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Growth and Yield Component Responses of Maize as Affected by Population Density

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Abstract

An experiment with five different plant densities ranging from 35,000 to 95,000 plants ha^{-1} was carried out to find out the optimum plant population that adapted well with the limited available resource. Barnli was used as the experimental cultivar. Observations were made on growth attributes, yield and yield components of maize. Leaf area index (LAI), total dry matter (TDM), biological yield and grain yield increased with plant density while plant height, leaf number per plant, stem diameter, time of flowering and maturity, cob per plant, 1000-grain weight, number of grains cob^{-1} responded negatively.

Introduction

Utilization of solar radiation is one of the most important factors in crop production, which ig influenced by canopy architecture. Photosynthetic efficiency and growth in maize were strongly related to the effect of canopy architecture on vertical distribution of light within the canopy. Radiation is transmitted through and between leaves, and radiant flux density and spectral composition change rapidly with canopy depth (Gardner *et al.,* 1985). It is reported that canopy light interception and photosynthesis are closely related to leaf area index (LAI) up to a "critical" LAI, which is rewired to intercept 95 per cent incident irritancy. Grain yield is functionally related to LAI and hence structure of the canopy in maize (Williams *et al.,* 1968).

The capture of solar radiation within the canopy could be increased by increasing plant density. Only 5 per cent of incident solar radiation is converted into chemical energy during the crop growing season by crop canopies. Pepper (1974) reported that increased plant densities can promote utilization of solar radiation by maize canopies. However, efficiency of conversion of intercepted solar radiation into economic maize yields will decrease with high plant population density because of mutual shading of plants (Buren, 1970). Crop production researchers have conducted many studies on plant competition to determine the optimum plant population density for maize (Olson and Sander, 1988). Unfortunately, no information is available about the optimum plant density of widely grown maize cultivar Barnali. Barnali is considered as the top ranking cultivar in respect of yield and wider climatic adaptability in Bangladesh. The yield of a single plant is affected by proximity to adjacent plants (Duncan, 1984). Plant population above a critical density has a negative effect on yield plant is due to the effects of interplant competition for light, water, nutrition and other potentially yield limiting environmental factors. So, we undertook such a study to investigate the performance of maize grown at different population densities and to find out the optimum plant population densities per unit area for higher growth and yield of maize.

Materials and Methods

The experiment was carried out in the field laboratory of Hajee Mohammad Danesh Agricultural College, Dinajpur during November 1994 to March 1995. The soils of the experimental site were sandy loam in composition and belonged to the tista-silty alluvial tract. Seeds of a maize variety Barnali was sown in line to maintain plant population 35,000 50,000 60,000 80,000 and 95,000 plant ha^{-1}. The experimental plots were divided into four blocks each representing a replication. Each block was then divided into five unit plot each of 4×4 m size. Fertilizers were applied as per recommendation. All plots were over seeded and thinned to the desired population densities at the seedling stage. The sampling for determination of TDM (including shoot weight only) and leaf area was made from 40 days after sowing (DAS) till maturity (150 DAS) at 10 days interval. In every sampling date lm ^{2} area was taken from each unit plot. At each harvest the following measures of plant size were obtained, leaf area, total shoot dry weight and from these measurements, the leaf area index (LAI), crop growth rate (CGR) were calculated as outlined by Radford (1967). Leaf area (only lamina area) was measured from the formula: leaf length $\times$ leaf breadth $\times$ 0.75.

Data on plant height, ear height, stem diameter, total leaf number, total biological yield, ear length and breadth, grain rows per ear, 1000-kernel weight and grain yield (t ha^{-1}) were collected from ten randomly selected plants from middle two row of each plot at final harvest. The data were analyzed statistically and the mean differences were tested by LSD or DMRT.

