit, the probability of households experiencing increased food security in post-harvest decreases by about 0.087unit or 8.7%. Estimate in column 5 also confirms the negative influence of these factors on food security. It indicates that a unit increase in these variables leads to 0.065 unit (6.5%) increase in the probability of household experiencing a decrease post-harvest food security status. Both farm and non-farm households depend on agriculture which is the primary source of food and which has been observed to be highly susceptible to climate change events. Devereux (2007) observes that drought and flood undermine farm yield and harvest, reduce household food availability and agricultural income, and consequently threatens household food security. There is therefore need to strengthen climate-related risk management strategies at the household level for improve food security.

The result further shows that households that experience loss of land are less likely to experience increased food security status in the post-harvest period. This is confirmed by its significant marginal effect estimate which shows that a unit increase in land loss decreases the probability of household to have an increased post-harvest food security by about 0.31 unit (31%). This agrees with the findings of several studies quoted in Maxwell and Weibe (1998). They note that a reduction in or loss of access to land in agrarian society leads .directly to a reduction in income and access to food. The loss of land could be in different forms including loss of ownership and or use right. As a significant asset, which is not only useful for farm production but assures security of livelihood and serves as safety net in crisis period, its loss especially during the planting period will negate the ability of households to have any produce during the harvest season. With about 75% of Nigerian households engaged in agriculture and land as a vital production input, it implies that loss of land, especially agricultural land will result to loss of livelihood for many households, reduction in farm produce available to both rural and urban consumers, general increase in food prices and decrease in household's purchasing power. As such, the loss (either ownership or use right) of land will negatively affect household food availability and accessibility and consequently, its food security status.

The marginal effect estimates for land holding show mixed results. As indicated, increase in household land holding could lead to either an increase or decrease in household food security status in post-harvest season depending on the use and productivity of the lands. As indicated by the marginal effect estimate for category 1 model, a unit increase in land ownership favours about 0.05 unit (5%) increase in household food security status in post-harvest season. Increase in household land ownership could translate to increased agricultural production especially for farming households, increase access to natural resources like forest products and better return to investment through rent and thus, increase in household's access to food and income. Chapoto et al. (2011) from their study in Zambia and Jeronim et al. (2010) note that accumulation of agricultural assets, such as land and livestock constitute a stock of resources that serve to generate sustained high levels of income, cushion households from shocks; and consequently decreases the risk of food insecurity. However, this is not possible if acquired lands are not of good quality for farming purposes and/or used productively. Rather, household experiences little or no return, and reduction in available income if such land is purchased. This could lead to decreased household food security even when household acquires more land asset. Since land ownership can only translate to food security if productively used, it implies that steps such as sustainable land management practices that enhance land productivity even in the face of climatic shocks will encourage increase food production and food security at household level.

Based on the marginal effect model, the sex of the household head has a negatively significant effect on the probability of households' decreased food security status in post-harvest period. It thus indicates that the probability of a male-headed household experiencing increased food security in the post-harvest is about 11.2% (0.112) higher than the female-headed household. This result is consistent with the findings of Dare et al. (2013), Olagunji et al. (2012) and Babatunde et al. (2008). This is not surprising considering gender disparity in access and control of productive resources which tend to favour the male folk, and consequently increase in their crop output, off-farm income and total household income. Hence, male compare to female-headed households are more likely to be food secure and less vulnerable. It therefore implies that female-targeted interventions such as input subsidies, weather-based insurance, and investment in processing and storage facilities will empower female-headed households and ensure improvement in their food security status in both seasons.

The positive and statistically significant estimate of livelihood variable in the category 2 marginal effect model is an indication that households that are basically dependent on agriculture are more likely to experience a decrease in their post-harvest food security status. Quantitatively, the probability of a household experiencing a decrease post-harvest food security status is 5.8% (0.058 unit) higher among agriculture than non-agriculture dependent households. Thus households whose livelihood depend largely on agriculture, which is itself very vulnerable to climate extremes, are faced with dwindling farm income and food availability and therefore unstable food security status. The result therefore shows the importance of household livelihood diversification especially to non-farm areas to ensure better food security status.

CONCLUSION AND RECOMMENDATION

The study highlights the dynamics in the food (in) security status of households, and the roles of shocks, sex and asset on this dynamics. The results indicate that most households fair better in terms of food availability and access during the post-harvest season. However, this condition is subject to reduction in the incidence of climate change factors and loss of farmlands during the farming period in addition to livelihood diversification. It therefore implies that interventions that improve productivity and/or minimize crop losses during post-planting and reduce post-harvest losses will greatly reduce chronic food insecurity among households. Enhancing farmers' access to climate-resistant crop varieties, inorganic fertilizer input, and investment in food processing infrastructure are measures that can enhance increased productivity and reduce post-harvest losses. Given that female-headed households are more food insecure than the male-headed households, gender-focused interventions are likely to address food insecurity situations in both households.

Conflict of Interest

The authors have not declared any conflict of interest.

REFERENCES

Abimbola OA, Kayode AA (2013). Food insecurity status of rural households during the post- planting season in Nigeria. J. Agric. Sustain. 4(1):16–35.

Adebayo OO (2012). Effects of family size on household food security in Osun State, Nigeria. Asian Journal of Agric. Rural Dev. 2(2):136–141.

Aromolaran AB (2004). Household income, women's income share and food calorie intake in South Western Nigeria. Food Policy 29(5):507–530.

Babatunde RO, Omotosho OA, Sholotan OS (2007). Factors influencing food security status of rural farming households in North Central Nigeria. Agric. J. 2(3):351-357.

Babatunde RO, Omotesho OA, Olorunsanya EO, Owotoki GM (2008). Determinants of vulnerability to food insecurity: A gender-based analysis of farming households in Nigeria. Indian J. Agric. Econ. 63(1):116–125.

CARE/WFP (2003). The Coping Strategies Index: Field Methods Manual. Nairobi: CARE and WFP.

Chapoto A, Banda DJ, Haggblade S, Hamukwala P (2011). Factors affecting poverty dynamics in rural Zambia. Working paper No. 5, Food Security Research Project, Lusaka, Zambia. http://fsg.afre.msu.edu/zambia/wp55.pdf. 2014.02. 020

Dare A, Siaka M, Adebayo BA, Clara RBO, Adebayo MS (2013). Food security and coping strategies in South-West Nigeria. Food Sec. 5(3):407–414.

Devereux S (2007). The impact of droughts and floods on food security and policy options to alleviate negative effects. Agric. Econ. 37(1):47–58.

Food and Agriculture Organization (FAO) (1996). Rome Declaration on World Food Security. World Food Summit, November. Rome, Italy. http://www.fao.org /docrep /003/ w3613e/w3613e00.HTM. 2014.03.004

Food and Agriculture Organization (FAO) (2002). The state of food insecurity in the World2001Rome: Food and Agriculture Organization. http://www.fao.org/docrep/003/y1500e/y1500e00.htm

Food and Agriculture Organization (FAO) (2003). Trade reforms and food security: Conceptualizing the Linkages, Rome. http://www.fao.org/3/a-y4671e/

Food and Agriculture Organization (FAO) (2006). The integrated phase and humanitarian phase classification technical manual. Food security analysis unit for Somalia, Nairobi. http://www.fao.org/docrep/010/i0275e/i0275e.pdf

Food and Agriculture Organization (FAO) (2010). Guidelines for measuring household and individual dietary diversity, Rome: Food and Agriculture Organization. http://www.fao.org/fileadmin/user_upload/wa_workshop/docs/FAO-guidelines-dietary-diversity2011.pdf

Idrisa YL, Gwary MM, Shehu H (2008). Analysis of food security status among farming households in Jere Local Government of Borno State, Nigeria. Agro-sci. J. Trop. Agric. Food Environ. Ext. 7(3):199 -205.

Jeronim C, Panagiotis K, Marco K, Mark S (2010). A model of vulnerability to food insecurity. ESA Working Paper No. 10-03. Agricultural Development Economics Division. http://www.fao.org/docrep/012/al318e/al318e.pdf. 2014.03.001

John KMK, Demi MS, Ditchfield PKA (2013). Comparative analysis of food security status of farming households in the costal and the forest communities of Central Region of Ghana. Asian J. Empir. Res. 3(1):39–61.

Khatri-Chatri A, Maharjan KL (2006). Food security and coping strategies in rural areas of Nepal: A case study of Dailekh District in Mid-Western Development Region. J. Int. Dev. Coop. 12(2):25 – 45.

Maxwell D (1996). Measuring food insecurity: The frequency and severity of "coping strategies.. Food Policy 21(2):291–303.

Maxwell D, Weibe K (1998). Land tenure and food security: A review of concepts, evidence and methods. Land Tenure Center, University of Wisconsin-Madison. P. 129. http://www.google.com.ng/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=1&ved=0CBwQFjAA&url=http%3A%2F%2Fwww.minds.wisconsin.edu%2Fbitstream%2Fhandle%2F1793%2F21885%2F10_rp129.pdf%3Fsequence%3D1&ei=bJhHVPL2DvGt7AbLioGYAg&usg=AFQjCNHxah390i3Xf0Ul84n8-yVI7chRFA

Maxwell D, Ahiadeke C, Levin C, Armar-Klemesu M, Zakariah S, Lamptey GM (1999). Alternative food-security indicators: revisiting the frequency and severity of coping strategies. Food Policy 24(4):411–429.

Maxwell D, Watkins B, Caldwell R (2008a). The Coping Strategies Index: A tool for rapid measurement of household food security and the impact of food aid programs in humanitarian emergencies: Field Methods Manual. http://www.fsnnetwork.org /sites /default/ files/ coping_strategies_tool.pdf. 2014.03.001

Maxwell D, Caldwell R, Langworthy M (2008b). Measuring food insecurity: Can an indicator based on localized coping behaviors be used to compare across contexts? Food Policy 33(6):533–540.

Maxwell D, Vaitla B, Coates J (2011). Capturing the "Access" element of food security: Comparing different indicators. Feinstein International Center, Tufts University: Medford, USA. http://fic.tufts.edu/assets/Different-Indicators-of-HFS.pdf. 2014.03.010

McFadden D (1984). Econometric Analysis of Qualitative Response Models,"in Griliches and Intriligator (eds), Handbook of Econometrics, Amsterdam, North Holland P. 2.

Migotto M, Davis B, Carletto G, Beegle K (2006). Measuring food security using respondents' perception of food consumption adequacy. Research paper No. 2006/88. United Nations University - World Inst. Dev. Econ. Res. pp. 1-19. http://www.wider.unu.edu/stc/repec/pdfs/rp2006/rp2006-88.pdf. 2014.12.020.

