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Differential Planting Density Influences Growth and Yield of Hybrid Maize (*Zea mays* L.)

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Abstract: The present study to evaluate the effect of different planting densities on growth and yield of hybrid maize was conducted at Research area, University College of Agriculture and Environmental Sciences, The Islamia University of Bahawalpur, Pakistan during August, 2012. The effect of four planting densities i.e. T_1 Control (92,000 plants ha^{-1}), T_2 (30,000 plants ha^{-1}), T_3 (50,000 plants ha^{-1}) and T_4 (70,000 plants ha^{-1}), was investigated by using maize hybrid (Hycorn). The results indicated that plant density of 50,000 and 70,000 plants per hectare produced maximum cob length of 18.6 cm, whereas plant density of 30,000 plants per hectare produced maximum stem diameter of 1.42 cm. For yield traits, 50,000 plants per hectare produced the maximum number of grains per row (30.14) and grains per cob (439.18). However, plant density of 70,000 plants per hectare produced maximum grain weight per cob (156.29 g), 1000-grain weight (388.22 g) and grain yield (9338 kg ha^{-1}). Therefore, planting density of 70,000 plants per hectare is recommended for obtaining maximum yield of maize. Results showed that stand density affects plant architecture, alters growth and developmental patterns and influences carbohydrate production. High plant population increases interplant competition for light, water and nutrients, which was detrimental to final yield. These results highlight the response of maize hybrid to identify optimum population densities under environmental condition of Bahawalpur, Pakistan.

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1. Introduction

Maize (*Zea mays* L.) is a vital food crop and gives a big volume of raw materials for farm animals and many agro-related industries in the world (Bello et al., 2010; Randjelovic et al., 2011). In Pakistan, maize (*Zea mays L.*) ranks 3rd in cereal crops after wheat and rice (Ahmad et al., 2010). It is a tropical plant but today it is grown in temperate, tropical and sub-tropical regions of the world. Production of maize crop is less in Pakistan (4268 kg ha^{-1}) when compared with other countries like Italy (9530 kg ha^{-1}), Canada (6630 kg ha^{-1}), Argentina (5650 kg ha^{-1}) and China (4570 kg ha^{-1}) Tahir et al., 2009).

The factors which hamper the yield potential of maize crop include unavailability of improved seed varieties and low optimal plant density per hectare (Nasir, 2000). Hybrids show different responses according to different plant densities which has a major impact on the yield of maize crop (Sarvari et al., 2002). This might have not good effect on yield of maize crop because it increases plant height, promote bareness, and as a result decreases the cobs number per plant and number of grains per cob (Sangoi and Salvador, 1998). Plant density affected mainly growth parameters of maize crop in most favorable growth situation and hence it is considered as an important factor to determine the extent of interplant competition (Sangakkara et al., 2004).Optimum plant density increased number of grains per cob, 1000-grain weight and ultimately increased grain yield of maize crop (Ahmad, 1994).

Keeping the importance of maize and the impact of plant density on its growth and yield the present study was conducted to investigate the effect of different planting densities on growth and yield of hybrid maize (*Zea mays* L.) under the agro-climatic conditions of Bahawalpur.

2. Material and Methods

The experiment was conducted at research area of the University College of Agriculture, and Environmental Sciences, The Islamia University of Bahawalpur, Pakistan (29° 24' 0" North, 71° 41' 0" East) in 2012. The soil of the site was sandy loam with pH = 8 and organic matter content 0.44 (<1%). Triplicate experiment was laid out in randomized complete block design (RCBD). Maize variety

(Hycorn) was sown on 22nd August 2012 into four planting densities i.e. T_1 Control (92,000 plants ha^{-1}), T_2 (30,000 plants ha^{-1}), T_3 (50,000 plants ha^{-1}) and T_4 (70,000 plants ha^{-1}). The net plot size was 5 m × 3 m with four rows. The desired plant densities were maintained in each treatment except T_1 (control) where only overlapped plants were removed by thinning. The land was irrigated before sowing to facilitate uniform germination.

