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EFFECTS OF PLANT POPULATION ON LEAF AREA INDEX, COB CHARACTERISTICS AND GRAIN YIELD OF IRRIGATED HYBRID MAIZE

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ABSTRACT

The effect of plant population on leaf area index, cob characteristics and grain yield of irrigated hybrid maize varieties was evaluated. Results indicate that increased plant population resulted in higher LAI and cob characteristics. The 66,000 plants per hectare treatment exhibited better cob characteristics and out yielded the 44,000 and 33,000 plants per hectare treatments. Varietal differences also showed significant differences in the parameters evaluated. Variety UTCH-1 exhibited higher LAI and superior number of cobs per plant, 1000-grain weight and total grain yield. Based on this study information on suitable plant population for each variety is important for successful irrigated maize production.

Keywords: Maize; Plant population; Leaf area index ; Grain and cob yields

INTRODUCTION

Maize is the agronomic grass species that is most sensitive to variations in plant density (Sangoi and Salvador, 1998). For each production system, there is a population that maximizes grain yield. Maize production in Nigeria is characterized by low productivity due to a variety of factors which include low plant density, poor soil management practices and many others. Irrigated agriculture is assumed to be more productive due to the control exerted on moisture supply. As this resource is not limiting, it can be assumed that yield from irrigated agriculture would be higher than for rainfed. Plant density for irrigated maize can be increased in excess of that recommended for rainfed (53,000 plants per hectare, SG 2000, 1996). This can be achieved with efficient utilization of plant density and adequate moisture supply. Plant density is one of the most important cultural practices determining grain yield (Sangoi and Salvador, 1998), as well as other important agronomic attributes of this crop. Stand density affects plant architecture, alters growth and developmental patterns and influences carbohydrate production and partition (Casal *et al.*, 1985). The importance of plant population as a factor determining growth and yield of early maize cultivars has been established (Gretzmacher, 1979; Zarogiannis, 1979; Bavec, 1988). At low densities, many modern maize hybrids do not tiller effectively and quite often produce only one ear per plant. Therefore, maize does not share the trait of most tillering grasses of compensating for low leaf area and small number of reproductive units by branching (Gardner *et al.,* 1985). On the other hand, the use of high populations heightens interplant competition for light, water and nutrients. This may be detrimental to final yield because it stimulates apical dominance, induces barrenness, and ultimately decreases the number of ears produced per plant and kernels set per ear (Sangoi and Salvador, 1998).

Leaf area is influenced by genotype, plant population and soil fertility (Tetio-Kagho and Gardner, 1988a; Tollernar, 1992; Murphy *et al*., 1996). Some experiments have shown that a LAI between 3 and 4 may be optimal for achieving maximum yield (Lindquist *et al*., 1998). Increasing plant population may accelerate leaf senescence (Tetio-Kagho and Gardner, 1988; Boyat *et al.,* 1990), increase the shading of leaves (Hashemi-Dezfouli and Herbert, 1992) and reduce the net assimilation of individual plants. An increase in plant population of 2-13 plants per m^2 decreased net assimilation per plant from 0.85 to 0.11 mg CO_2 m^{-2} s^{-1}, but increased grain yield per area (Dwyer *et al.*, 1991). This increase in grain yield can be explained by the increase in LAI and net assimilation rate. Under the low plant population of 13,000 plants per hectare, grain yield lost due to missing plants was poorly compensated by the increased yield of surrounding plants. When two or three adjacent plants were missing, compensation for missing plants was only 16 and 34%, respectively (Pommel and Bonhomme, 1998). Nafziger (1996) found that two plants on either side of a missing plant compensate 47% of the yield lost because of the missing plants at 44,478 plants per hectare.

Under optimal water and nutrient supply, like for example, well managed irrigated agriculture, increased plant population results in smaller cobs, but the increased number of cobs per area usually results in higher grain yields. In a study, Cox (1996) found that a low plant population of 45,000 plants per hectare averaged 15% lowered grains than the high plant population (90,000 plants per hectare). However, early maturing cultivars showed more linear responses than late maturing cultivars. Increased plant population decreases the mass and diameter of cobs, the diameter and number of kernels per cob, but not the number of kernels per row (Remison and Lucas, 1982). Kernel weight per cob may (Hashemi-Dezfouli and Herbert, 1992) or may not (Tetio-Kagho and Gardner, 1988b) be affected by plant population.

MATERIALS AND METHODS

Site Description, Treatments and Experimental Design

A field trial was conducted at the University Farm of the Ahmadu Bello University, at Shika, Zaria (11^o 11'N, 7 ^{o} 38' E) in the dry season of 2000 and 2001. The experiment was designed as a split plot in randomized complete blocks with three replicates. It comprised eight treatments: three maize varieties, two irrigation regimes and three plant population densities (33,000, 44,000 and 66,000 plants per hectare). The main plot consisted of irrigation regime (7-day and 14-day interval) while the subplots consisted of three maize varieties (Oba Super 1, Pannar 6195 and UTCH-1) and plant population.

