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Effect of Plant Density on Yield and Yield Components of Pearl Millet (*Pennisetum Glaucum* (L.) R.Br.) in a Semi Arid Environment in Northern Nigeria

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Abstract

Field experiment was conducted at Maiduguri and Gashua during 2000 and 2001 cropping seasons to evaluate three millet varieties (SOSAT – C88, LC-IC9702 and ZATIB) at four plant densities (26,667; 35,556; 53,333 and 88,888 plant per hectare) for grain yield and other agronomic characters. The experiment was laid out in a Randomized Complete Block Design (RCBD) replicated four times. Observations were taken on number of days to 50% flowering, leaf area index (LAI), plant height, number of tillers per plant, harvest index (HI) and grain yield. The results indicated significant differences among the varieties in all the character studied. LC – IC19702 was the earliest to flower compared with either SOSAT –C88 or ZATIB. The numbers of tillers per plant and harvest index were significantly higher at the lower plant densities. The highest grain yield was recorded at 53,333 plants per hectare which was comparable with the yield obtained at 35,556 plants per hectare. The variety SOSAT – C88 gave the highest grain yield in both locations.

Key words: Millet, variety, plant density, grain yield, location, character.

Introduction

Pearl millet (*Pennisetum glaucum* (L) R.Br) is the most dominant food crop in the Sahel savanna zone of Nigeria and it is ranked second only to sorghum (*sorghum bicolor*) in the Sudan savanna zone (Nwasike *et al.*, 1982). The Sudan–Sahelian savanna region is characterized by inadequate rainfall, high soil and air temperature and high evapotranspiration. These areas have high potential for millet production in Nigeria. Over 40% of the land sown annually to cercal in Nigeria is devoted to millet (Gwadi et al., 2003). Thus, millet is sown annually on about 5.2 million hectares with an average yield of 900 kg/ha. However, yields of between 500 – 800 kg/ha obtained by resource poor farmers are low (Singh *et al*., 1983).

The possibility of minimizing yield fluctuations by manipulating cultural practices needs to be examined; low plant density and the use of local millet varieties have been identified as possible reasons for low yield (Egharevba and Abed, 1986; Grema and Odo, 1998; Yakamba,

2001). Most farmers sow millets plants at 2 – 3 per hill giving plant densities between 53, 333 and 80,000 plants per hectare (Grema and Odo, 1998).

Many studies have shown that the agronomic requirements of a crop differ among varieties (I.A.R, 2002). Thus, for any introduced or newly developed variety the evaluation of its agronomic requirements becomes necessary. Recently, the Lake Chad Research Institute, in collaboration with the International Crops Research Institute for the Semi Arid Tropics (ICRISAT) developed some high yielding millet varieties but are not yet evaluated agronomically in the Sudan and Sahel savanna zones of Nigeria. The present study was, therefore, undertaken to determine the effect of varieties and plant density on grain yield and other agronomic characteristics of pearl millet.

Materials and Methods

A field experiment was conducted during the 2000 and 2001 rainy seasons at the Lake Chad Research Institute Farm, Maiduguri (11º 54' N, 13º E) and the Institute's experimental site at Gashua (12º 54' N 11º 05' E) in the Sudan and Sahel savanna zones of Nigeria. The soils of the experimental sites are sandy loam and loamy sand in Maiduguri and Gashua, respectively. The annual precipitation for Maiduguri were 650 and 728 mm for 2000 and 2001 while Gashua recorded 325.2 and 256.2 mm in 2000 and 2001, respectively.

The treatments consisted of three pearl millet varieties (SOSAT-C88, LC-IC9702 and ZATIB) and four plant densities (26,667; 35,556; 53,333 and 88,888 plants/ha) which were factorially combined and laid out in a randomized complete block design with four replications. Gross plot size was 22.5 m^2 while the net plot size was 15 m^2. The trial was sown on 25th and 28th June, 2000 and 2001, respectively at Maiduguri while Gashua was planted on 25th July each year in 2000 and 2001. Fertilizer was applied at recommended rate of N, P_2O_5 and K_2O was 60:30:30 kg/ha (BOSADP, 1993). Seedlings were thinned to two plants per hill 7-10 days after emergence (DAE). Two hand hoe weeding were done at 2 and 4 weeks after sowing (WAS).