Munizaga AM, Heydecker BG, Ortúzar JD (2000). Representation of heteroscedasticity in discrete choice models. Transp. Res. Part B. 34(3):219–240.

Olagunji FI, Oke JTO, Babatunde RO, Ajiboye A (2012). Determinants of food insecurity in Ogbomosho Metropolis of Oyo State, Nigeria. Production, Agric. Technol. J. 8(1):111 -124.

Orewa SI, Iyangbe CO (2010). Determinants of daily food calorie intake among rural and low-income urban households in Nigeria. Acad. J. Plant Sci. 3(4):147–155.

Phillips TP, Taylor DS (1990). Optimal Control of Food Insecurity: A Conceptual Framework. Am. J. Agric. Econ. 62(6):1304–1310.

Population Reference Bureau (2010). 2010 World Population Data Sheet. www. prb.org/publications/Datasheets/2010/2010wpds. 2014.03.015.

Scaramozzino P (2006). Measuring Vulnerability to food insecurity. ESA Working paper No. 06 – 12. Agricultural and Development Economics Division. The Food and Agriculture Organization of the United Nations. ftp://ftp.fao.org /docrep /fao/009/ ah630e /ah630e00.pdf. 2014.03.015

Victoria AO, Benjamin CA (2012). Analysis of Food Security Situation among Nigerian rural farmers. Int. J. Agric. Biosyst. Sci. Eng. 6(12):1–5.

von Grebmer K, Headey D, Béné C, Haddad L, Olofinbiyi T, Wiesmann D, Fritschel, H, Yin S, Yohannes Y, Foley C, von Oppeln C, Iseli B (2013). Global Hunger Index: The Challenge of Hunger: Building Resilience to Achieve Food and Nutrition Security. Bonn, Washington, DC, and Dublin: Welthungerhilfe, International Food Policy Research Institute, and Concern Worldwide. http://www.ifpri.org

Webb P, Coates J, Frongillo EA, Rogers BL, Swindale A, Bilinsky A (2006). Measuring household food insecurity: Why it's so important and yet so difficult to do. J. Nutr. 136(5):1404S–1408S.

World Bank (1986). Poverty and Hunger: Issues and options for food security in developing countries. World Bank, Washington DC. http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/1999/09/17/000178830_98101901455676/Rendered/PDF/multi_page.pdf

academicJournals

Vol. 10(xx), pp. xx-xx, xx April, 2015
DOI: 10.5897/AJAR20xx.xxx
Article Number:xxxxxx
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Land Use/Land Cover Dynamics in the Central Rift Valley Region of Ethiopia: Case of Arsi Negele District

Mikias Biazen Molla

Wondo Genet College of Forestry and Natural Resources, Hawassa University, P. O. Box 128, Shashemene, Ethiopia.

Received 1 April, 2014 ; Accepted 1 January, 2015

The objective of this research paper was to assess the spatial and temporal Land Use/Land Cover Changes (LU/LCC) in Arsi Negele District. Rapid population growth, agricultural expansion, environmental fluctuations, degradation of natural resource and loss of biodiversity are the most visible socio-economic and environmental problem in the study area. Satellite imagery, ground control point data and household level socioeconomic survey were used to produce land cover maps and explaining the historical trends of the study area. ERDAS Imagine and ArcGIS software was used to accomplish the analysis. The analysis result showed that in 1973 most of the study area had been covered by dense acacia woodland and shrub land. Between 1973 to 1986, cultivated grass and bare land increased by 8.98, 33.9, and 36.5 ha respectively. While, shrub and acacia woodland decreased by 6.17 and 73.21 ha, respectively. Between 1986 and 2010, cultivated acacia woodland and land increased by 15.38, 4.63, and 38.52 ha. However, bare and grass land decreased by 19.23 and 39.3 ha, respectively. Furthermore, the trend and magnitude of LU/LCC between 1973 to 2010 acacia woodland and land decreased by 22.72 and 13.58 ha, but shrub land and cultivated land increased by 22.82 and 13.14 ha. Socio-economic survey result revealed that acacia woodland and shrub land decreased, but cultivated land land and grass land increased in the derg regime. However, currently, natural resource conservation activity has got a great emphasis, thus spatial coverage of acacia woodland has increased. Expansion of agricultural land, population growth and the associated demand for land were the major driving forces for the observed LU/LCC changes in the study area. Therefore, loss of biodiversity, soil degradation, and environmental deterioration are largely the results of LU/LCC. Hence, land resources management practices, utilization of alternative energy sources and family planning education are some of the appropriate interventions to reduce this dramatic change.

Key words: Remote sensing, GIS, land use/land cover changes (LU/LCC), accuracy, landsat, imagery.

INTRODUCTION

Land is the major natural resource on which economic, social, infrastructure and other human activities are undertaken. Changes in land use have occurred at all times in the past, present, and are likely to continue in the future (Lambin et al., 2003; Moser, 1996).

LU/LCC and its impacts on terrestrial ecosystems including forestry, agriculture, and biodiversity have been identified as high priority issues at global, national, and

E-mail: mikiasmolla@gmail.com

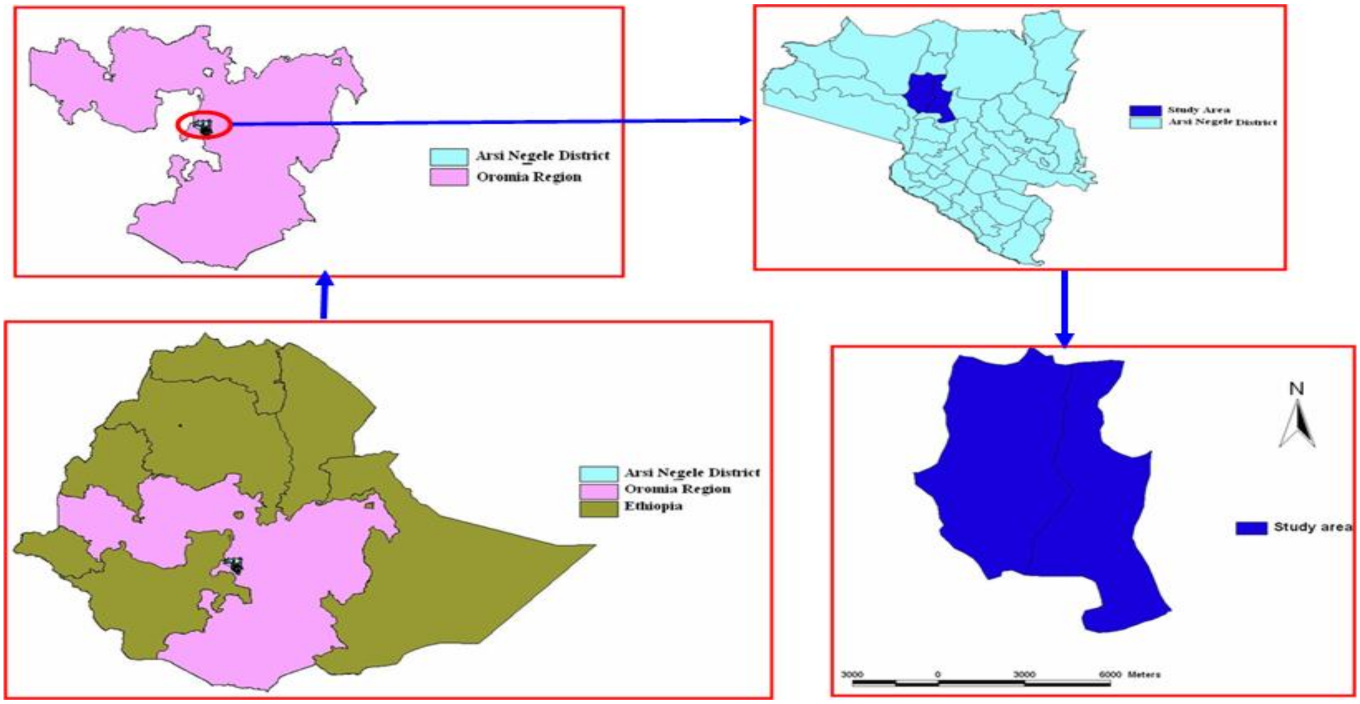

Figure 1. Location map of study area.

regional levels (Fu et al., 2000; Zeleke,et al., 2001). LU/LCC can also affect biodiversity, biogeochemical cycles, soil fertility, hydrological cycles, energy balance, land productivity, and the sustainability of environmental service provision (Lambin, 1997; Geist and Lambin, 2002). Apart from these, it may directly have serious impacts on future food security (Brown et al., 1995). This means LU/LCC affects both environmental quality and the quality of life, which are the two aspects that affect human wellbeing. Hence, LU/LCC is a central issue that requires investigation to sustainable development (Lambin, 1997) and represents a vibrant and dynamic area of research. LU/LC dynamics is also a result of complex interactions between several biophysical and socio-economic conditions, which may occur at various temporal and spatial scales (Reid et al., 2000). This kind of information is required in many aspects of land use planning and policy development, as a prerequisite for monitoring, modeling and environmental change, and as a basis for land use statistics at all levels. This study was conducted in two peasant associations (PA's) located in the central Rift Valley region of Ethiopian, which is a dry land area.

The livelihood of the community is based on agriculture and mixed farming system which is exposed to rapid deforestation. The area has a reasonable agricultural potential, which is reflected in the diversity of crops and animal resources. Remote sensing image processing, GPS reading and field observation were employed in this study. Remote sensing image processing and classification is an appropriate method for the identification of LU/LC changes in the past and present to provide information on the causes and drivers of changes. GCP's and field observation gives accurate information on the current LU/LC, however information on changes in LU/LC may also be dependent on the knowledge and memory of those giving the information.

The general objective of this study is to analyze the rate, pattern, causes, and socio-economic and environmental implications of LU/LC dynamics using GIS and Remote sensing techniques in Arsi Negele District.

MATERIALS AND METHODS

Description of the study area

The study was conducted from September to June 2011 time period. The study was undertaken in the lowland part of Central Refit Valley region of Arsi Negele district. Since this area has immense and visible natural resources degradation (land degradation, deforestation and soil erosion), environmental deterioration, poor livelihoods communities living standards, seasonal variation, occurrence of unusual long rainy and dry season. The area is located between 7°09' to 7°41'N and 38°25' to 38°54'E at an altitude of 1600 m.a.s.l and found in 210 km south of Addis Ababa (Figure 1).

