MAIZE CULTIVAR RESPONSE TO POPULATION DENSITY AND PLANTING DATE FOR GRAIN AND BIOMASS YIELD

Abdul Aziz*, Hidayat ur Rehman** and Najibullah Khan***

ABSTRACT

Three maize genotypes viz; Pahari (short season), Kisan (mid season) and Ehsan (full season) were evaluated at four planting densities (30,000; 60,000; 90,000 and 120,000 plants ha^{-1}) and four planting dates (June 16, July 01, July 16 and August 01) at Cereal Crops Research Institute (CCRI) Pirsabak, Nowshera (Pakistan) to determine the optimum planting density and date for grain and biomass yield. Planting on July 01, registered the highest grain yield which was 18 and 19% more than planting on June 16 and August 01, respectively. Mid season maize cultivar Kisan gave 17% more grain yield than short season cultivar Pahari and 6% more than full season cultivar Ehsan. The planting density of 90,000 plants ha^{-1} gave 25% higher grain yield than planting density of 30,000. Early planting on June 16 produced 11% more biomass than late planting on August 01. Full season cultivar Ehsan yielded 22% more biomass than did short season cultivar Pahari. The highest density of 120,000 plants ha^{-1} gave 38% more biomass than 30,000 plants ha^{-1}. It is concluded that maize variety Kisan may be planted on July 01 at density of 90,000 plants ha^{-1} in Peshawar valley for obtaining maximum grain yield.

Keywords: Population density, Biomass, Dry matter accumulation, Solar radiation interception, Assimilates partitioning.

INTRODUCTION

Maize (*Zea mays L*) ranks second to wheat in total production on global basis. It is the third most important cereal crop after wheat and rice in Pakistan and is one of the valuable crops of the North-West Frontier Province (NWFP), where more than half of the maize in the country is produced. It is a staple food in NWFP and is used in bread making, corn flakes, corn syrup, cornstarch, textiles, paper making and food industries as well. A by-product of corn industry i.e. corn oil contains sufficient amount of un-saturated fatty acids and is thus most suitable for human consumption in place of oil derived from animal sources.

Like other field crops, maize growth and grain yield is also affected by several factors. Late sowing of maize manifested significant reduction in grain yield. Stabbenborg *et al.* (1999) reported that low growth rate in the late sown crop is mainly due to unfavorable environmental effects encountered during the reproductive phase and due to the low net assimilation rate. Ahmad *et al.* (2001) suggested July 15 as an optimum planting date for maize in Peshawar region. Variation in biomass yield across sowing dates was associated more with differences in the amount of radiation intercepted than differences in radiation use efficiency. Shorter hybrids had greater assimilate allocation to the grain than the taller hybrids (Benga *et al*. 2000). Higher rain yield has been reported in mid-season maize varieties by several researchers (Aziz *et al*. 1992; Taran et al. 1998 and Revilla *et al.* 2000).

Maize plant population for maximum economic grain yield varies from 30,000 to 90,000 plants ha^{-1} depending on planting date, water availability, soil fertility and maturity (Sangoi, 2001). Improved endurance in high stands has allowed maize to intercept and use solar radiation more efficiently, contributing to the remarkable increase in grain yield potential. Pepper (1974) reported that increased plant densities promote utilization of solar radiation by maize canopies. However, efficiency of conversion of intercepted solar radiation into economic maize yield will decrease with high plant density because of mutual shading of plants. Dry matter production in crop plants is directly related to the utilization of solar radiation, which is influenced by canopy structure (Daughtry *et al.* 1983). Alessi and Power (1975) observed that total dry matter production was maximum at

* Agricultural Research Institute, D.I. Khan - Pakistan
** Department of Plant Breeding and Genetics, NWFP Agricultural University, Peshawar - Pakistan
*** Crop Science Division, Pakistan Agricultural Research Council, Islamabad - Pakistan

the highest plant densities. The objective of this study was to explore the response of maize cultivars to various planting dates combined with different plant densities in terms of grain and biomass yield.