Results and Discussion

Increasing population density decreased the plant height and 1st cob height (Table 1). The maximum plant height and 1st cob height of 204.65 and 123.45 cm were produced by the lowest plant population of 35,000 plants ha^{-1} and the minimum plant height and cob height of 181.24 and 103.85 cm were produced by the

Table 1: Effect of plant population on different characters studied in maize

Plants ha^{-1}	Plant height (cm)	Cob height (cm)	Stem diameter (cm)	No. of leaves per plant	50 % tasseling (days)	50 % silking (days)	Maturity (days)
35,000	204.65 a	123.45 a	3.17 a	16.72 a	84.04 b	89.84 b	140.32 a
50,000	199.85 a	119.55 ab	3.01 ab	15.95 a	86.96 ab	91.63 ab	142.17 a
65,000	193.25 ab	113.65 abc	2.76 bc	15.04 a	88.42 ab	93.41 ab	145.31 a
80,000	187.20 ab	107.63 bc	2.54 cd	14.13 a	90.14 a	95.62 ab	148.32 a
95,000	181.24 b	103.85 c	2.38 d	13.23 a	91.78 a	96.83 a	150.12 a
CV (%)	5.5	6.7	7.1	10.7	4.1	4.1	4.7
SE'	ns	5.4	0.14	ns	ns	ns	4.81

ns = Not significant. The figures in a column having common letter (s) do not differ significantly

Table 2: Effect of plant population on changes of total dry matter (g m^{-2}) with time

Plants ha^{-1}	Days after sowing (DAS)										
	40	50	60	70	80	90	100	110	120	130	140
35,000	29.0d	64.0d	119.0d	176.0d	284.0c	451.2c	660.2d	919.3c	1072.0c	1190.5d	1277.2d
50,000	33.0d	70.0d	1,32.0d	215.2cd	319.2c	502.3c	740.2c	982.1c	1147.1c	1248.4cd	1329.2cd
65,000	48.0c	19.0c	156.0c	250.3bc	369.0b	570.4b	856.4b	1103.0b	1255.3b	1340.3bc	1417.3bc
80,000	57.0b	108.0b	180.0b	278.0ab	401.2ab	623.3a	916.5ab	1180.4ab	1329.0ab	1430.2ab	1487.2ab
95,000	6.0a	121.0a	202.1a	300.5a	433.5a	679.2a	983.0a	1258.5a	1408.0a	1489.1a	1565.4a
SE±	2.92	4.79	7.39	13.23	17.75	25.52	78.00	41.5	43.74	51.61	50.78
$LSD_{0.05}$	6.36	10.43	16.11	39.71	38.68	54.81	360	90.4	95.36	112.5	110.69
CV (%)	8.9	7.51	6.61	10.6	9.1	6.3	6.1	5.41	5.0	5.45	5.07

Values sharing a common letter in each column are not significantly different ($p = 0.05$)

Table 3: Effect of plant population on the changes of LAI with time

Plants ha^{-1}	'Days after sowing (DAS)									
	40	50	60	70	80	90	100	110	120	130
35,000	0.40d	0.68d	1.17d	1.87c	2.24d	2.93c	2.49c	2.19b	1.75b	1.40a
50,000	0.53c	0.88c	1.71c	2.06bc	2.41cd	2.90c	2.88bc	2.50b	2.01ab	1.61a
65,000	0.63b	1.04bc	1.94b	2.42b	2.90bc	3.68b	2.95bc	2.37b	1.98ab	1.58a
80,000	0.72b	1.18b	2.02b	2.98a	3.08b	3.95b	3.06b	2.32b	1.86b	1.49a
95,000	1.01a	1.66a	2.95a	3.17a	3.78a	4.72a	3.91a	3.02a	2.21a	1.50a
SE±	0.03	0.05	0.05	0.05	0.25	0.34	0.20	0.07	0.04	NS
$LSD_{0.05}$	0.08	0.10	0.11	0.10	0.55	0.74	0.44	0.16	0.16	NS
CV (%)	7.45	6.25	3.69	2.68	12.35	12.93	9.25	4.10	3.28	-