According to National Metrological Services Agency (NMSA) (2010) at Arsi Negele station shows that the mean annual minimum and maximum temperatures of 6.8 and 27.2°C respectively, while rainfall varies between 250 to 750 mm per annum. Coniferous forests of podocarpus species, woodland and broadleaf forests prevail in the district. At mid-altitude, tropical dry evergreen montane forest dominates. The overall farming system is strongly oriented towards grain production dependent on the use of oxen for land preparation (ORS, 2004).

Methods of data collection

The main objective of this study was to provide reliable and concise information to local community, decision makers on the trend, rate, and distribution of land use/land cover dynamics in the study area in both quantitative and qualitative forms. The systematic study of land use/ land cover dynamics requires good and adequate data to assess the changes clearly. In order to achieve the objective of the study, both primary and secondary sources of data were used.

Primary data collection

The primary data sources were generated by the researcher in order to measure the independent variables. Data were collected through structured questionnaire, field observation, and key informants interview. Ground survey was conducted using GPS and digital camera in order to check the current feature of the study area.

Key informant interview: In addition to the ground surveying, interviews were carried out on individuals who have lived long time in the study area and had detail information about the past and present LU/LC types. The informants selected were older peoples, PA leaders, development agent (DA's).

Purposive types of questions were asked to get the general information about the study area. Such information served as a means to cross check the remote sensing data.

Household survey data: To support the data obtained from remote sensing images, household level data were collected through semi-structured questionnaires. This survey focused on information about demographic characteristics of the households, household asset (land, land size), and individual level land use system, perceptions on trends of land cover and impact of land use/ land cover in the study area.

Secondary data

Different secondary sources of data were used to drive the required information for this study. Some of the major sources include; metrological data, satellite images (MSS, TM and ETM$^+$ which are obtained from Ethiopia Map Agency (EMA)).

RESULTS AND DISCUSSION

Trend and patterns of LU/ LCC in the study area

As previously discussed, the information obtained from key informant, interpretation of remotely sensed imagery and field observations are the main points to classify the LU/LC classes in the study area. Hence, the total coverage or size of the area was estimated to be about 6,500 ha or 65 km^2. This is own estimate using the boundary map of the study area. Determining the trend and rate of land cover conversions are necessary for the development plan in order to establish rational land use policy (Solaimani et al., 2010). The statistical value of LU/LC distribution of the study area in the year 1973, 1986 and 2010 was derived from land sat image and is presented as follows.

Table 1 shows the value of each LU/LC classes for each study year respectively. As indicated in Table 1, a significant amount of land in the study area of a specific year (1973) is covered by dense acacia woodland (2345.8 ha or 36.1%), shrub/bush land (1801.2 ha or 27.7%), followed by cultivated land (which covers 1324 ha or 20.4% out of the total area). The rest (956.5 ha or 14.7%) and 72.5 ha (or 1.1%) is covered with grazing/grass land and bare land respectively. The coverage of acacia woodland and shrub/bush land was larger than other land cover classes, while grazing/grass land and bare land cover smaller area due to the fact that during this time there were low pressure of population and small agricultural activities, and relatively the environmental condition was also safe and undisturbed. At the same time, the distribution, intensity, coverage, and duration of rainfall and temperature trend was regular.

In 1986, cultivated land, grazing/grass land and bare land occupied about 1440.8 ha or (22.22%), 1397.2 or (21.5%) and 547.0 or (8.4%), respectively. However, acacia woodland and shrub/bush land comprised of 1394.1 ha or (21.4%) and 1721.0 ha or (26.5%) respectively. This indicates that the cultivated land has increased by 1.8%, grazing/grass land by 6.8% and bare land by 7.3%, while acacia woodland and shrub/bush decreased by 14.7 and 1.2% respectively. During this time, there was land redistribution for crop production, intensive agricultural expansion and population growth. On the other hand, farmers were cutting trees illegally and expanding their agricultural activities in the area.

The pattern of LU/LC distribution in 2010 also followed similar trends with that of 1986. Hence, as can be seen from Table 1, cultivated land was yet again the main land use class covering 1810 ha or 27.8% of the total area. Similarly, acacia woodland and shrub/bush land showed a big incremental change from the previous decades (21.4 to 23.2% and 26.5 to 40.7%) respectively from 1986 to 2010 due to a number of factors such as government attention to sustainable use of natural resources and environmental protection and people's awareness about the role of natural resource for their livelihood as the major reasons.

On the other hand, grazing/grass and barren land showed a decreasing or negative trend, which is from 9 to 7.0% and from 6 to 1.3% respectively from 1986 to 2010.

This means when the degraded area cover with trees, shrub/bush, and other vegetation, the coverage of open/barren land decreased and the area returned to the previous land feature. Acacia woodland and shrub/bush land account for the largest amount in 1973 (Figure 2). This means during this period, it was highly likely that a portion of the land was unexploited and human

Table 1. Amount and coverage of Land Use/ Land Cover classes in the study area in 1973, 1986, and 2010.

S/No.	Land Use/ Land Cover classes	1973		1986		2010	
		Area (ha)	**Area (%)**	**Area (ha)**	**Area (%)**	**Area (ha)**	**Area (%)**
1	Bare Land	72.5	1.1	547.0	8.4	85.4	1.3
2	Grazing/ Grass land	956.5	14.7	1397.2	21.5	454.0	7.0
3	Cultivated land	1324.0	20.4	1440.8	22.2	1810.0	27.8
4	Shrub/Bush land	1801.2	27.7	1721.0	26.5	2645.4	40.7
5	Acacia Woodland	2345.8	36.1	1394.1	21.4	1505.3	23.2
	Total	**6,500**	**100**	**6,500**	**100**	**6,500**	**100**

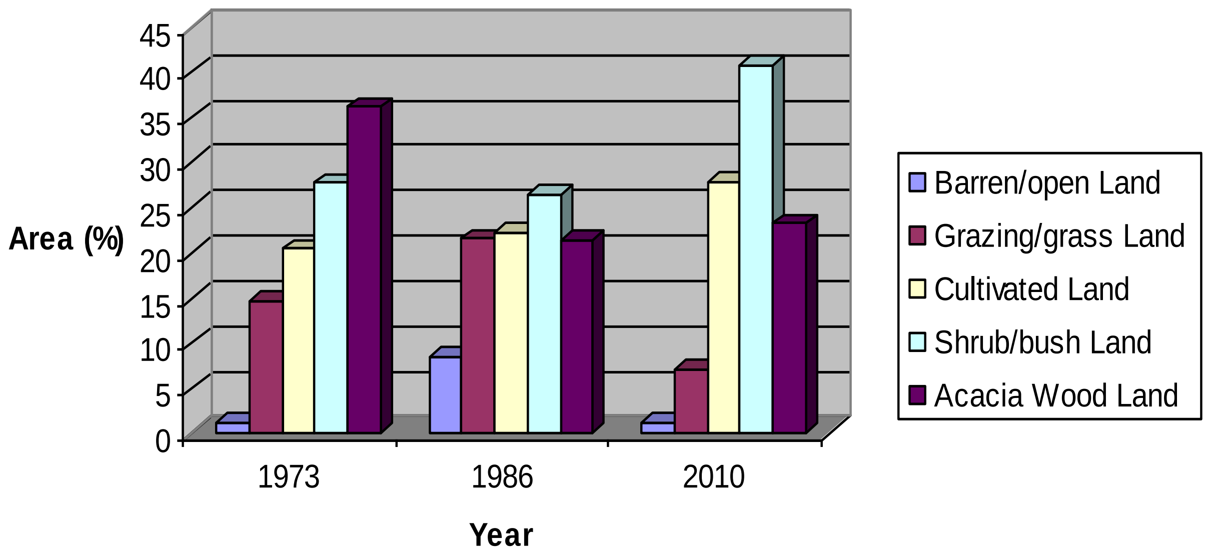

Figure 2. Error! No text of specified style in document.**.** Major Land Use/ Land Cover classes in 1973, 1986 and 2010.

population was also relatively low in the study area. Furthermore, agricultural activities were practiced in small amount, because during this time the feudal families occupied the majority of the land holding system. While in 1986 the coverage of shrub/bush land was still high, as compared to the previous decade the amount is decreased, due to government land use policy, expansion of agricultural activity and population growth.

It is evident from community elders and justification of Garedew et al. (2009) that the area in 1970's were covered by dense acacia based grass land which is used as a home of different wild animals and support the livelihood of the community in various form.

However, as can be seen from the graph in 2010, cultivated land and shrub/bush land accounts for the largest amount in this period as the government gives more attention for degraded land rehabilitation activities, control illegal tree cutting and charcoal productions in the study area. Though, as a result of population growth the demand of farmland increased from time to time; hence, the coverage of cultivated land increases. Figures 3 to 5 show the trend and patterns of LU/LC of the study area derived from Land-sat images of the respective period in the study area in 1973, 1986 and 2010.

The trend of the change in all maps shows different patterns, depending on the nature of land use type which covers the area, population pressure, government's attention and people's awareness about environmental protection and conservation activities.

LU/LCC map and matrix result

LU/LCC in between 1973 and 1986

The following table information was derived from the thematic image of LU/LC classes. The detection of LU/LCC is performed using ERDAS Imagine 8.7 software and GIS analyst model using classified images of the different years as inputs. To clearly understand the major change sources and its destination, conversion matrix for each period is analyzed. The following illustrate the