MATERIALS AND METHODS

Field experiments were conducted from 1998 to 2000 at the CCRI Pirsabak, Nowshera (34^0 N latitude and 288 m elevation) Pakistan. Soil type at the institute is sandy loam with PH 7.7 and low (0.62%) in organic matter. The four planting dates were June 16, July 01, July 16 and August 01 in all the study years. Three cultivars, one each from three relative maturity groups were seeded in four population densities at each time. The cultivars, all developed at CCRI Pirsabak, were Pahari (an early maturing variety of 80-85 days), Kisan (a medium maturing variety of 90-95 days and Ehsan (a late maturing variety of 100-110 days). Plant densities were 30,000, 60,000, 90,000 and 120,000 plants ha^{-1}. There were four replications using split-split plot arrangements in which the planting dates were assigned to main plots, cultivars to sub-plots and plant density levels to sub-subplots. Each sub-subplot had an area of 15 m^2 comprising four rows 5m long and 75cm apart. Distance between plants varied from 44cm to 11cm at 30 and 120 thousand plants ha^{-1}, respectively. All plots were hand planted having 02 seeds per hill and were thinned to the desired density 20 days after sowing. Fertility level were adjusted to obtain maximum maize yield by applying 150 kg ha^{-1} N in two split doses and 75 kg ha^{-1} P_2O_5. Half of N and all P_2O_5 were applied at planting time. The remaining N was applied 30 days after sowing. Primextra (Atrazine) herbicide was applied as pre-emergence at the rate of 2.5 L ha^{-1}. Plots were also hand weeded during crop season when needed. Furadan granule (Insecticide) was applied at the rate of 15 kg ha^{-1} in two doses, 10 and 25 days after emergence to control stem borer (*Chillo Partellus Swin).* Crop was irrigated as and when required. A net plot area of 7.5 m^2 (two central rows) was harvested from each plot soon after physiological maturity. Immediately after maturity, the plants were cut at ground level and weighed for biomass yield. Biomass yield, defined as the above ground weight of a crop at harvest, was calculated following Stoskopf (1981). Fresh ear weight of each plot was recorded and grain moisture content (mc) determined. Harvested ears were dried, shelled and the grain and cob weights recorded separately. Shelling percentages were, therefore, measured directly. Grain yield was adjusted to 14% mc using the formula as described by Aziz *et al.* (1992).

$$\text{Grain Yield (tons ha}^{-1}) = \frac{\text{Fw (100-mc\%) x shel\% x 10,000}}{\text{86x 7.5 x 1000}}$$

Fw	=	Fresh weight of ear (kg per plot)
Mc %	=	Moisture contents (%) in the grain at harvest
Shel %	=	Shelling percentage
10,000	=	Square meters per hectare
86	=	(100-14) as the 14% standard moisture content
7.5	=	Area per plot in m^2
1000	=	kg in a ton

The data were subjected to ANOVA technique using MSTATC computer software individually for all the traits, to assess statistical differences among the treatments.

Grain Yield

The data in Table 1 indicated that grain yield of maize was significantly ($P<0.01$) affected by planting date with highest grain yield of 6.00 tons ha^{-1} obtained, when the crop was sown on July 1. Lowest grain yield of 4.87 tons ha^{-1} was noted with planting on August 01. Cultivars also differed significantly ($P<0.01$) for grain yield, with highest grain yield of 5.80 tons ha^{-1}, produced by medium maturity cultivar Kisan. Early maturing cultivar Pahari gave the lowest yield of 4.80 tons ha^{-1}. Analysis of variance also revealed significant ($P<0.01$) interaction between cultivars and planting dates. The cultivar Kisan gave higher grain yield (6.56 tons ha^{-1}) when sown on 1st July, while lowest grain yield (4.21 tons ha^{-1}) was recorded in cultivar Pahari with planting on 16^{th} of June. Maize grain yield was significantly ($P<0.01$) affected by various plant density regimes (Table II). Highest grain yield of 5.80 tons ha^{-1} was recorded at 90.000 plants ha^{-1}, thereafter it reduced significantly. Grain yield of 4.36 tons ha^{-1} was obtained at lowest density of 30,000 plants ha^{-1}.

Significant interaction ($P<0.01$) was noted between planting date x plant density. Grain yield was highest at a density of 90,000 plants ha^{-1} with sowing on 1^{st} July, whereas lowest grain yield was found at a density of 30,000 plants ha^{-1} with 1^{st} August planting. Combined analysis showed significant interaction ($P<0.01$) between cultivar x plant density. Results (Table III) revealed that cultivar Kisan and Ehsan gave highest grain yield at a density of 120,000 plants and 60,000 plants ha^{-1}, respectively. Grain yield was lowest for cultivar Pahari at a density of 30,000 plants ha^{-1}.