Cultural Practice

The land was ploughed and harrowed to a fine tilth and ridged at 75 cm and the field marked out into 36 plots of 11.25 m^2 (3 m x 3.75 m) sizes each of ridges and basins. The plots were neatly arranged to allow for ease of irrigation. Paths of 1m across the row and 75 cm (one ridge) along the rows was allowed to separate adjacent plots on the field. Two seeds of the maize seeds were planted and later thinned to one plant per stand. Optimum plant densities were attained by varying the plant spacing accordingly. Irrigation regime was imposed four weeks after sowing. Recommended cultural management practices were followed (NAERLS, 2001). Compound fertilizer (15:15:15) was used at the rate of 120kgN, 60kgP and 60kgK per ha. Fifty percent of the N and all of the P and K were applied two weeks after sowing (FPDD, 1989). The remaining N (60 kg/ha) was applied at six weeks after sowing as urea in granular form. The plots were hand weeded at two weeks after sowing and also weeded and earthened up at six weeks after sowing. A 100mm cutthroat flume was used to measure the amount of water diverted into each plot.

Data Collection

Leaf area index was measured by taking the length and breadth from the widest point, of a functional leaf measured with a ruler. The product of the length and breadth was multiplied by a factor (0.75) to calculate the leaf area (Watson, 1950). To find the LAI, the leaf area obtained from the individual leaves was added and divided by the number of plants sampled. The leaf area per plant was then multiplied by the number of plants/m^2 and divided by the land area covered by the plant (Duncan and Hasket, 1968). Cob length was determined by randomly selecting five cobs from each sub-plot. The length of each cob was then measured after which the lengths of all the five cobs were added and the average was calculated. Cob diameter was determined by selecting five cobs which were measured using a vernier caliper. The diameters were added and then divided by the number of cobs to find the average. The numbers of rows per cob were determined by selecting five cobs and counting the rows, after which the numbers were added and then divided by the total number of cobs to get the mean. The number of grains of each row was counted to determine number of grains per cob. These were then added and divided by the total number of rows per cob. The average for the five selected cobs was then determined. Grain yield was determined by threshing and cleaning the harvested cobs from each net plot. The grains were then weighed and expressed in kilogram per hectare by extrapolation.

RESULTS AND DISCUSSION

Leaf Area Index (LAI)

Leaf area index (LAI) is an important factor determining grain yield by increasing net crop assimilation. High plant populations have been shown to increase LAI (Dwyer *et al.*, 1991). Table 2 shows the trend of LAI as affected by plant population. At the tasselling stage, leaf area index was significantly affected by variety and plant density. Variety UTCH-1 exhibited a significant difference in LAI when compared with Oba Super-1. At the maturity stage, variety UTCH-1 had significantly higher LAI than variety Oba Super-1, but was statistically similar LAI with variety Pannar. Plant population also had a significant effect on LAI. The 66,000 plant density treatment had significantly higher LAI than the 33,000 plants per hectare treatment. The same trend was repeated in the second year. Variety UTCH-1 and plant population of 66,000 plants ha^{-1} exhibited higher LAI than the other treatments and could be advantageous in increasing grain yield in similar conditions and environments. The implications of this result are that by maintaining higher plant populations, it is possible to attain higher yield as yield contributing factors like LAI are higher at higher populations. These results are consistent with results by Dwyer *et al.*, (1991), that showed that higher plant population may increase maize LAI.

Table 1: Maize leaf areai (LAI) as affected by variety and plant population

Treatment	Leaf area index (LAI)			
Variety	2000		2001	
	Tasselling	Maturity	Tasselling	Maturity
Variety				
Oba Super-1	3.13b	2.86b	2.08c	1.84c
Pannar	3.71a	3.65ab	4.12b	3.76b
UTCH-1	4.12a	3.76a	6.25a	5.45a
SE±	0.30	0.28	1.25	1.90
Plant population (Plants per hectare)				
33,000	1.95b	1.60b	2.10b	1.77b
44,000	3.93b	3.94b	4.00b	3.38b
66,000	5.26a	4.83a	5.83a	4.83a
SE±	1.00	1.00	1.2	0.90
Interaction				
Variety X population	NS	NS	NS	NS

Means within a column followed by same letters are not significantly different (P>0.05)

Cob Characteristics

The effect of plant population on cob characteristics is shown in Table 2. Cob characteristics determine the amount of grain that will eventually be obtained from a given variety. The cob characteristics recorded include cob length (CL), number of kernel rows (NKR), number of kernels per row (NKPR), cob diameter (CD), diameter of shelled cob (DSC) and weight of 1000 kernels (WK). The results obtained show that variety had a significant effect on all cob characteristic parameters except cob diameter in both years (Table 2). In the first year, variety UTCH-1 had significantly higher cob length, number of kernel rows, number of kernels per row, diameter of shelled cobs and weight of 1000 kernels. In the second year, variety UTCH-1 also produced cobs with significantly longer cobs, and higher number of kernel rows while variety Oba Super-1 produced significantly higher number of kernels per row, diameter of shelled cobs and weight of 1000 kernels. Plant population density also had a significant effect on cob characteristics with the exception of cob diameter and diameter of shelled cob in both years.