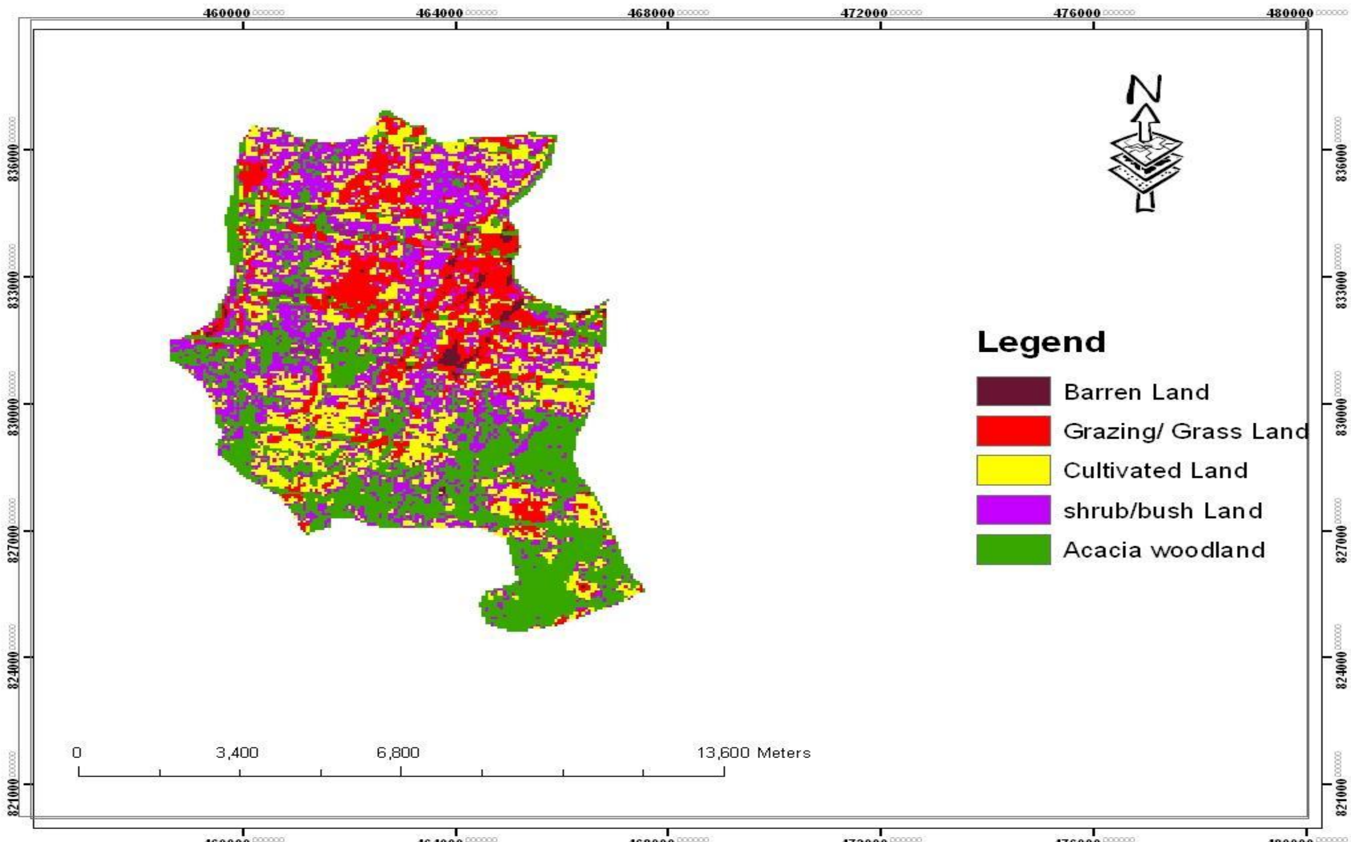

Figure 3. Classified Land Use/ Land Cover map of the study area in 1973.

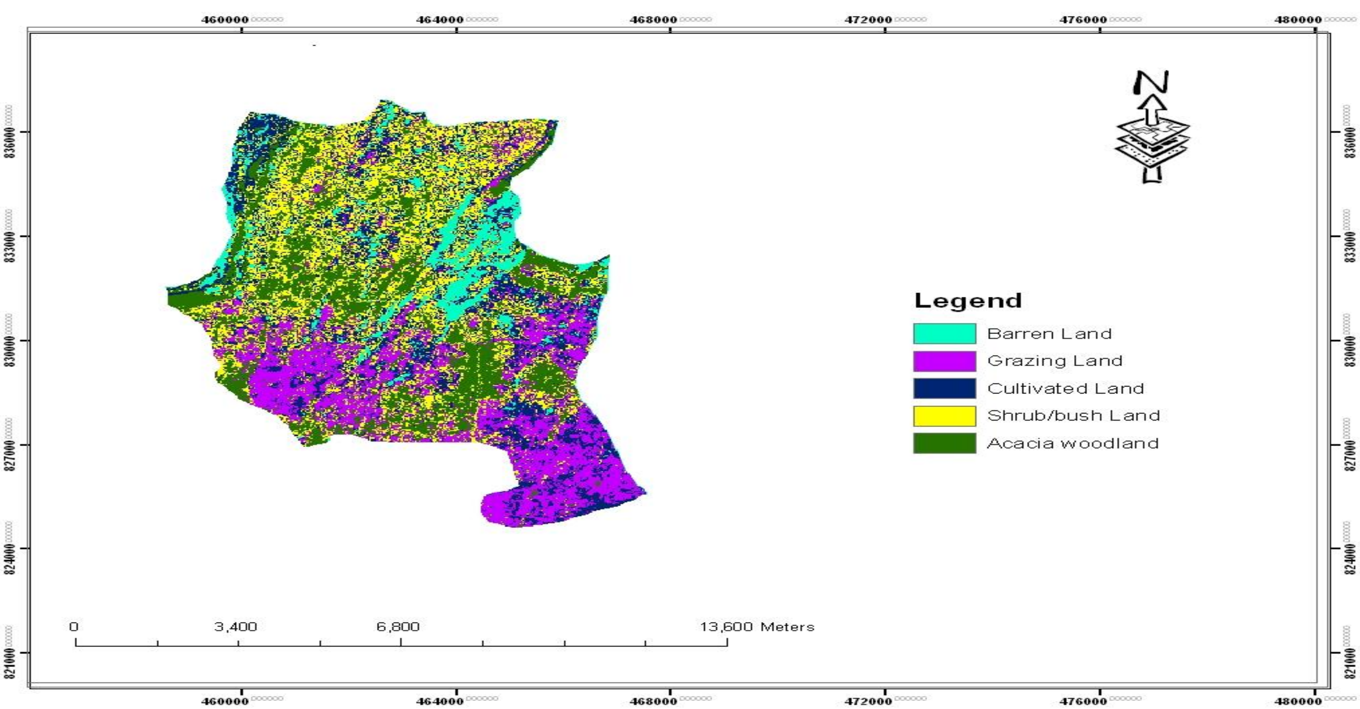

Figure 4. Classified Land Use/ Land Cover Map of the study area in 1986.

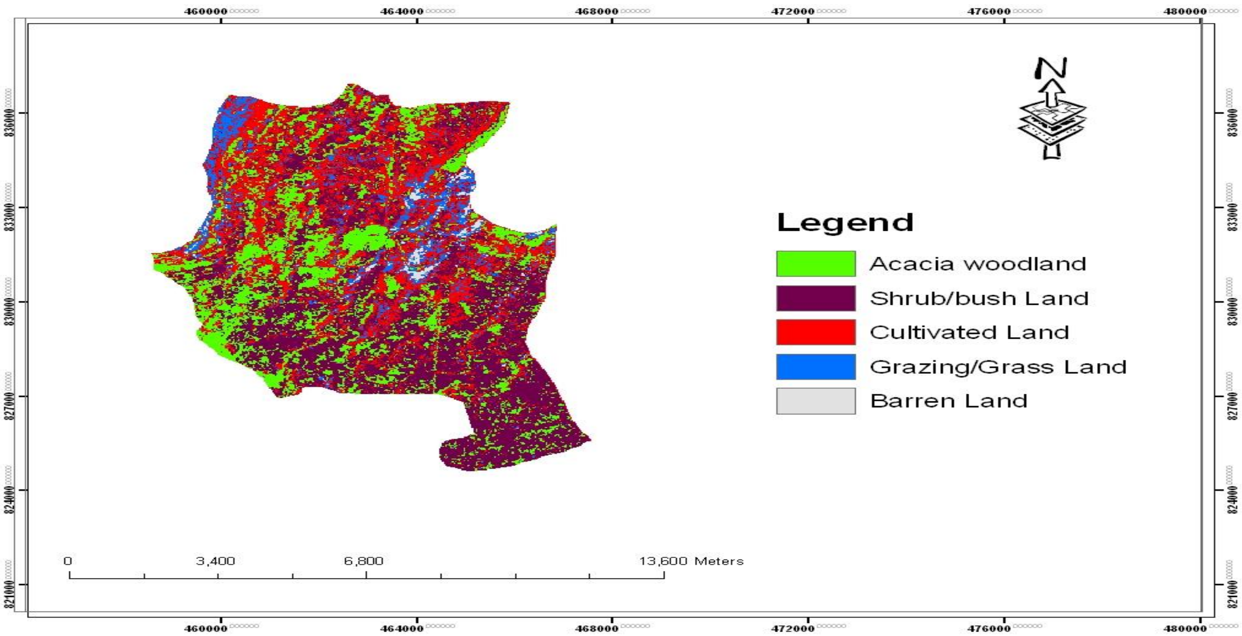

Figure 5. Classified Land Use/ Land Cover map of the study area in 2010.

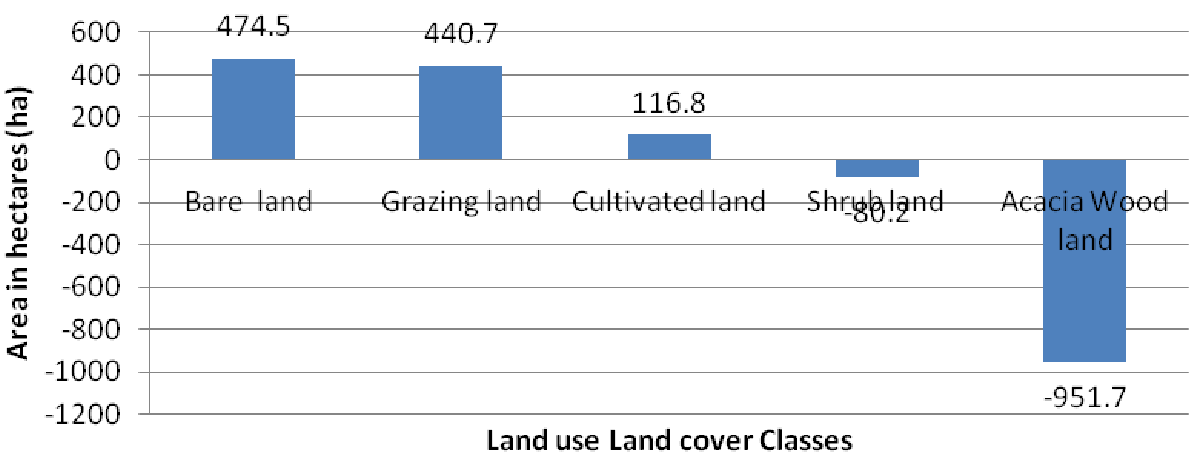

Figure 6. Magnitude of Land Use/ Land Cover changes during 1973-1986.

magnitude of LU/LC changes during 1973 to 1986 in hectares.

As indicated in the bar graph of Figure 6, bare, grazing and cultivated land showed an increasing trend, while shrub/bush land and acacia woodland showed deceasing trend. To explain briefly, in 1973, there were 2.345.8 and 1.801.2 ha of acacia woodland and shrub/bush land respectively. From this amount, 951.7 and 80.2 ha of land respectively were converted into other land cover classes and that of others (bare, grazing and cultivated land) increased in the year 1986. Figure 7 confirmed the physical distribution of LU/LC in the years between 1973 and 1986; this map shows the matrix result of land use/land cover change in the year between 1973 and 1986. As can be seen from the map, 58.5, 95.6, 372.2, 661.3 and 767.2 ha or a total of 1954.8 ha of land were not changed to other land cover type.