Observations and measurements made included number of days to 50% flowering, leaf area index (LAI), plant height, harvest index and grain yield. The number of days to 50% flowering was determined by careful observation on daily basis when half the number of plants in plot had flowered. Leaf area index was determined at 6, 8, 10 and 12 WAS by computing from the formula described by Dugje (1992).

LAI	=	P x L (i) x A (i)/100,000,000
where		
P	=	Plant density per hectare
L	=	Number of fully expanded green leaves per plant
A	=	Single leaf area (cm)
i	=	Specific week of measurement
100,000,000mm	=	Ground area cover by plant per hectare

Plant height was determined by randomly selecting ten plants per plot and measuring the height from the ground level to the base of the panicle with a meter rule at full physiological maturity. Harvest index was measured using the final grain weight per net plot divided by total dry matter measured at harvest.

HI = (Grain weight/net plot at harvest)/ (Total dry matter/net plot at harvest).

Number of fillers per plant was determined by counting the number of fillers per plant at harvest.
Grain yield was measured by recording thrashed grain from each net plot using a salter scale. This was then extrapolated to grain yield per hectare using the formula.

Grain yield = (Grain yield per net plot (kg) x 10,000m²)/Net plot area (m²)

All data were subjected to analysis of variances with the treatment means compared using the Least Significant Difference (LSD) (Gomez and Gomez, 1984).

Results

Effect of variety and plant density on growth characters

The results show significant difference in time to 50% flowing and plant height among the varieties (Table 1), LC – IC9702 was the earliest to flower followed by SOSAT – C88 and ZATIB at both Maiduguri and Gashua. ZATIB was significantly ($P<0.05$)) taller than either SOSAT – C88 or LC – IC 9702. However, the difference between SOSAT – C88 and ZATIB was not significant in 2000 and 2001 at Maiduguri and Gashua, respectively. Plant density had no significant ($P<0.05$) effect on time to 50% flowering and plant height at Gashua except at Maiduguri (Table 1). Flowering was however, delayed by one and two days in 2000 and 2001 at lowest plant density compared with highest plant density. Plant height increased with increasing plant density. Plants grown at 53,333 plants per hectare regardless of variety were taller than those grown at other plant densities.

Interaction between variety and plant density on height in 2000 at Gashua was significant (Table 2). Tallest plant for SOSAT – C88 and LC – IC9702 were recorded at 53,333 and 35,556 plants per hectare, respectively. Differences in height among the various plant densities in respect of ZATIB were not significant.

Statistically significant differences were observed in leaf area index (LAI) among the three pearl millet varieties (Table 3); LAI increased as the varieties advanced in age. SOSAT – C88 and ZATIB consistently had higher LAI compared with LC – IC9702 in both locations. Similarly, the effect of plant density on LAI was significant. LAI increased with increasing plant density. The highest LAI was attained at 88,888 plants per hectare in week 8 and thereafter declined with time.

A significant interaction between variety and plant density on LAI showed that all the varieties attained maximum LAI at 26,667 plants per hectare (Table 4).

There was no significant ($P>0.05$) difference in tiller production among the three pearl millet varieties, but significant ($P<0.05$) variations was observed on harvest index (H. I.) in both locations (Table 5). The results indicated superior HI for LC–IC9702 compared with either SOSAT–C88 or ZATIB. The influence of plant density on tiller production and HI was significant (Table 5). The results indicated that tiller production and HI decreased with increasing plant density except at Gashua where HI in creased with increasing plant density. The highest average tiller production and HI were recorded at the lowest plant density (Table 5).

There was significant variation in grain yield among the three pearl millet varieties (Table 5). SOSAT–C88 produced significantly ($P<0.05$) higher grain yield than the others, while LC–IC9702 gave the least grain yield in both locations (Table 5). Plant density had no significant ($P<0.05$) influence on grain yield except at Gashua where grain yield increased with increasing plant density. Grain yield was significantly ($P< 0.05$) higher in 2000 than in 2001. The highest grain yield was obtained at 53,333 plants per hectare.