Grain yield was highest with July 01 planting (Table I). The results revealed that grain yield was decreased by 25 and 50 kg ha^{-1}, with delay of one day in sowing from July 01 to 16 and July 16 to August 01, respectively. The increase in grain yield of 1^{st} July sown crop could be attributed to improvement in ears per plant, grains per ear, and 1000-grain weight. Decrease of 18 and 19% in grain yield under early and late sowing, respectively might be due to lower nutrient uptake and reduced photosynthetic translocation in the developing grain. It is therefore, evident that July 01 is optimum planting time for maize grain production in Peshawar region. These results are in line with Fakorede (1985) who also reported a decrease of 30-38 kg ha^{-1} in maize grain yield for each day of delayed sowing. Highest grain yield with optimum planting time has been reported by Martiniello (1985) and Albus *et al.*(1990). Yield increased with optimum planting date probably due to improved physiological conditions during the silking period for optimum kernel set (Barbieri *et al.* 2000). Ahmad *et al.* (2001) concluded that delayed sowing decreased shelling percentage, which ultimately resulted in lower grain yield. Cultivar Kisan produced 6 and 17% more grain yield than cultivars Ehsan and Pahari, respectively (Table I). This cultivar showed better performance in all environments at higher plant density. The superior performance of cultivar Kisan could be attributed to its inherent yield potential and its better response to the environmental stress created by the increased plant density and changing planting dates. It could be argued that Kisan, a mid-season cultivar of maize, was less affected by seasonal fluctuations. Availability of earlier hybrids with shorter plants, lower leaf number, upright leaves, smaller tassels and reduced anthesis silking interval has enhanced the ability of maize to withstand high plant populations without showing excessive barrenness (Sangoi, 2001).

Highest grain yield obtained with density of 90,000 plants ha^{-1} (Table III) might be due to large number of plants m^2 which compensated the effects of decrease in other yield components like grain weight, ears $plant^{-1}$ and grains ear^{-1}. These components though decreased on per se basis, yet yield actually increased on per unit area basis. Plants grown with wider spacing consume more nutrients and absorb more solar radiation for improved photosynthesis and hence perform better at individual basis. The reason for deviation of this linearity in case of grain yield per unit area is that the yield does not solely depend on the performance of individual plant but is also dependent on total number of plants per unit area and yield contributing parameters. Higher grain yield (25%) was observed at higher density up to an optimum limit i.e. 90,000 plants ha^{-1}. These studies revealed that a density of 90,000 plants ha^{-1} would be the optimum for maximum grain production for the genotypes tested. Akbar *et al.* (1996) reported that optimum plant density produced greater yield due to utilization of available soil nutrients more efficiently coupled with other growth factors. They also observed lowest grain yield with highest density because of smaller ear size, less number of ears $plant^{-1}$ due to more competition for growth factors. Porter *et al.* (1997) suggested that plant distribution was a yield limiting factor when other limiting factors, such as nutrient deficiencies were eliminated.

Biomass Yield

Results showed that planting dates effects on biomass production were significant (Table IV). Biomass yield decreased consistently with subsequent delays in sowing. Highest biomass yield of 20.69 tons ha^{-1} was recorded with early planting on June 16, while the lowest biomass yield of 18.45 tons ha^{-1} was obtained with late sowing (August 01). Significant difference for biomass yield was also observed among the genotypes. Highest biomass yield of 21.54 tons ha^{-1} was obtained for cultivar Ehsan, while cultivar Pahari gave the lowest biomass yield (16.83 tons ha^{-1}). Interaction between planting date x cultivar was also significant ($P<0.01$). Highest biomass yield of 23.42 tons ha^{-1} was produced with sowing on June 16 for cultivar Ehsan and the lowest biomass yield was recorded for cultivar Pahari with late planting on August 01.

Plant density also had significant (P<0.01) effect on biomass yield (Table V) as biomass yield increased progressively with successive increase in plant density. Biomass yield was maximum (23.58 tons ha^{-1}) at highest density (120,000 plants ha^{-1}). On the other hand, the lowest biomass yield of 14.53 tons ha^{-1} was obtained at the lowest density of 30,000 plants ha^{-1}.