However, 63045.2 ha of land were changed to different land cover type in the 13-year duration. The change has adverse impact on the livelihood of the community as well as in the physical environment.

LU/LCC in between 1986 and 2010

In the year between 1986 and 2010, grassland and bare

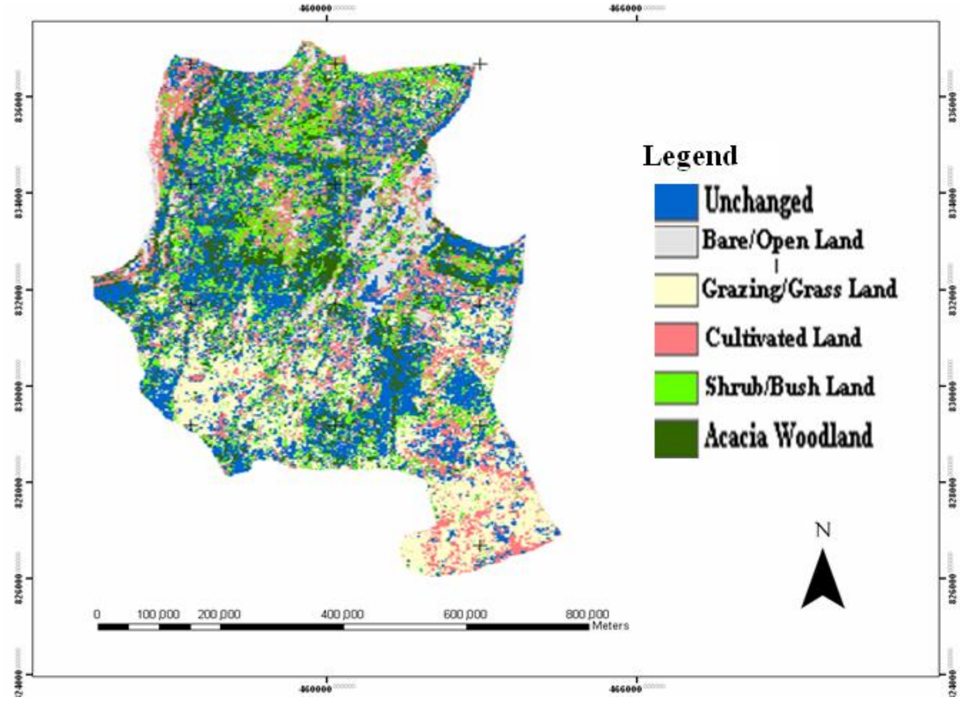

Figure 7. Land Cover changes of the study area from 1973 to 1986.

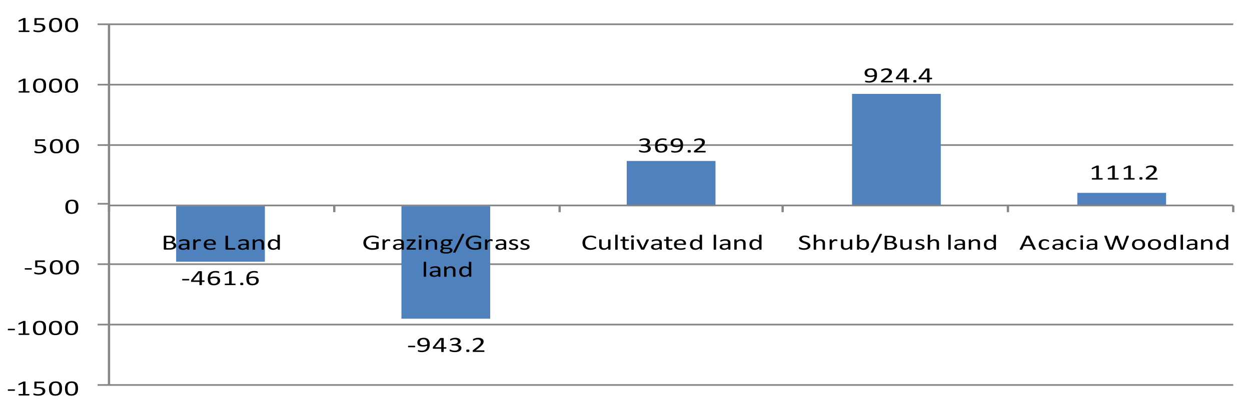

Figure 8. Magnitude of Land Use/ Land Cover changes during 1986 to 2010.

land shows a remarkable change to other land cover classes. About 965.3 ha of grazing land was converted to shrub/bush land followed by the conversion of 294.8 and 124.9 ha of land to acacia woodland and cultivated land respectively.

Correspondingly, about 668.4 and 385.9 ha of shrub/bush land were converted to cultivated, grazing and acacia woodlands respectively. Similarly, 299.8 and 446.2 ha of acacia woodland was also changed to cultivated land shrub land.

In general, based on the matrix result, it was concluded that 1787.2 ha of different cover of land were unchanged. Shrub/bush land, acacia woodland and cultivated land showed incremental changes with the total percentage of 39.91, 23.00 and 24.59% respectively. This improvement could be attributed to the implementation of conservation programs through coordinated efforts of development workers, other experts, and involvement of the community at large. The percentage of bare land and grazing/grass land has shown a slight decrease to 7.36 and 14.5% respectively.

On the other hand, Figure 8 describes the overall increment and reduction of land use/land cover in the year between 1986 and 2010. Bare land and grazing/grass

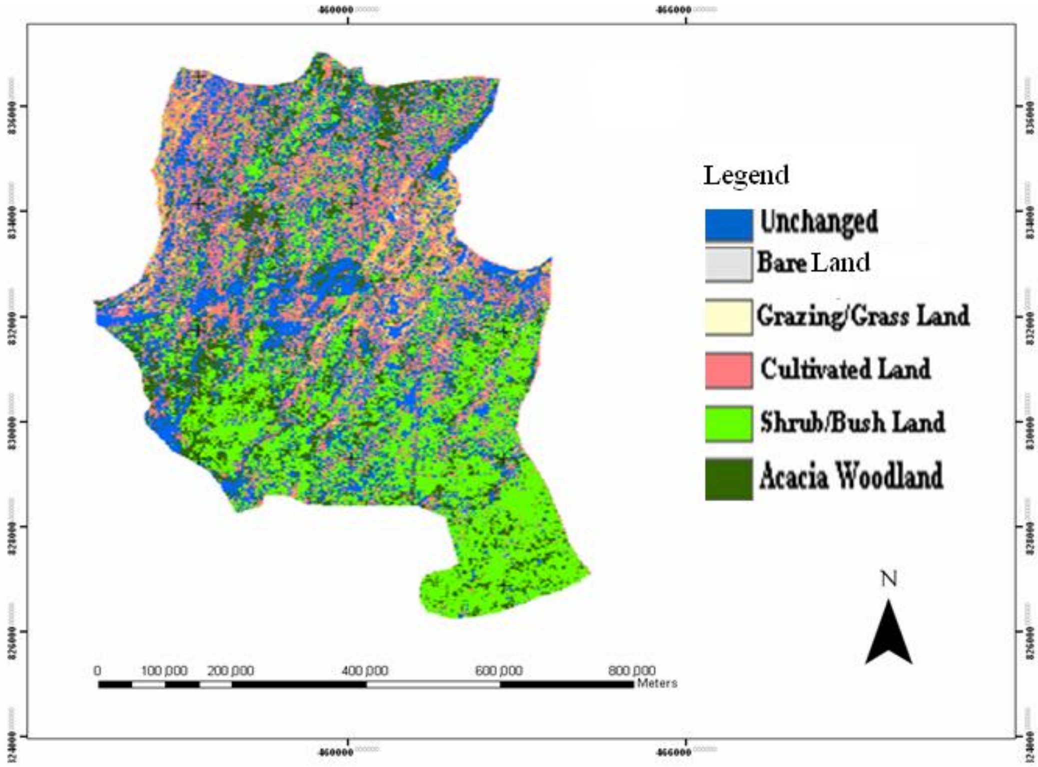

Figure 9. Land Cover type of the study area from 1986 to 2010.

land reduce the amount of coverage, whereas the cultivated land, shrub/bush land and acacia woodland increased by 369.2, 924.4 and 111.2 ha.

Figure 9 illustrates the matrix map result of land use/land cover change in the year between 1986 and 2010. The result depict 1797.2 ha of land area were not changed to other land cover type.

However, a total of 63202.8 ha of land were changed to different land cover type in the 24-year duration. Thus, 1304.4 ha of various land use type were changed to cultivated land, because of population growth. The change has adverse impact on the physical environment as degradation of natural resources, deforestation, soil erosion, soil fertility reduction, biodiversity losses are the main results of land cove change in the study area. However, the existing government greatly emphasizes on environmental conservation and protection activities by including the local community for sustainable use of natural resources in the area.

Therefore, the degraded shrub/bush land and other vegetation cover becomes a good situation. The local peoples were also helped to understand the role of natural resources for their livelihood and to start an integrated conservation activity with local development agents and other voluntary organizations. The following map (Figure 9) showed the coverage of LU/LC in the years between 1986 and 2010.

LU/ LCC between 1973 and 2010

In the time period between 1973 and 2010, a dramatic decrease in the area of grazing/grass land which is about 348.1, 285.7 and 94.9 ha of land was noticed; lands were converted into cultivated, shrub/bush and acacia woodland respectively. About 660.8 ha of Shrub/bush land in 1973 was directly converted to cultivated land in 2010. Cultivated land, shrub/bush land and to some extent, acacia woodland cover were shown to have incremental changes from 1986 to 2010. In recent year, the expansion of cultivated land has been limited by the emerging lack of suitable land.

Over the entire study period, the annual rate of the cropland area increased. While the rate of the woodland and shrub/bush land area declined and showed a fluctuating trend between the study years. In this year, the coverage of bare land has minimum but it is positive; however, grazing /grasses land and acacia wood land decreased by 502.5 and 840.5 ha of land respectively. As can be seen from Figure 10, cultivated land and shrub/bush land show high coverage of land than other land cover types in the study area.