Discussion

The results showed significant effect of plant density on time to 50% flowering. The delayed flowering at lower plant densities could be attributed to large area per plant and less inter and intra plant competition for available growth resources such as sunlight, soil nutrient and moisture. Earlier workers (Yusuf, 1985; Olufajo and Pal, 1991; Isa, 1998; Yakamba, 2001) have reported similar incidences of delayed flowering due to low plant density. LC-IC9702 flowered earlier than the other two varieties in this study and had shorter height compared with either SOSAT-C88 or ZATIB. The early flowering of LC-IC9702 could be due to differences in genetic composition among the three pearl millet varieties. Similar result has been reported by Yakamba (2001).

Higher plant densities significantly increased leaf area index (LAI) and plant heights. The increase in LAI could be attributed to inter plant competition for soil nutrient and moisture, which subsequently increased the rate of light interception. The above observation agrees with the findings of Okiror (1982); Azam-Ali *et al*. (1984) and Olufaju and Pal (1991) who reported increased LAI at higher plant densities. However, higher plant densities reduced tiller production and HI This could be due to inter and intra plant competition for available growth resources.

The effect of plant density on grain yield was not significant except at Gashua where grain yield increased with increasing plant density. This could be attributed to better utilization of available soil nutrients at higher plant densities. This finding tallied with those of Egharevba and Abed (1986) and Yakamba (2001). The lower grain yield obtained in 2001 relative to 2000 was probably due to differences in rainfall distribution between years.

In conclusion, the result of the study has shown that grain yield varies from year to year depending upon the season and site. The highest grain yield was recorded at 53,333 plants per hectare which was comparable with the yield obtained at 35,556 plants per hectare. The increase in grain yield at higher plant densities could be attributed to better utilization of soil nutrients. SOSAT-C88 recorded the highest grain yields in both locations. The lower grain yield recorded in 2001 compared to 2000 was attributed to differences in rainfall distribution between years.

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Table I: Effects of variety and plant density on number of days to 50% flowering and plant height in pearl millet

Treatment	**Maiduguri**				**Gashua**			
	50% flowering DAS		Plant height (cm)		50% flowering DAS		Plant height (cm)	
	2000	**2001**	**2000**	**2001**	**2000**	**2001**	**2000**	**2001**
Variety								
SOSAT-C88	63.00	62.87	209.75	177.82	55.00	54.00	170.10	155.12
LC-IC9702	55.00	57.91	158.61	150.27	51.12	50.00	138.53	141.66
ZATIB		64.25	63.00	209.17	200.38	55.56	54.66	186.15	157.92
SE±		0.24	0.37	4.35	5.87	0.75	0.71	3.45	4.74
LSD (0.05)	0.47	0.75	8.83	11.92	1.52	1.44	7.00	9.62	
Plant density per hectare								
26,667		61.17	62.33	180.43	172.20	54.17	53.17	164.78	151.80
35,556		61.25	61.25	195.74	175.62	53.58	52.67	160.77	149.72
53,333		60.58	61.17	201.00	176.47	53.17	52.17	168.92	147.38
88,888		60.17	60.33	192.81	180.33	54.67	53.42	165.23	150.37
SE±		0.27	0.42	5.02	6.78	0.86	0.82	3.90	5.48
LSD (0.05)	0.55	0.88	10.16	NS	NS	NS	NS	NS	

NS = Not Significant

DAS = Days after sowing

Table 2: Interaction between variety and plant density on plant height in 2000 at Gashua

Plant Density per Hectare	Pearl Millet Variety		
	SOSAT-C88	LC-IC9702	ZATIB
26,667	180.65	125.80	187.90
35,556	151.90	145.15	185.25
53,333	184.65	137.92	184.20
88,888	163.20	145.25	187
SE±		6.91	
LSD(0.05)		14.05	

WAS = Weeks after sowing

Table 3: Effect of variety and plant density on leaf area index (LAI) at 6, 8, 10 and 12 weeks after sowing (WAS)

