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EFFECT OF PLANT POPULATION DENSITIES ON YIELD OF MAIZE

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ABSTRACT

A field experiment to determine the effect of plant population densities on maize was conducted at the Agricultural Research Institute, Dera Ismail Khan, in mid July 2009. The effect of six plant population densities i.e. T_1 (40000 plants ha^{-1}), T_2 (60000 plant ha^{-1}), T_3 (80000 plants ha^{-1}), T_4 (100000 plants ha^{-1}), T_5 (120,000 plants ha^{-1}) and T_6 (140,000 plants ha^{-1}) was investigated using maize variety Azam. Results showed that plant population of 40000 ha^{-1} produced maximum number of grains per row (32.33) and grains per ear (447.3). However, 60000 plants ha^{-1} produced the maximum number of ears per plant (1.33), number of grain rows per ear (15.44), biomass yield (16890 kg ha^{-1}) and grain yield (2604 kg ha^{-1}). Therefore, planting density of 60000 plants ha^{-1} (keeping plant to plant distance of 22.70cm) is recommended for obtaining higher yield of maize.

Key words: Biomass, grain yield, maize, population density

INTRODUCTION

Maize (*Zea mays* L.) is an important food and feed crop of the world. Maize is the third most important cereal crop of Pakistan after wheat and rice. About 60% maize is grown in irrigated and 36% in rain fed areas of Pakistan. Basically it is a tropical plant but at present it is being cultivated extensively with equal success in temperate, tropical and sub-tropical regions of world. It is a short duration crop and is grown twice in a year. In Pakistan grain yield of maize is very low as compared to other maize growing countries like Italy (9530 kg ha^{-1}), Canada (6630 kg ha^{-1}), China (4570 kg ha^{-1}) and Argentina producing average maize yield of 5650 kg ha^{-1} (Tahir *et al*., 2009).

There are a number of biotic and abiotic factors those affect maize yield considerably; however, it is more affected by variations in plant density than other member of the grass family (Vega *et al.,* 2001). Maize differs in it's responses to plant density (Luque *et al.*, 2006). Liu *et al*. (2004) also reported that maize yield differs significantly under varying plant density levels due to difference in genetic potential. Correspondingly maize also responds differently in quality parameters like crude starch, protein and oil contents in grains (Munamava *et al*., 2006). Plant populations affect most growth parameters of maize even under optimal growth conditions and therefore it is considered a major factor determining the degree of competition between plants (Sangakkara *et al*., 2004). The grain yield per plant is decreased (Luque *et al*., 2006) in response to decreasing light and other environmental resources available to each plant (Ali *et al*., 2003).

Stand density affects plant architecture, alters growth and developmental patterns and influences carbohydrate production. At low densities, many modern maize varieties do not tiller effectively and quite often produce only one ear per plant. Whereas, the use of high population increases interplant competition for light, water and nutrients, which 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, 2001).

Keeping this in view, the present study was formulated to optimize the planting density of maize (var. Azam) under the agro-climatic conditions of Dera Ismail Khan.

MATERIALS AND METHODS

The study was conducted at the Agricultural Research Institute, Dera Ismail Khan. The experiment was laid out in a randomized complete block design with three replications. The net plot size was 1.5x5m^2 with 4 rows. Six plant population densities of maize i.e. T_1 (40000 plants ha^{-1}), T_2 (60000 plant ha^{-1}), T_3 (80000 plants ha^{-1}), T_4 (100000 plants ha^{-1}), T_5 (120,000 plants ha^{-1}) and T_6 (140,000 plants ha^{-1}) were evaluated using maize variety Azam in mid July. The desired plant densities were achieved with intra-row spacing of 33.33cm in T_1, 22.70cm in T_2, 18.60cm in T_3, 13.50cm in T_4, 11.10cm in T_5 and 9.60cm in T_6 and 75cm inter-row spacing in all treatments. The land was irrigated before its final preparation. It was then given 3-4 ploughings (including operation with disc plough, cultivator and rotavator) to make a fine seed bed. Sowing was done manually. Fertilizers were applied @ 110:90:75 NPK kg ha^{-1}. All phosphorus and potash were applied at the time of sowing. Nitrogen was applied in three equal split doses i.e. first dose was applied at seed bad preparation. The second dose was applied 20 days after sowing and third dose 40 days after sowing. The soil of site was silty clay, the pH = 7.78 and the organic matter content <1%. The field was irrigated at 7-day intervals. Herbicide "Primextra-Gold" was applied @ 3 L ha^{-1} one week after sowing.