Values sharing a common letter in each column are not significantly different ($p = 0.05$)

Table 4: Effect of plant population on the changes of CGR with time per unit area of land

Plants ha^{-1}	Days after sowing (DAS)									
	50	60	70	80	90	100	110	120	130	140
35,000	2.50c	5.50d	7.21b	9.31d	16.75d	20.92d	23.44b	17.39a	11.82a	8.69a
50,000	3.70bc	6.20c	8.33b	10.45c	18 .34cd	23.78c	24.26b	16.55b	10.08a	8.10ab
65,000	4.30b	6.50c	9.46a	11.97b	20.16c	28.67b	24.71b	15.21c	8.55c	7.72b
80,000	5.10a	7.20b	9.83a	12.30ab	22.20b	29.33ab	26.39a	14.89c	8.28c	7.51b
95,000	5.50a	8.10a	9.84a	13.31a	24.62a	30.42a	27.48a	15.03c	8.10c	7.58b
SE ±	0.34	0.21	0.48	0.46	0.85	0.66	1.08	0.36	0.41	0.33
$LSD_{0.05}$	0.74	0.45	1.05	0.01	1.84	1.43	2.35	0.78	0.90	0.72
CV (%)	10.8	4.40	7.60	5.71	5.90	3.50	6.00	3.22	6.20	5.90

Values sharing a common letter in each column are not significantly different ($p = 0.05$)

Table 5: Yield and yield components of maize as affected by plant population

Plants/ ha	No. of ears/plant	Ear length (cm)	Ear diameter (cm)	Grain rows per ear	1000-grain	Yield (t/ha) weight (g)	Harvest index (%)
35,000	1.38 a	16.72 a	14.74 a	13.98 a	254.84 a	4.19 d	38.96 a
50,000	1.23 b	15.95 ab	14.04 ab	13.16 ab	250.14 a	4.69 cd	38.01 ab
65,000	1.18 b	15.04 abc	13.26 bc	12.66 bc	245.72 a	5.14 bc	36.92 ab
80,000	1.10 bc	14.13 bc	12.54 cd	11.94 cd	238.50 a	5.63 ab	35.88 ab
95,000	1.10 c	13.24 c	12.12 d	11.23 d	234.60 a	5.88 a	33.95 b
SE ±	0.06	1.08	0.40	0.47	ns	0.27	1.00
$LSD_{0.05}$	0.13	2.36	0.87	1.03	ns	0.58	2.24
CV (%)	7.3	10.2	4.2	5.3	4.9	7.4	7.3

Values sharing a common letter in each column are not significantly different (p = 0.05)

population of 950000 plant ha^{-1} respectively. Shafshak *et al.* (1984) observed the same findings in maize and they stated that increase of population density decrease plant height so that plant parts ration remained nearly the same. Increasing population density decreased stem diameter (Table 1) and this was statistically significant. Identical view were expressed for maize by Shafshak *et al*. (1984) and Jolliffe *et al*. (1990). Leaf number also followed the same pattern as plant height and stem diameter.

Leaf number was greater at the low population density than at the high population density. These results agree with earlier reports suggesting that this decrease resulted from greater interplant competition at higher plant densities (Fakorede and Mock, 1978).

Table 1 revealed that tasseling and silking significantly delayed with increase in population densities. Variation of 50 percent tasseling was significant among the treatments but silking did not vary significantly though lower populated plants produced silk earlier than densely populated plants. Higher density also delayed maturity. Iremiren and Milbourn (1978) and Shafshak *et al.* (1984) reported the same findings and these may due to lower growth and development in the denser communities.

Total Dry Matter (TDM): Effects of population density on increasing total dry matter were significant from the second harvest (42 DAS) onward (1st harvest was not presented) (Table 2). Higher dry matter accumulation was observed among the plants of higher population densities. Higher dry matter per unit area was obtained due to higher number of plants of the area but dry matter per plant was lower in relation to lower plant densities. After second harvest there was an increased rate of leaf and leaf area development which commensurate with the linear growth of dry matter accumulation.