Significant interaction (P<0.01) was observed between planting date x plant density for biomass yield. Maximum biomass yield of 24.63 tons ha^{-1} was noted at the highest plant density with early sowing on June 16. Lowest density of 30,000 plant ha^{-1} with late planting on August 01 gave the lowest biomass yield of 13.81 tons ha^{-1}.

The data revealed that biomass yield increased 11% with early planting on June 16 (Table V). This may be due to efficient use of solar radiation in early season. Late planting reduced vegetative growth because of less photosynthetic activity at later stages of plant growth. Late planting reached the critical day length quickly, which terminated vegetative growth, resulting in shorter plants with fewer and smaller leaves. Reduction in vegetative growth might have ultimately resulted in lower biomass yield. Crop growth rate depends on the amount of radiation intercepted by the crop and on the efficiency of conversion of intercepted radiation into dry matter. Dale and Drennan (1997) noted highest biomass yield with early planting.

Vigorous vegetative growth, greater dry matter accumulation and less photoassimilates partitioning from vegetative to reproductive phase are the main indicators of higher biomass yield (Akbar *et al.* 1996). Cultivar Ehsan gave 22% more biomass yield than cultivar Pahari (Table IV). Late maturing cultivars took more days to maturity and hence had a better chance to utilize more nutrients and more photosynthetic activity, which ultimately resulted in higher biomass production. It can be concluded that cultivar Ehsan, when grown early, will produce maximum biomass yield, expressing full varietal potential by exposure to extended growing season and supplemented by maximum number of plants at highest density. Biomass yield was maximum at highest density (Table V). An increase of 38% in yield at highest density may be due to the greater number of plants per unit area, which ultimately resulted in higher biomass yield. Megyes *et al.* (1999) also reported significant biomass yield reduction at lowest plant density. Crop growth rate is positively correlated with leaf area, increasing rapidly with the increase in leaf area index (LAI). Thus the increasing total dry matter production at higher population is the result of higher LAI (Bahadur *et al.* 1999).

CONCLUSION

It could be concluded from the present study that maize varieties should be cultivated according to the areas of their adaptability for increased grain and biomass yield per unit area. The study further indicated that Kisan is an ideal maize cultivar for higher grain production when planted on July 01 in Peshawar valley at optimum density of 90,000 plants ha^{-1}.

Table I ***Grain yield (tons ha^{-1}) of maize cultivars as affected by planting dates***

	Planting Dates				
Cultivars (C)	**June 16**	**July 01**	**July 16**	**August 01**	**C. Mean**
Pahari	4.21 f	5.29 d	5.21 d	4.51 ef	4.80 c
Kisan	5.36 c	6.56 a	6.02 b	5.28 d	5.80 a
Ehsan	5.20 d	6.17 b	5.66 c	4.81 e	5.46 b
P. Mean	4.93 c	6.00 a	5.63 b	4.87 c	

Means followed by different letters are significantly different at P<0.01.

Table II ***Grain yield (tons ha^{-1}) of maize of as affected by plant densities and planting dates***

	Planting Dates (P)				
Density (Plants ha^{-1})	**June 16**	**July 01**	**July 16**	**August 01**	**D.Mean**
30,000	4.11 g	4.92 e	4.50 f	3.89 g	4.36 c
60,000	5.26 cd	6.30 a	5.92 b	5.31 cd	5.70 ab
90,000	5.38 cd	6.40 a	6.16 b	5.27 cd	5.80 a
120,000	4.92 e	6.39 a	5.93 b	5.01e	5.57 b
P.Mean	4.93 c	6.00 a	5.63 b	4.87 c	

Means followed by different letters are significantly different at P<0.01.

Table III ***Grain yield (tons ha^{-1}) of maize cultivars as affected by plant densities***

	Cultivars (C)			
Density (Plants ha^{-1})	**Pahari**	**Kisan**	**Ehsan**	**D. Mean**
30,000	3.70 f	4.66 e	4.71 e	4.36 c
60,000	4.89 e	5.82 b	6.38 a	5.70 ab
90,000	5.47 c	6.34 a	5.59 bc	5.80 a
120,000	5.16 d	6.38 a	5.17 d	5.57 b
C. Mean	4.80 c	5.80 a	5.46 b	

Means followed by different letters are significantly different at P<0.01.