Treatment	Maiduguri								Gashua							
	Weeks After Sowing															
	2000				**2001**				**2000**				**2001**			
	6	8	10	12	6	8	10	12	6	8	10	12	6	8	10	12
Variety																
SOSAT-C88	0.98	1.46	1.26	0.65	0.92	1.46	1.46	1.20	1.27	1.44	1.19	0.64	0.92	1.59	1.56	1.26
LC-IC9702	0.79	1.14	0.97	0.53	0.94	1.46	1.30	0.98	1.18	1.04	0.73	0.51	0.72	1.45	1.44	1.31
ZATIB	0.81	1.64	1.23	0.65	1.04	1.69	1.63	1.17	1.28	1.40	1.23	0.63	0.70	1.56	1.53	1.38
SE±	0.02	0.02	0.06	0.03	0.02	0.03	0.02	0.01	0.03	0.04	0.02	0.01	0.02	0.02	0.02	0.02
LSD (0.05)	0.04	0.04	0.12	0.06	0.04	0.06	0.04	0.02	0.06	0.08	0.04	0.02	0.04	0.04	0.04	0.04
Plant Density per Hectare																
26,667	0.42	0.74	0.69	0.33	0.55	0.80	0.75	0.59	0.71	0.72	0.63	0.37	0.38	0.82	0.79	0.66
35,556	0.64	0.99	0.82	0.42	0.70	1.08	0.99	0.83	0.86	0.93	0.85	0.45	0.48	1.02	1.10	0.89
53,333	0.88	1.50	1.21	0.61	1.02	1.60	1.69	1.17	1.23	1.37	1.19	0.67	0.80	1.61	1.57	1.20
88,888	1.63	2.42	1.89	1.07	1.50	2.61	2.42	1.87	2.14	2.19	1.79	0.98	1.51	1.68	2.71	2.52
SE±	0.02	0.02	0.07	0.07	0.02	0.04	0.02	0.02	0.06	0.04	0.02	0.04	0.02	0.02	0.02	0.03
LSD (0.05)	0.04	0.04	0.14	0.08	0.04	0.08	0.04	0.04	0.12	0.08	0.04	0.08	0.04	0.04	0.04	0.06

Table 4: Two years combined interaction between Variety and Plant density on Leaf Area Index (LAI) at 10 WAS at Maiduguri and Gashua

Plant Density per Hectare	Maiduguri			Gashua		
	Pearl Millet Variety					
	SOSAT-C88	LC-IC9702	ZATIB	SOSAT-C88	LC-IC9702	ZATIB
26,667	2.32	1.89	2.26	2.30	2.00	2.43
35,556	1.43	1.22	1.71	1.49	1.22	1.35
53,333	0.83	0.85	1.04	0.98	0.83	0.99
88,888	0.88	0.57	0.72	0.70	0.69	0.74
SE±		0.060			0.024	
LSD (0.05)		0.12			0.05	

WAS = Weeks after sowing

Table 5: Grain yield, Tillers and Harvest index as influenced by Variety and Plant density

Treatment	Maiduguri						Gashua					
	Grain yield (Kg/ha)		Tillers/plant		Harvest Index		Grain yield (Kg/ha)		Tillers/plant		Harvest Index	
	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
Variety												
SOSAT-C88	2165	1406	4	4	0.19	0.18	1743	873	3	3	0.17	0.16
LC-IC9702	1533	143	4	4	0.20	0.22	1487	748	3	3	0.19	0.16
ZATIB	1692	1298	4	3	0.17	0.15	1729	721	3	3	0.16	0.13
SE±	94.54	40.37	0.20	0.16	0.003	0.005	47.53	69.51	0.21	0.17	0.005	0.004
LSD (0.05)	191.91	81.96	NS	NS	NS	NS	96.46	NS	NS	NS	0.01	0.01
Plant Density per Hectare												
26,667	1714	1367	5	4	0.21	0.19	1524	741	4	4	0.17	0.14
35,556	1880	1381	4	4	0.19	0.18	1711	586	3	4	0.16	0.14
53,333	1906	1419	4	4	0.17	0.17	1842	944	3	3	0.18	0.15
88,888	1686	1347	3	3	0.17	0.17	1478	844	3	3	0.17	0.17
SE±	109.17	46.62	0.33	0.19	0.004	0.005	57.19	80.26	0.24	0.19	0.006	0.004
LSD (0.05)	NS	NS	1.07	NS	0.01	NS	116.06	162.93	0.47	NS	0.01	0.008

NS = Not Significant