Data were collected on the following parameters:

Leaf area index: Leaf area index was measured as:

$$\text{Leaf area index} = \frac{\text{Area of green leaves plant}^{-1}}{\text{Area occupied by plant}} \times 100$$

Plant height at maturity (cm): At maturity, five plants were selected randomly from each plot. Their height was measured from the soil surface to the tip of panicle / flag leaf with the help of a meter rod and average height was calculated.

Number of ear ($plant^{-1}$): Five plants were selected randomly; their ears were counted, recorded and averaged.

Number of grain rows (ear^{-1}): Five plants were selected randomly from each plot and grains rows of each ear were counted, averaged and recorded.

Number of grains (row^{-1}): Five cobs were collected randomly from each plot and number of grains in each cob was counted and averaged.

Number of grains (ear^{-1}): Five plants were selected randomly from each plot; their grains per ear were counted, averaged and recorded.

Biomass yield (kg ha^{-1}): The total biomass yield was measured as:

Biomass yield = Economical yield x K

1000-grain weight (g): Two samples of thousand grains were taken at random from each treatment, weighed by digital balance in the laboratory and average was recorded.

Grain yield (kg ha^{-1}): After sun drying, the cobs were threshed manually and yield was recorded on per plot basis, and then was converted into kg ha^{-1} by using the following formula:

$$\text{Grain yield (kg ha}^{-1}) = \frac{\text{Ploy yield (kg) x 10, 000}}{\text{Plot size (m}^2\text{) x 1000}}$$

The data thus obtained were subjected to the analysis of variance technique by using MSTATC computer software and means were separated by LSD test (Steel *et al*., 1997). Meteorological data at the experimental site revealed the highest temperature (39°C) in August and the lowest (17°C) in October. The relative humidity was the highest in August (67%) and the lowest (40%) in October. The crop received rain showers (21 and 11 mm) during the months of September and October. Harvesting was done 70 days after sowing.

RESULTS AND DISCUSSION

Leaf area index: LAI is an important parameter of maize. The data regarding LAI as affected by plant population densities are given in table-1. It is revealed that LAI was significantly affected and increased in linear fashion with increase in plant population. The treatments having plant population of 120,000 and 140,000 plants ha^{-1} produced higher LAI of 2.77 and 2.52, respectively. The lowest LAI was obtained with population of 40000 plants ha^{-1}. Valadabadi and Farahani (2010) investigated that leaf area is influenced by genotype, plant population, climate and soil fertility. They further reported that highest physiological growth indices are achieved under high plant density, because photosynthesis increases by development of leaf area. In our research, the increase in LAI explains the general crop trends that increasing plant density increases leaf area index on account of more area occupied by green canopy of plants per unit area. Previous research findings also indicated that in high maize density, leaf area index, total dry weight and crop growth rate increased than low maize density throughout crop growth season (Saberali, 2007).

Plant height at maturity (cm): Plant height is an important component which helps determining the growth attained during the growing period. The data showed that plant height was significantly affected by plant population densities (Table-1). The tallest plants (197.2cm) were recorded in T_4 (100000 plants ha^{-1}), which were, however, statistically at par (193.0cm) with T_3 (80000 plants ha^{-1}). Short statured plants (150.8cm) were recorded in T_6 (140,000 plants ha^{-1}) due to crowding effect of the plant and higher intra-specific competition for resources. This trend explains that as the number of plants increased in a given area the competition among the plants for nutrients uptake and sunlight interception also increased (Sangakkara *et al*., 2004).