Generally, the LU/LC types in the three decades gradually changed with differing rates depending on the existing socio-economic, political, and environmental situation. Acacia woodland and shrub/bush land covered

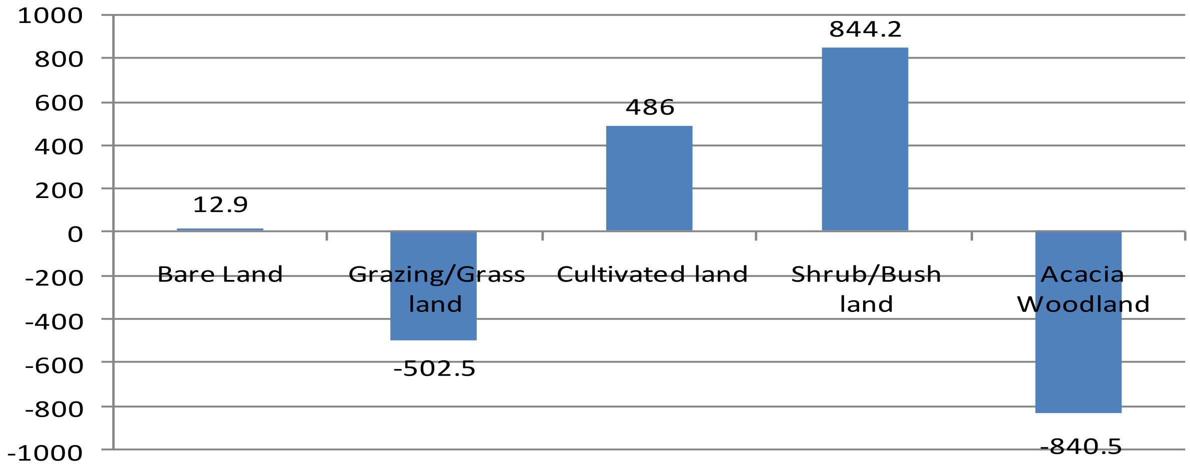

Figure 10. Magnitude of Land Use/Land Cover changes during 1973 to 2010.

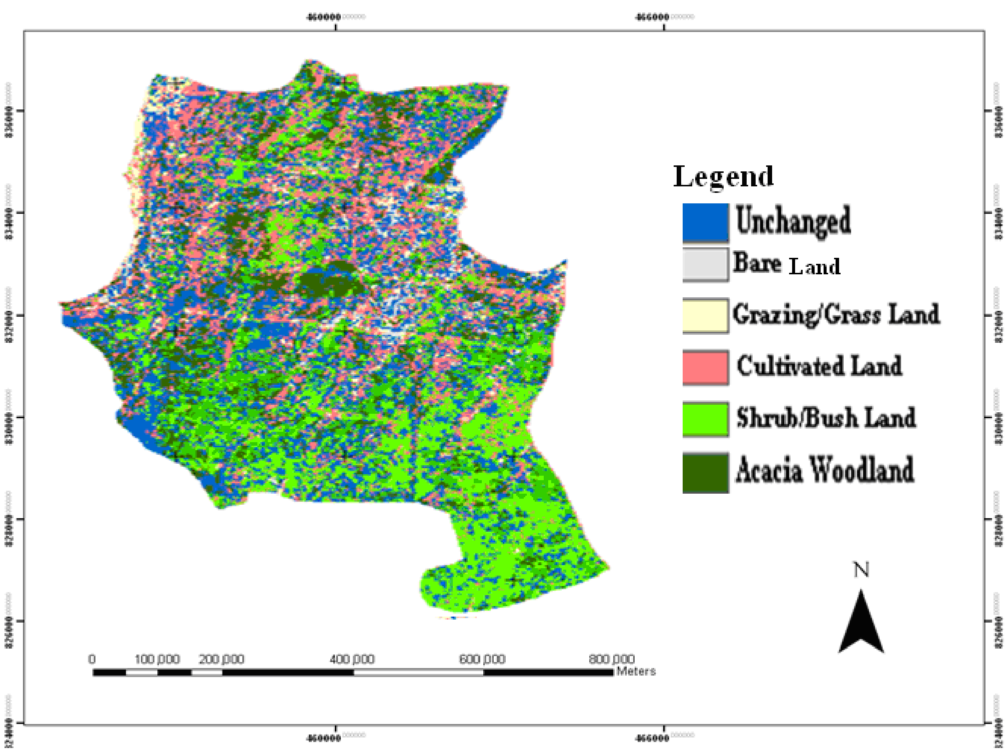

Figure 11. Land Cover changes of the study area from 1973 to 2010.

more area followed by cultivated land in the period from 1973 to 1986. However, the cumulative results of 1986 to 2010 showed coverage of shrub/bush and cultivated land increased followed by acacia woodland; while bare land and grazing land decreased.

In the years from 1973 to 2010, shrub/bush and cultivated land again covered larger area. At the same time, the coverage of cultivated land has also increased due to population growth.

Figure 11 illustrates the matrix result of LU/LCC in the year between 1973 and 2010. The matrix Table 2 shows a total 1877.4 ha of land area were not changed to other land cover types. However, a total 63122.6 ha of land were changed to different land cover type in the 24-year duration.

The coverage of shrub/bush land shows greatest

Table 2. Trend and magnitude of Land Use/ Land Cover dynamics during 1973-1986, 1986-2010, and 1973-2010.

Land Use/ Land Cover Classes	Amount of land cover area in						Observed change in Area (ha)			Annual rate of changes in (ha/year)		
	1973		1986		2010		1973 - 1986	1986 - 2010	1973 - 2010			
	ha	%	ha	%	ha	%				1973 - 1986	1986 - 2010	1973 - 2010
Bare Land	72.5	1.1	547	8.4	85.4	1.3	474.5	-461.6	12.9	36.5	-19.23	0.35
Grazing land	956.5	14.7	1397	21.5	454	7	440.7	-943.2	-502.5	33.9	-39.3	-13.58
Cultivated land	1324	20.4	1441	22.2	1810	27.8	116.8	369.2	486	8.98	15.38	13.14
Shrub land	1801	27.7	1721	26.5	2645	40.7	-80.2	924.4	844.2	-6.17	38.52	22.82
Acacia woodland	2346	36.1	1394	21.4	1505	23.2	-951.7	111.2	-840.5	-73.21	4.63	-22.72
Total	6,500	100	6,500	100	6,500	100						

change compared to the others. The main reason for the improvement of shrub/bush land in the study area wasthe government who gives more attention to the conservation and protection of environmental conservation activities. The following map (Figure 11) showed coverage of LU/LC in the years between 1973 and 2010.

Annual rate and trends of LU/LCC

In this study, 13, 24 and 37 year gap satellite image were used to calculate annual rate of land use/ land cover change of the study area from 1973 to 1986, 1986 to 2010, and 1973 to 2010. According to Zubair (2006), the annual rate of LU/LC change of the two years were calculated by dividing observed change by its duration or year gaps between two study periods and is expressed as hectares per year. Observed changes were also calculated by subtracting the recent year data from the previous year data.

As shown on Table 2, the land use/land cover analysis of the study area based on the satellite image confirmed that the largest amount of 2346 ha (36.1%) of land was covered by dense acacia woodland followed by shrub/bush land and cultivated land occupying 1801 ha (27.7%) and 1324 ha (20.4%), respectively. The share of bare land and grassland relatively covers small area 72.5 ha (1.1%) and 956.5 ha (14.7%) of land respectively in the year 1973. The annual rate of change in 1973 to 1986 was very high in acacia woodland and shrub land and showed negative results; -73.21 and -6.17 respectively.

While cultivated land 8.98 ha, grazing land 33.9 ha and bare land 36.5 ha of land were changed to other different land covers; in 1986, cultivated land, grazing/grass land and bare land cover were the largest area, about 1440.8 ha (22.22%), 1397.2 (21.5%) and 547.0 (8.4%), respectively. However, acacia woodland and shrub/bush land covered 1394.1 ha or (21.4%) and 1721 ha or (26.5%), respectively.

In this period, the annual rate of shrub/bush land and cultivated land and acacia woodland increased covering 38.52, 15.38, and 4.63 ha, while grazing/grass and bare land covers decreased by -39.3 and -19.23 ha of land, respectively.

According to information obtained from the interviews with key informants, the cause of increase in agricultural land was mainly due to population growth resulting in expansion of cultivated land into marginal and communal lands. Similarly, between 1973 and 2010, acacia woodland and shrub/bush land cover the highest parts which is 2645 ha (40.7%) and 1505 ha (23.2%) respectively, followed by cultivated land 1810 ha (27.8%); while the rest, bare land and grass land accounts for 454 ha (7%) and 85.4 ha (1.3%) respectively.

The annual rate of shrub/bush land, cultivated land and bare land were 22.82, 13.14, and 0.35 ha of land cover respectively. The other major change during this period is reduction of the size of acacia woodland by -22.72 ha, followed by grazing land that account for -13.58 ha. The negative result was due to increment of population pressure as a result of the need for more cropland.

Accuracy assessment

According to Anderson et al. (1976), the recommended standard of accuracy in the identification of LU/LCC mapping from the remote sensor data should be 85 to 90%. On the other hand, Kappa coefficient is important information in accuracy assessment. The overall accuracy and

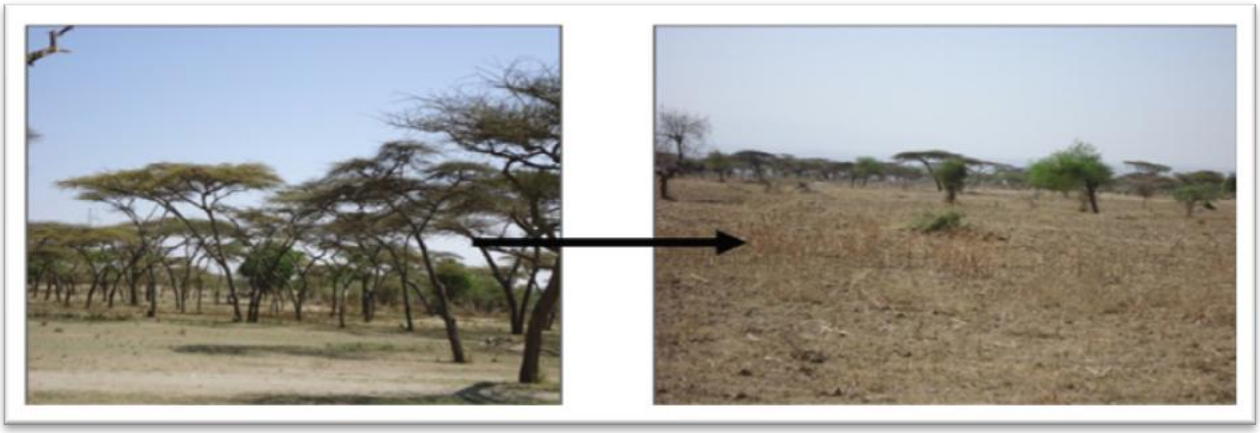

Figure 12. Acacia woodland converted in to cultivation land.