The seedbed was prepared by using cultivator and rotavator as required, and then sowing was done manually on ridges. The fertilizers NPK were applied at the rate of 220-115-123 kg ha^{-1} respectively. All phosphorus and potash were applied at the time of sowing, while nitrogen was applied in three equal splits: 1st at 5-6 leaf stage, 2nd at 8-10 leaf stage and 3rd at flowering stage (Tasseling). Weeding was done manually. Furadan (3-G) was applied at rate of 20 kg ha^{-1} at 4-5 leaf stage to protect the crop from maize borer and shoot fly. Growth and yield data were collected by using standard principles and procedures. Ten plants were selected randomly from three places of one square meter of each plot before harvesting and their height was measured by measuring tape from ground to top of plant. The average was worked out to calculate plant height (cm). Length of ten randomly selected cobs from each plot was also measured by measuring tape and then average cob length (cm) was calculated. Stem diameter (cm) was measured by means of vernier caliper at three places of each stem from ten randomly selected plants per plot and average of three values was worked out. At the end ten values were averaged for mean stem diameter.

Numbers of grains per row of each cob from ten randomly selected cobs were counted individually and then average was calculated. Number of grain rows per cob_was calculated by selecting ten cobs randomly from each plot and then average was taken to get grain rows per cob. Cobs from ten randomly selected plants were counted and average number of cobs per plant was worked out. Three samples, each of 1000-grains were taken randomly from the seed lot of each plot, weighed separately and then average was taken. Grain weight per cob (g) was calculated by weighing separately the grains of ten randomly selected cobs from each plot and then average was calculated.

All the cobs from each sub plot were harvested, sun dried and finally shelled to record grain yield per plot, which was later converted into kgha^{-1}.

All the collected data were analyzed by means of statistical software Statistix® 8.1. Fishers Analysis of Variance at 5% probability was used to calculate the significance among experimental treatments. Statistically significant means were separated by means of LSD (Least Significant Difference) at α: 0.05.

3. Results and Discussion

3.1 Growth parameters

Plant height at maturity is a key function of the genetic, nutritional and environmental factors. Higher plant densities lead to the weaker plants of high stature which prone to lodging and diseases and result in lower yield of grains (Chandiposha and Chivende, 2014). Different planting densities had a non-significant effect on plant height (Table 1). However relatively higher plant height (261.07 cm) was observed inT_3 (50,000 plants ha^{-1}) while lesser plant height (256.14 cm) was observed in T_1 (density 92,000 plants ha^{-1}). The non-significant difference in plant height against different densities might be due to the genetic makeup of hybrid maize or due to increase in mutual shading. The similar results were also found by Tokatlidis and Koutroubas (2004).

Cob length is also an important parameter which contributes to the production potential of maize crop. Longer the length of the cob higher is the probability of more and vigorous grains and hence the grain yield. Different planting densities significantly affected the cob length. Table 1 reveals that maximum cob length (18.66 cm) was found in T_4 (70,000 plants ha^{-1}) and (18.64 cm) in T_3 (50,000 plants ha^{-1}) when compared with that of control. Minimum cob length (15.54 cm) was observed in T_1 having maximum plant density (92,000 plants ha^{-1}). Cob length (17.40 cm) of T_2 was found at par as compared to control having cob length 15.54 cm. Akein et al. (1994) and Shangoi et al. (2002) found that the cob length decreases with the increase of plant density. The same was observed in our experiment where the higher plant densities resulted into decreased cob length. The plants at lower to optimum densities utilized space, water and nutrients more efficiently without any serious competition.

Stem diameter is an important index of inter plant competition. Water and nutrient supply is maintained through stem and then photo-assimilates are translocated towards stem. It contributes prominently towards biological and stalk yield of crop. All the plant densities significantly affected the stem diameter (Table 1).