Number of ears ($plant^{-1}$): The number of ears per plant was significantly affected by different plant population densities (Table-1). As regards the effect of varying population densities, the maximum and equal number of ears $plant^{-1}$ (1.33) was produced in T_2 (60000 plants ha^{-1}) and T_3 (80000 plants ha^{-1}) as compared to T_6 (140,000 plants ha^{-1}) which produced lowest number of ears per plant. The use of high plant densities may reduce the supply of nitrogen, photosynthates and water to the growing ear. Also, high stand establishment creates competition for light, aeration, nutrients and consequently compelling the plants to undergo less reproductive growth (Zamir *et al*., 2011). The use of high plant densities may reduce the supply of nitrogen, photosynthates and water to the growing ear.

Number of grain rows (ear^{-1}): The data pertaining to number of grain rows per ear as influenced by different plant population densities are presented in table-1. It is revealed from the data that plant population had significant effects on the number of grain rows per ear. The treatments having population of 60000 and 80000 plants ha^{-1} produced the highest number of grain rows per ear of 15.44 each. While the lowest number of grain rows per ear (13.44) was recorded with 140,000 plants ha^{-1}. The number of grain rows per ear decreased as the plant population increased. Usually under high population stress, the late developing distal spikelets fail to set kernels and when the slow growing silks finally emerge, little or no pollen is available for fertilization. Also, high stand density reduces ear shoots growth, which results in fewer spikelet primordia transformed into functional florets by the time of flowering. The limited carbon and nitrogen supply to the ear finally stimulates young kernel abortion immediately after fertilization (Sangoi, 2001).

Number of grains (row^{-1}): The data given in table-1 indicated that number of grains per row was influenced significantly by different plant population densities. The maximum number of grains per row (32.33) was recorded in T_1 (40000 plants ha^{-1}) followed by T_2 (60000 plants ha^{-1}) with 29.77 number of grains per row. The lowest number of grains per row (18.78) was recorded in T_6 (140,000 plants ha^{-1}), possibly due to less availability of nutrients to grain formation.

Number of grains (ear^{-1}): The grains per ear were significantly affected by different plant population densities (Table-1). The treatments with 40000 plants ha^{-1} produced the highest number of grains per ear (447.3) followed by T_2 (400.8) having population of 60000 plants ha^{-1}. The lowest number of grains per ear (253.1) was recorded in treatment having 140,000 plants ha^{-1}. The increase in number of grains per ear in T_1 might be due to availability of more resources to plants on account of low population density. When the number of individuals per area is increased beyond the optimum plant density, there is a series of consequences that are detrimental to ear ontogeny that result in barrenness (Sangoi, 2001).

1000-grain weight (g): The mean data regarding 1000-grain weight are presented in table-1. Perusal of the data revealed that grain weight was significantly affected by different plant population densities. The treatment having population of 80000 and 40000 plants ha^{-1} produced the highest grain weight of 350.0 and 333.0g, respectively. The increase in grain weight in T_3 and T_1 might be due to availability of more resources (nutrient + water) for comparatively less number of plants which they utilized efficiently. The lowest grain weight (166.7g) was recorded in treatment having plant population of 140,000 plants ha^{-1}. Low grain weight in high plant population density was probably due to availability of less photosynthates for grain development on account of high inter-specific competition which resulted in low rate of photosynthesis and high rate of respiration as a result of enhanced mutual shading (Zamir *et al*., 2011).

Table 1. Physiological and agronomic parameters as affected by plant population densities in maize.