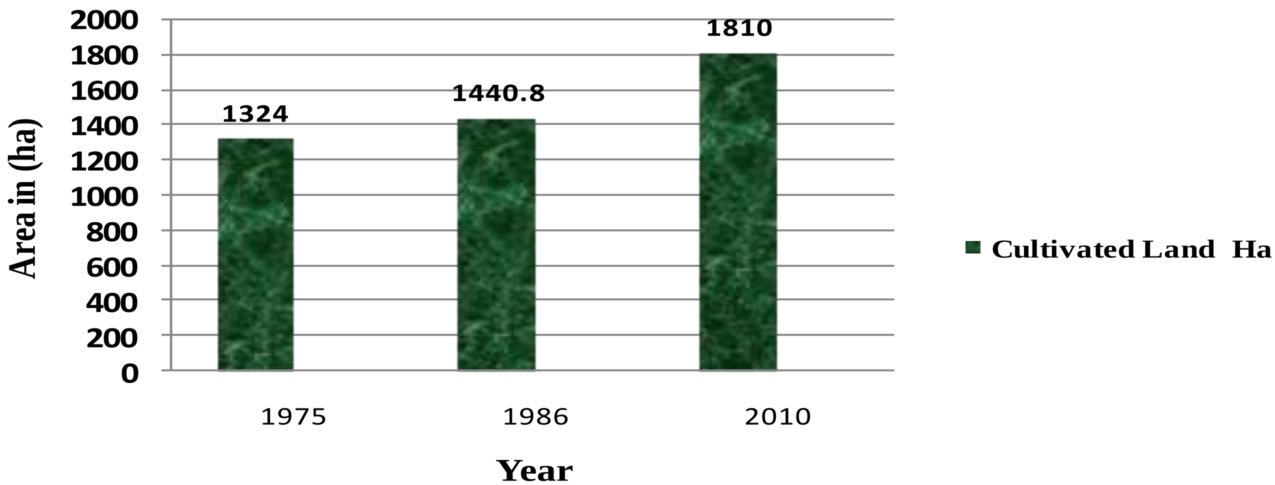

Figure 13. Trends of agricultural expansion in 1973, 1986 and 2010.

Kappa analysis were used to perform a classification accuracy assessment based on error matrix analysis. Therefore, overall classification accuracy for the five classes was established as 92% with Kappa coefficient or statistics of 0.8978%.

Proximity and underlying causes of LU/LC dynamics

Proximate causes of LU/LC dynamics

To meet the demands of large population means the need for more food production, more water requirement, and more infrastructure development to sustain increasing pressure for maintaining quality of life (Chaudhary et al., 2008). Agricultural expansion is one of the major proximate or direct causes of LU/LCC in the study area. The coverage of total cultivated land increased overtime. As indicated in Table 2, cultivated land accounts for 1324.0 ha (20.4%), 1440.8 ha (22.2%) and 1810.0 ha (27.8%) in the year from 1973, 1986 and 2010 respectively.

Over the years, researchers have identified agricultural expansion as a major or primary factor in almost all studies on LU/LCC and deforestation (IUCN, 2000). Hence, the major cause of acacia woodland, shrub/bush land and other vegetation change is related to agricultural activities of the study area. Figure 12 shows expansion of agriculture at the expense of acacia woodland, shrub/bush, and other vegetation in the study area.

From 1973 to 2010, cultivation of agriculture was the driving force for 20.4 and 27.8% of the natural vegetation loss respectively. From the households interviewed in the area, all of them responded that their agricultural plot has been expanded significantly in the past 10 to 20 years. The drive to expand has been largely set off by the need to fulfill household food demand. Figure 13 shows the

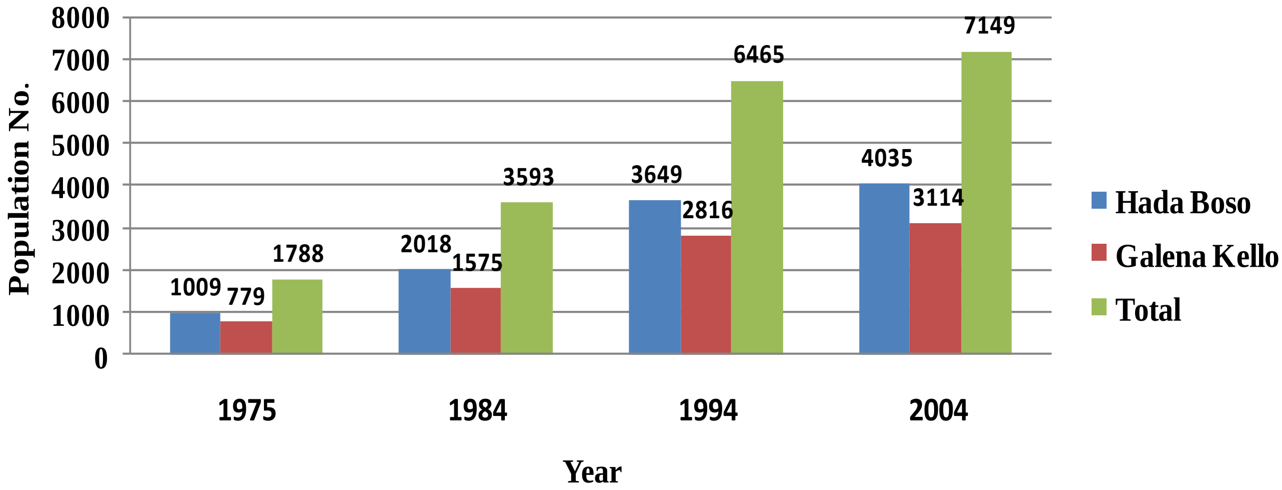

Figure 14. Estimated population in the year 1975, 1984, 1994 and 2004.

incremental change of agricultural land in the three periods.

Underlying cause of LU/LC dynamics

Population pressure is believed to be one of the underlying causes of the observed LU/LCC in the study area. This study showed that there was rapid LU/LC change in the study sites, with cropland replacing woodland and wooded-grassland forests due to the population growth and its resulting expansion of agricultural land. Population pressure has a negative effect on land because more shrubs and trees are cut for fuel and cultivation of the existing natural landscape. The present study found that a dramatic change in LU/LC happened over time, associated with rapid population growth. Among others, Pimentel et al. (1986), Abernathy (1993), and Mortimore (1993) have shown that population growth is a major driving force in land cover changes and that it contributes to resource degradation.

Data obtained from the study area showed that the rural population in the study area in 1973, 1986 and 2010 years were 1788, 3593 and 7149 respectively. However, for the area under study, data on rural population density were not available. People may supplement their income from agriculture with little or no off-farm employment. The population in the study area depends almost entirely on the land they cultivate. Figure 14 revealed that thepopulation number in the year 1975, 1984, 1994 and 2004 was estimated to be; 1788, 3593, 5465 and 7149 respectively in the study sites.

The increasing number of rural population from time to time, needs more agricultural land because there is increase in demand of food production. Farmers' lack of livelihood security has forced them to use the woodlands to cope with recurrent household shocks. As clearly pointed out by the World Commission on Environment and Development, "Those who are poor and hungry will often destroy their immediate environment in order to survive (Belay, 1995).

Fuel wood is another problem associated with population growth. The spatial and demographic growth of population has definitely had an impact on agricultural land and availability of fuel wood in the surrounding area. Relation of population growth to the cultivated land showed the change was significant with the addition of only 116.8 ha of cultivated land between 1973 and 1986 and 369.2 ha between 1986 and 2010, and 486 ha between 1973 and 2010 (Table 2).

Impact of LU/LC dynamics

Rain fed agricultural production system is the mainstay of farmers in the study area. According to the information obtained from the key informant, soil fertility and crop productivity declined from time to time.

Land conversion is the greatest cause of extinction of terrestrial species; of particular concern is deforestation, where logging or burning is followed by conversion of land to agriculture or other land uses (Abbas et al., 2009).

As can be seen from Table 3, in the year 1973, amount of production in common crop type was very high without the use of any fertilizers. Similarly, in 1986, the farmers used fertilizers like (dap and urea) to enhance their production and productivities but the production declined. According to the two kebeles information in 2010, in all common crop type the production declined due to degradation of natural vegetation as a result loss of soil fertility. Farmers used input (like dap, urea, and locally prepared compost) to maximize the productivity of the soil.

Land use and land cover change play an important role

Table 3. Types of crop and inputs used.

Type of crops	1973[a]		1986[a]		2010[b]	
	Inputs used	Production (ha/q)	Inputs used	Production (ha/q)	Inputs used	Production (ha/q)
Teff	no	6 - 15	Dap	6 - 14.5	Dap and Urea	3 – 9.5
Wheat	no	10 - 15	no	7 - 12	Dap	5 - 8
Barely	no	8 - 14	no	6 - 8	Dap	5 – 7.5
Faba Bean	no	4 - 8	no	2.5 - 6	no	2.5 – 4.5

Data sources: [a] Arsi Negele District Agricultural Office and [b] PA's Office (2011).

Table 4. Number, number per hectare and frequency of trees cut in each peasant Associations.

Peasant Association	Number	Number/hectare	Frequency (%)
Hada Boso	89	209	56
Gallena Kello	68	189	49
Total	**157**	**398**	**105**

in environmental change. The change constitutes loss of biodiversity, land degradation and climatic change (Ashenafi, 2008) as many farmers supposed that conversion of acacia woodland and shrub/bush land to other cover types can cause degradation of soil and land resources, increased run-off rate (soil erosion) and decline in soil fertility. Hence, agricultural production decreased overtime. Excessive land degradation, along with other climatic factors such as unpredictability and high intensity of rainfall could lead to reduced average crop yields.

Deforestation and LU/LCC are becoming locally common features wherever there are escalating human populations, because fuel wood demand tends to exceed supplies in the study area (Nejibe, 2008). In Arsi-Negele town, 87.3% of the populations are directly supporting their life by distillation of katikala and fuel wood has continued to provide all the energy required for distillation of it. The large volumes of fuel wood consumed for katikala distillation coupled with other factor is driving rapid deforestation and land cover change in the study area. Fuel wood has been identified as one of the most significant causes of acacia woodland and other vegetation decline in the study area. In the area, there are only four woody species, which are the most preferable for fuel wood and charcoal production. These were *Acacia tortillis, Acacia senegal, Acacia seyal and Balanite aegypticus.* These types of wood species were the most frequently mentioned and preferred fuel wood plants by consumers, as shown in Table 4.