Table 1. Growth and yield parameters of maize (*Zea mays* L.) in response to differential planting density

Treatment	Plant height (cm)	Cob length (cm)	Stem diameter (cm)	Grains per row	Grain rows cob^{-1}	Cobs per plant	Grain weight cob^{-1} (g)	1000-grain weight (g)
*T_1	256.14	15.5 b	1.18 b	23.8 c	13.95	0.80	103.40 b	249.12 c
T_2	259.62	17.4 ab	1.42 a	25.8 c	14.08	1.08	124.29 ab	335.46 b
T_3	261.07	18.6 a	1.34 a	30.1 a	14.49	0.88	148.92 a	339.61 b
T_4	256.66	18.6 a	1.21 b	28.2 ab	14.27	0.84	156.29 a	415.22 a
p-value	0.995	0.043	0.007	0.031	0.860	0.315	0.037	0.050
LSD (0.05)	NS	2.25	0.11	3.89	NS	NS	35.55	58.09

*T_1 – Control- 92,000 plants ha^{-1}, T_2= 30,000 plants ha^{-1}, T_3= 50,000 plants ha^{-1}, T_4= 70,000 plants ha^{-1}
NS: non-significant

Maximum stem diameter (1.42 cm) was recorded in the treatmentT_2 where the plant population was maintained with 30,000 plants ha^{-1}, which was statistically similar to the plant population of 50,000 plants ha^{-1} having stem diameter 1.34 cm. These were followed by the treatment with plant population 70,000 plants ha^{-1} with 1.21 cm stem diameter.

Minimum stem diameter (1.18 cm) was recorded in the control treatment having plant density (92,000 plants ha^{-1}). It was observed that as plant density increased the stem diameter decreased, so inverse relationship was found between plant density and stem diameter. Decrease in stem diameter at higher plant densities might be due to higher plant competition for available resources like nutrients, water, air, space and other similar factors. Plant competition reduces nutrient and water uptake which ultimately reduces production of assimilates and their supply to stem. These results are in agreement with those of Sener et al. (2004) who had found that the stem diameter increases by decreasing plant density.

3.2 Yield parameters

Number of grains per row of cob plays a key role in the final yield production of maize crop. More the number of grains per row of cob more will be the grain yield. Table 1 exhibits that different plant population significantly affected the number of grains per row of cob. Plant density of 50,000 plantsha^{-1} gave the highest number of grains per row of cob (30.14), which was statistically similar to the plant density of 70,000 plants ha^{-1} having 28.28 grains per row. These were followed by plant density of 30,000 plants ha^{-1} with 25.82 grains per row. Minimum number of grains per row of cob (23.86) was recorded in control treatment with a plant density of 92,000 plants ha^{-1}. This may be a result of lesser availability of nutrients for grain formation. In experiment, it was observed that number of grains per row decreased when plant population increased. Significant effect of different planting densities on number of grains per row of cob are in line with the findings of Lemcoff and Loomis (1994) who concluded that use of high plant density decreased number of grains per row, grain size and number of grains per plant.

Different plant densities had not significant effect on the number of grains rows per cob (Table 1). All treatments had almost similar number of grain rows per cob. Apparently treatment T_1 (control) having maximum number of plant population produced less number of grain rows per cob but data was statistically non-significant. These results are similar to the findings of Daynard and Muldoon (1983) and Dwyer et al. (1991) who reported that interactive effect of different plant population densities was non-significant on number of grain rows per cob.

Number of cobs per plant depends upon genetic character of the hybrid and is a vital yield contributing parameter, which is affected by environmental conditions (Asghar and Mehdi, 2010). Different planting densities had not significant effect on the numbers of cobs per plant (Table 2), which might be due to the genetic makeup of the hybrid. It is revealed that the number of cobs per plant was not influenced by hybrids to a significant level. These results are in accordance with the findings of Bakht et al., (2011).

Grain weight per cob was significantly affected by varying planting densities (Table 1). Maximum grain weight per cob (156.29 g) was recorded in T_4 where the planting density was 70,000 plants ha^{-1}, which was statistically similar with that of T_3 having grain weight 148.92 g and T_2 (124.29 g) grain weight per cob. Minimum grain weight per cob (103.40 g) was recorded in T_1 (control) having planting density 92,000 plants ha^{-1}.