Treatments	Leaf area index	Plant height (cm)	Ear (plant^{-1})	Grain rows (ear^{-1})	Grains (row^{-1})	Grains (ear^{-1})	Grain weight (g)	Biomass yield (kg ha^{-1})	Grain yield (kg ha^{-1})
T_1: 40000 plants ha^{-1}	1.21^{c}	181.4^{c}	1.22^{ab}	14.66^{ab}	32.33^{a}	447.3^{a}	333.3^{a}	15560^{b}	2146^{ab}
T_2: 60000 plants ha^{-1}	1.68^{bc}	188.9^{b}	1.33^{a}	15.44^{a}	29.77^{b}	400.8^{b}	300.0^{ab}	16890^{a}	2604^{a}
T_3: 80000 plants ha^{-1}	1.94^{b}	193^{ab}	1.33^{a}	15.44^{a}	28.22^{bc}	361.2^{c}	350.0^{a}	16890^{a}	2346^{ab}
T_4: 100000 plants ha^{-1}	2.50^{a}	97.2^{a}	1.10^{bc}	14.22^{ab}	26.89^{c}	287.3^{d}	246.7^{bc}	15330^{b}	1751^{bc}
T_5: 120,000 plants ha^{-1}	2.77^{a}	163.7^{d}	1.10^{bc}	15.00^{ab}	20.66^{a}	282.7^{d}	216.7^{cd}	13780^{c}	1351^{cd}
T_6: 140,000 plants ha^{-1}	2.52^{a}	150.8^{e}	1.00^{c}	13.44^{b}	18.78^{e}	253.1^{e}	166.7^{b}	13330^{c}	746.3^{d}
$LSD_{0.05}$	0.542	6.963	0.190	1.903	1.730	23.57	56.73	1165.0	623.2
CV (%)	14.19	2.14	8.81	7.12	3.64	3.82	11.60	4.18	18.78

Means sharing similar letter (s) in respective column/row do not differ significantly at 5 % level of probability.

Table 2. Mean squares of physiological and agronomic parameters of maize.

Source of variation	d.f	Leaf area index	Plant height at maturity (cm)	No. of ear (plant^{-1})	No. of grain rows (ear^{-1})	No. of grains (row^{-1})	No. of grains (ear^{-1})	1000-grain weight (g)	Biomass yield (kg ha^{-1})	Grain yield (kg ha^{-1})
Replication	2	0.020^{*}	12.373^{*}	0.002^{*}	1.113^{*}	2.740^{*}	214.903^{*}	172.222^{*}	4320123.500^{*}	30147.056^{*}
Treatments	5	1.060^{*}	997.905^{*}	0.055^{*}	1.803^{*}	84.356^{*}	17558.689^{*}	15222.222^{*}	6780908.667^{*}	1425361.822^{*}
Error	10	0.089	14.648	0.011	1.094	0.904	167.838	972.222	409723.567	117340.056

* Means sharing similar letter (s) in respective column/row do not differ significantly at 5 % level of probability.

Biomass yield (kg ha^{-1}): Biomass yield was significantly affected by different plant population densities (Table-1). Treatments having population of 60000 and 80000 plants ha^{-1} produced the maximum biomass yield of 16890 kg ha^{-1} each, while the lowest biomass yield (13330 kg ha^{-1}) was recorded with population of 140,000 plants ha^{-1}. Several studies have shown that biomass yield decreases progressively as the number of plants increases in a given area because the production of the individual plant is reduced (Hamidia *et al*., 2010). The higher biomass in T_2 and T_3 having comparatively less plant population was possibly due to optimum utilization of soil and other environmental resources by the crop.

Grain yield (kg ha^{-1}): Grain yield is a function of integrated effects of genetic make up of cultivars and the growing conditions. The data on grain yield revealed that grain yield was significantly affected by plant population densities (Table-1). The maximum grain yield (2604 kg ha^{-1}) was recorded in T_2 (60000 plants ha^{-1}) followed by T_3 (80000 plants ha^{-1}) which produced grain yield of 2346 kg ha^{-1}. The higher grain yield in T_2 and T_3 was possibly due to higher number of ears (plant^{-1}) and number of grain rows (ear^{-1}) in these two treatments. These results are supported by Emam (2001) who verified that kernels ear^{-1} and kernels ear^{-1} row are the most important yield adjustment components in response to plant population density in maize. The minimum grain yield of 746.3 kg ha^{-1} was recorded in T_6 having population of 140,000 plants ha^{-1}.

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