The destruction of woodland resources has a complex implication on the status of the environment because vegetation cover and dead plant biomass are known to reduce soil erosion by intercepting and dissipating raindrops and wind energy. Having intercepted this rainfall, they facilitate the infiltration rate of water to the ground. Moreover, specific species like *A. etbaica* and *R. natalensis* which are preferred by katikala distillers were extinct from the study site. Figure 15 shows illegal charcoal production in the study area.

The major purpose for cutting tree in the study area was for fuel wood sale at Arsi-Negele town due to high demand especially for katikala and charcoal production. Most of the poor farmers in the study area earns their income from the sale of firewood and charcoal.

The extent and type of LU/LCC directly affects wildlife habitat and thereby affect local and global biodiversity. Human alteration of landscape from natural vegetation (e.g. wilderness) to any other use typically result in habitat loss, degradation and fragmentation, all which can have devastating effect on biodiversity (Abbas et al., 2009). From the total respondent, 75% reported the interference of human beings in the study area as reason for alteration of the existing environment; this result can result in habitat loss, degradation of ecosystem services and livelihood support systems. As shown in Table 5, in the past two decades, there were many wild animals and different varieties of bird species in the study area, especially, in Abijata-Shalla and Langano lakes. However, most wild animals and bird species were extinct due to the destruction of their habitats; these can in turn be causes for devastating effect on biodiversity (Mihiret, 2001).

In addition to different wild animal and bird species, there were different types of trees like *A. tortilis*, *A. senegal, A. seyal, B. aegptiaca*, *Ficus sycomorus,* and *Maytenus senegalensis* that are dominant tree species in the study area (EWNHS, 2009).

These species are nowadays rarely seen. According to the key informants or respondents in this study, before 15 or 20 years back there were various wild animals and dense acacia woodland in the study area. However, due

Figure 15. Illegal charcoal production in Arsi Negele District. Source: Arsi Negele District Department of Natural Resources Office (2011).

Table 5. Major types of wild animals and bird species.

Wild Animals		Birds Species	
Local Name	**Scientific name**	**Local Name**	**Scientific name**
Lion	*Panthera leo*	Great White Pelicans	*Pelecanus onocrotalus*
Tiger		Lesser Flamingoes	*Phoeniconaias minor*
Hyena	*Crocuta crocuta*	Greater Filamingoes	*Phoenicopterus rubber*
Baboons	*Papio spp*.	Herons	*Ardeola spp*.
Greater kudu	*Tragelaphus trepsiceros*	Cormorants	*Phalacrocorax spp*.
Colobus monkey	*Colobus gureza*	Plovers	*Vanellus spp*.
Buffalo	*Syncerus caffer*	Black-winged stilt	*Himantopus himantopus*
Ape		Shovelers	*Anas spp*
Fox		little stint	*Calidris minuta*

to conversion of woodland into cultivated land, wild animals have been displaced. This means, land conversion is the greatest cause of migration of wild animals and destruction of tree species. Therefore, as noted in Table 5, some wild animals species were extinct and endangered.

Conclusions

The pattern of LU/LCC in different categories shows variation during the three periods, 1973 to 1986, 1986 to 2010, and 1974 to 2010 within which that comparison had been made. In 1973, most of the study area was covered by dense acacia woodland and shrub/bush lands (36.1 and 27.7%) respectively, followed by cultivated land (20.4%).

In the three decades, cultivated land was expanded by 844.2 ha at the expense of acacia woodland, shrub/bush land and bare/open land. The current population pressure has led to a high demand for additional land; as a result, shortage of cultivated land is the major problem for farmers in the study area.

Hence, the expansion of cultivated land and grassland to marginal land lead to more severe land degradation. Agricultural land was increasing from 1324.0, 1440.8 and 1810.0 ha in 1973, 1986 and 2010. The amount of increase in cultivation land during the 1973 to 2010 periods was 1810 ha (27.8%).

Agricultural expansion is one the major proximate or direct causes of LU/LCC in the study area. This implies that population pressure is believed to be one of the major driving forces for the change of LU/LC in the study area. Hence, in the case of this analysis, the major driving force to changes in LU/LC is increased population change.

LU/LCC has a significant impact on degradation of soil and land resources, increase run-off rate (soil erosion) and declining soil fertility. It has also introduced very large impacts on surface and ground water quality and quantity, as well as biological diversity. Overall, these changes affect the livelihoods of societies directly or indirectly. Destruction of woodland and other vegetation cover to gain fuel wood and areas for cultivation can result in an unstable environment.

RECOMMENDATIONS

Based on the findings the following points are recommended:

i) Population growth is specifically one of the major factors for agricultural expansion and LULC changes in general in the study area. The current family size of the households in the study area will not be sustained by the existing farming practices. Therefore, stakeholders should provide formal or informal education to households about the impacts of population increase which is of most important advantage.

ii) Develop and implement new reforestation programs and sustainable management of the remaining natural resources. Ensure that management systems guarantee a return to the communities that manage the coverage and sustainable use of the resources in the study area.

iii) Create livelihood opportunities rather than the expansion of agricultural land and create awareness on how the communities should manage and conserve the existing natural resources.

iv) Agricultural land use system should be supported by experts, research institutions for the sustainable utilization of existing natural resources.

Conflict of Interest

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

This research was funded by Volkswagen Foundation (Mechal Project, Reference Number Ref. Nr. I/83 735) Wondo Genet, Ethiopia. The authors are grateful to the Head of Wondo Genet College of Forestry and Natural Resources for providing vehicle and other materials. The author also thanks the farmers who participated in this research, and the reviewers for their comments on the manuscript.

REFERENCES

Abbas II, Muazu KM, Ukoje JA (2009). Mapping Land Use-land Cover and Change Detection in Kafur Local Government, Katsina, Nigeria (1995-2008) Using Remote Sensing and GIS, ISSN: 2041-0492

Abernathy VD **(**1993). Population Politics: The Choices That Shape Our Future. Plenum Press/Insight Books, New York.

Anderson JR, Hardy EE, Roach JT, Witmer RE (1976). A Land Use and Land Cover Classification System for Use with Remote Sensor Data; Geological Survey Professional Paper 964. Washington.

Ashenafi B (2008). Land Use /Land Cover Dynamics in Prosopis juliflora invaded area of Metehara and the Surrounding Districts Using Remote Sensing and GIS Techniques. M.Sc. Thesis, Addis Ababa University, Ethiopia.

Belay T (1995). Population pressure and problems of arable land degradation in Ethiopia. Proceedings, Addis Ababa University, April 18-19, 1995, Wabe Shebelle Hotel, Addis Ababa.

Brown K, Pearce D (1995). The Causes of Deforestation. University of College London Press, London.

Chaudhary BS, Saroha GP, Manoj Y (2008). Human Induced Land Use/ Land Cover Changes in Northern Part of Gurgaon District, Haryana, India: Natural Resources Census Concept.

EWNHS (2009). Settlement expansion and natural resource management problems in the Abijiata-Shalla Lakes National Park, Walia. Ethiopian Wildlife and Natural History Society (EWNHS).

Fu BJ, Chen LD, Ma KM, Zhou HF, Wang J (2000). The relationships between land-use and soil conditions in the hilly area of the Loess Plateau in northern Shaanxi, China. Catena 36:69–78.

Garedew E, Sandewall M, Soderberg U, Campbell BM (2009). Land-use and land-cover dynamics in the central rift valley of Ethiopia. Environ. Manage. 44:683-694.

Geist HJ, Lambin EF (2002). Proximate causes and underlying driving forces of tropical deforestation. Bioscience 52:143-150.

IUCN/SSC/ISSG (2000). IUCN Guidelines for the Prevention of Biodiversity Loss Caused by Alien Invasive Species. IUCN. The World Conservation Union Species Survival Commission, Invasive Species Specialist Group.

Lambin EF (1997). Modelling and monitoring land-cover change processes in tropical regions. Progr. Phys. Geogr. 21:375–393.

Lambin EF, Geist HJ, Lepers E (2003). Dynamics of land-use and land-cover change in tropical regions. Ann. Rev. Environ. Resour. 28:205-241.

Mihiret E (2001). Wildlife Resource and Current Management Problems of Abijiata- Shalla Lakes National Park. Addis Ababa: EWNH 4p.

Mortimore M (1993). Population growth and land degradation. Geo-J. 31:15-21.

Moser SC (1996). A partial instructional module on global and regional land use/cover change: assessing the data and searching for general relationships. Geo-J. 39(3):241-283.

National Meteorological Services Agency (NMSA) (2010). Ten-day Agro-meteorological Bulletin 1-10 April. 20:10.

Nejibe M (2008). Impact of Katikala production on the degradation of woodland vegetation and emission of CO and PM during distillation in Arsi-Negele Woreda.

Oromia Regional State (ORS) (2004). Socio-economic profile of East Shoa zone. The Oromia Regional State Government, Ethiopia.

Pimentel D, Dazhong W, Eigenbrode S, Lang H, Emerson D, Karasik M (1986). Deforestation: Interdependency of fuelwood and agriculture. Oikos 46:404-412.

Reid RS, Kruska RL, Muthui N, Taye A, Wotton S, Wilson CJ, Mulatu W (2000). Land-use and land-cover dynamics in response to changes in climatic, biological and socio-political forces: The case of southwestern Ethiopia. Landsc. Ecol. 15:339-355.

Solaimani K, Arekhi M, Tamartash R, Miryaghobzadeh M (2010). Land use/cover change detection based on remote sensing data (A case study; Neka Basin). Agric. Biol. J. N. Am. 1(6):1148-1157

Zeleke, G. and H. Hurni, 2001. Implications of land use and land cover dynamics for mountain resource degradation in the northwestern Ethiopian highlands. Mountain Research and Development 21(2):184–191.

Zubair AO (2006). Change detection in land use and Land cover using remote sensing data and GIS (A case study of Ilorin and its environs in Kwara State). M.Sc. Thesis, University of Ibadan, Nigeria.


African Journal of Agricultural Research
Related Journals Published by Academic Journals
■ African Journal of Environmental Science & Technology
■ Biotechnology & Molecular Biology Reviews
■ African Journal of Biochemistry Research
■ African Journal of Microbiology Research
■ African Journal of Pure & Applied Chemistry
■ African Journal of Food Science
■ African Journal of Biotechnology
■ African Journal of Pharmacy & Pharmacology
■ African Journal of Plant Science
■ Journal of Medicinal Plant Research
■ International Journal of Physical Sciences
■ Scientific Research and Essays
academicJournals