The 66,000 plants per hectare treatment exhibited the best cob characteristics (Table 2). The significance of this study is that by manipulating plant population, with optimal water and nutrient supply, yield determining cob characteristics will be enhanced leading to greater yield. It should be noted that increased plant population may lead to smaller cob but this is compensated by the larger numbers of cobs. This result is in tandem with results obtained by Remison and Lucas (1982).

Table 2: Effect of variety and plant population on cob characteristics.

Treatment	CL (cm)		NKR		NKPR	
	2000	2001	2000	2001	2000	2001
Variety						
OS1	19.0^{b}	18.7^{b}	14.0^{b}	13.9^{b}	33.8^{b}	39.7^{a}
PN	19.3^{a}	20.6a	15.1^{a}	14.5^{a}	37.3^{a}	36.4^{a}
UTCH-1	19.4^{a}	20.1^{a}	14.4^{a}	14.7^{a}	35.3^{a}	36.1^{b}
SE±	0.10	0.60	0.35	0.28	1.15	1.20
Plant population (ha^{-1})						
33,000	21.2^{a}	19.7^{b}	14.5^{a}	14.1^{a}	40.1^{a}	39.6^{a}
44,000	19.4^{a}	20.1^{a}	13.8^{b}	14.3^{a}	36.7^{a}	34.5^{ab}
66,000	18.4^{b}	20.5^{a}	14.0^{a}	13.9^{b}	34.0^{b}	33.9^{b}
SE±	0.9	0.25	0.22	0.12	2.0	1.8
	CD (cm)		DSC (cm)		WK (g)	
	2000	2001	2000	2001	2000	2001
Variety						
OS1	4.3	4.7	1.7^{b}	2.0^{a}	263^{a}	283^{a}
PN	4.5	4.4	1.7^{b}	1.7^{b}	247^{b}	259^{b}
UTCH-1	4.6	4.6	2.0^{a}	1.9^{a}	274^{a}	281^{a}
SE±			0.10	0.10	9.0	8.0
Plant population (ha^{-1})						
33,000	4.4	4.5	1.5	1.8	287^{a}	263^{b}
44,000	4.3	4.6	1.8	1.8	255^{b}	263^{b}
66,000	4.2	4.6	2.0	1.7	269^{a}	287^{a}
SE±					10.5	8.0

Means in a column followed by same letters are not significantly different (P>0.05).CL (cob length), NKR (number of kernel rows), NKPR (number of kernels per row), CD (cob diameter), DSS (diameter of shelled cob), WK (weight of 1000 kernels).

Grain yield

Grain yield varied significantly with plant population and variety over the years. Variety UTCH-1 produced significantly more grain yield than variety Oba Super-1 but was not significantly different from variety Pannar (Table 3). Similarly, a plant population of 66,000 plants per hectare produced significantly higher grain yield than the other plant population namely 44,000 plants per hectare and 44,000 plants per hectare respectively.
population namely 44,000 plants per hectare and 44,000 plants per hectare respectively.

Table 3: Maize grain yield as affected by variety and plant population

Treatment	Grain yield (kg/ha)	
	2000	2001
Variety		
OS1	3220[b]	3576[b]
PNR	3664[a]	4056[b]
UTCH-1	3808[a]	4320[a]
SE±	185	240
Plant population (Plants per hectare)		
33,000	2846[b]	2944[b]
44,000	3997[ab]	4012[ab]
66,000	4325[a]	4664[a]
SE±	270	301
Interaction		
Variety x population		

Means in a column followed by same letters are not significantly different (P>0.05)

In the second year, the same trend is maintained, variety UTCH-1 produced significantly grain yield than variety Oba Super-1 but was not significantly different from variety Pannar. Both 44,000 and 66,000 plants per hectare significantly out yielded the 33,000 plants per hectare treatment. There was no significant interaction among variety and population density.

CONCLUSION

With hybrid maize in this location, a higher yield can be achieved by increasing plant population to 66,000 plants per hectare under irrigated conditions from the present recommendation of 53,000 plants per hectare. Similarly, grain yield components like leaf area indices, (LAI), and higher cob characteristics (weight of 1000 kernels, cob length, number of kernel rows and number of kernels per row) were significantly higher due to increase in plant population to 66,000 plants ha^{-1}. For this reason, the information on forming suitable plant population for hybrid maize varieties in the dry season is one of the key factors for planning a successful maize production programme. It is therefore recommended that for similar ecologies, a plant population of 66,000 plants per hectare will optimize moisture and nutrient and produce higher yields under irrigated conditions.

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