Leaf area index (LAI) was observed from 40 DAS to 130 DAS and was presented in Table 3. Increasing population densities increased leaf area index. LAI rose to a peak near 4th harvest and then tended to decline. The lowest LAI (2.94) is associated with lowest population density (35,000 plants ha^{-1}). The decline in leaf area index in the last four harvest was largely due to tiller senescence, rather than leaf loss on the main axis. Identical findings were observed by Dale *et al.* (1980) When LAI was its maximum, shortly after flowering, LAI ranged from 2.39-5.69 with various plant populations.

Crop growth rate (CGR) is a measure of the growth rate of plants per unit land area per unit time. The CGR emerged with a characteristic rapid increase in all the treatments and continued until the attainment of maxima, as soon followed by a slow decrease (Table 3). Table 3 showed the SGR increased with plant densities. The CGR in denser population reached their peak earlier than the thinner stand. Jolliffe *et al.* (1990) reported the similar findings in their experiment with maize plants. CGR is positively correlated to leaf area, thus SGR increased rapidly along with the increasing LAI. Similar cases were also reported for maize (Allison, 1969). Thus the increasing SGR at higher population (Table 3) was the result of higher LAI as mentioned earlier (Table 4).

The reproductive capacity of maize due to the variation of population density was evaluated at final harvest in terms of number of ears per plant, ear length and breadth, 1000-kernel weight, yield (t ha^{-1}) and harvest index (HI) and was presented in Table 5.

The number of ear per plant reduced significantly as the plant population of 35,000 plant ha^{-1} gave the maximum (1.38) and 95,000 plants he gave only one ear $plant^{-1}$ (Table 5). Table 5 also revealed that ear length and ear breadth followed the same pattern as ear $plant^{-1}$. Ear length and ear breadth were significantly smaller at the higher plant densities. These results are in agreement with the findings of Karim *et al.* (1938) where they reported that ear length and number of ears plant decreased linearly with increase in plant population. This is due to more plant competition for nutrients, solar radiation and water from the same area by more plants from the early stage of crop establishment. Due to smaller and thinner cob breadth, the number of grain rows per co were lesser in densely populated stands of maize plants. Similar results have been reported by other researchers (Dale *et al.,* 1980, Hashemi-Dezfouli and Herbert, 1992).

Table 5 showed that 1000-grain weight did not differ significantly among the treatments which indicates grain weight is independent to environmental variations rather genetically controlled.

However, the kernel weight had a decreasing tendency with increasing plant densities. Regarding grain yield, it was also observed that the grain yield gradually increased as the population density was increased. The highest plant population of 95,000 plant ha^{-1} yielded the maximum (5.88 t ha^{-1}) and the minimum (4.19 t ha^{-1}) grain yield was produced by 35,000 plants ha^{-1}. It may be further observed that despite reduction in number of ear per plant and decreasing tendency of 1000-grain weight due to increase in the plant population. Thereby, the grain yield continued to increase progressively as population density increased upto 95,000 plants ha^{-1}. Dale *et al*. (1980), Anjum *et al.* (1992) and Bangarwa *et al.* (1988) also reported that highest density produced the highest average yield and grain yield and grain was lower at lowest plant population. Table 5 revealed that harvest index (HI) increased with decreasing plant population but the variation among the treatments was not significant while Begna *et al.* (1997) reported that harvest index was not affected by population density. It was concluded that Bernal+ plants were more tolerant of high plant density as evidenced by grain yield and total dry matter, but its vegetative phase was slight longer as well as reproductive development. Comparatively short days to 50 percent tasseling, silking and maturity and higher harvest index are indications that moderate plant population density and proper management more suitable for Barnali cultivation.

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