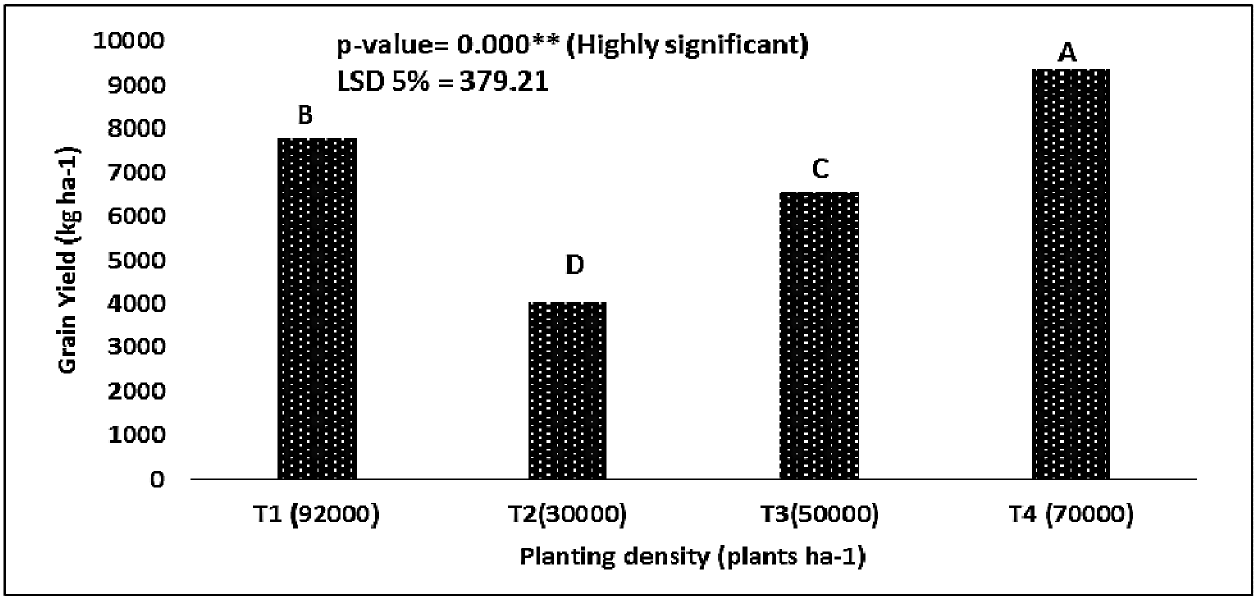

Figure 1. Effect of differential planting density on grain yield of Maize (*Zea mays* L.)

Our findings about the interaction between grain weight (g) per cob and planting densities are supported by the findings of Cusicanqui and Lauer (1999) who observed that number of cobs, weight of cobs and grain weight per cob were highest at wide spacing.

1000-grain weight showed a statistically significant response to the varying plant densities used during the course of the experiment (Table 1). Maximum 1000-grain weight (388.22 g) was recorded in treatment T_4 where plant population was maintained at 70,000 plants ha^{-1} and minimum 1000-grain weight (301.78g) was recorded in T_1 (control) where plant population was 92,000 plants ha^{-1}. While data regarding to 1000-grain weight of treatment T_2 (335.46 g) and T_3 (339.61 g) was statistically at par with each other. It means when plant population increases, 1000-grain weight decreased. These results were in the line with the findings of Akein et al. (1994) who reported that 1000-grain weight increased when plant population decreased in maize.

Grain yield is the end product of many complex morphological and physiological processes occurring during growth and development of a crop (Fig. 1). Different planting densities significantly influenced grain yield of hybrid maize. Maximum grain yield (9338.0 kg ha^{-1}) was recorded in T_4 (70,000 plants ha^{-1}) that was followed by T_1 (92,000 plants ha^{-1}) having grain yield of 7794.2 kg ha^{-1}. Minimum grain yield was found in T_2 (30,000 plant per hectare), which was 4067.7 kg ha^{-1}. Gozubenli et al. (2004) also observed that grain yield of maize crop enhanced with increasing planting population up to 90,000 plants per hectare and decreased in higher plant densities. Increased competition among plants for resources like nutrients, water, and light were the possible reasons for the lower grain weight under densely populated plants and vice versa

4. Conclusion

It was concluded that optimal plant population (70,000 plants ha^{-1}) has allowed maize to intercept and use available resources more efficiently which contribute in remarkable increase of grain yield**.**

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Competing Interests

Authors declare that they have no competing interests.

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