Table IV ***Biomass yield (tons ha^{-1}) of maize cultivars as affected by planting dates***.

	Planting Dates (P)				
Cultivars(C)	**June 16**	**July 01**	**July 16**	**August 01**	**C.Mean**
Pahari	16.86 e	17.56 e	16.59 e	16.29 e	16.83 c
Kisan	21.79 b	21.01 bc	19.66 d	19.15 d	20.40 b
Ehsan	23.42 a	21.15 bc	21.69 b	19.91 cd	21.54 a
P.Mean	20.69 a	19.91 bc	19.32 b	18.45 c	

Means followed by different letters are significantly different at P<0.01.

Table V ***Biomass yield (tons ha^{-1}) of maize as affected by planting dates and plant densities***

	Planting Dates (P)				
Density (Plants ha^{-1})	**June 16**	**July 01**	**July 16**	**August 01**	**D. Mean**
30,000	15.50 k	14.22 i	14.60 i	13.81 I	14.53 d
60,000	19.90 h	18.86 i	18.11 ij	17.80 J	18.67 c
90,000	22.72 cd	22.15 de	20.98 fg	20.48 gh	21.58 b
120,000	24.63 a	24.40 ab	23.58 bc	21.72 ef	23.58 a
P.Mean	20.69 a	19.91 ab	19.32 b	18.45 b	

Means followed by different letters are significantly different at P<0.01.

REFERENCES

Ahmad, N., A. Waheed and F. S. Hamid. 2001. Different sowing dates of maize cultivars and their performance. Pakistan J. Biol. Sci. 1: 106-108.

Akbar, H., P. Shah, A.Z. Khan, H. Saeed and M. Munir. 1996. Biomass, grain yield and harvest index as criteria for comparing corn types at different nitrogen levels and planting densities. Sarhad J. Agric. 12: 117-121.

Albus, W.L., J. Weigel and H. Sayfikar. 1990. The effect of planting date on irrigated corn in South Eastern North Dakota. North Dakota for Res. 2: 21-25.

Alessi, J. and J.F. Power. 1975. Effect of plant spacing on phenological development of early and mid season corn hybrids in a semiarid region. Crop Sci. 15: 179-182.

Aziz, A., M. Saleem., H. Rahman and F. Muhammad. 1992. Genetic variability for yield and disease resistance in full and short-season varieties of maize. Sarhad J. Agric. 8: (2) 195-198.

Bahadur, M. M., M. Ashrafuzzaman, M.F. Choudhury and S.M. Shahidullah. 1999. Growth and yield components response of maize as affected by population density. Pakistan J. Biol. Sci. 4: 1092-1095.

Barbieri, P.A., H.R.S. Rozas, F.H. Androde and H.E. Echevevria. 2000. Row spacing effects at different levels of nitrogen availability in maize. Agron. J. 92: 283-288.

Benga, S. H., R.I. Hamilton, L.M. Dwyer and D.L. Smith. 2000. Variability among maize hybrids differing in canopy architecture for above ground dry matter and grain yield. Maydica. 45: 135-141.

Dale, A.E. and D.S.H. Drennan. 1997. Transplanted maize for grain production in Southern England. II. Effects of planting date, transplant age of planting cultivar on growth, development and harvest index. J. Agric. Sci. 128:37-44.

Daughtry, C.S.T., K.P. Gallo and M.E. Bauer. 1983. Spectral estimates of solar radiation intercepted by corn canopies. Agron J. 72:527-531.

Fakorede, M.A.B. 1985. Response of maize to planting dates in a tropical rain forest location. Nigeria Exptl. Agric. 21: 19-30.

Martiniello, P. 1985. Recurrent visual selection in S_1 progenies for early vigor in maize. Maydica 30: 301-308.

Megyes, A., A. Dobos, T. Ratonyi, and L. Huzsval. 1999. Effect of fertilization and plant density on the dry matter production of maize hybrids. Cereal Res. Comm. 27:433-438.

Pepper, G.E. 1974. Effect of leaf orientation and density on the yield of maize Ph. D. Thesis Iowa State Univ. Ames, lowa (USA).

Porter, P.M., D.R. Hicks, W.E. Lueschen, J.H. Ford, D.D. Warnes and T.R. Hovertad. 1997. Corn response to row width and plant populations in the northern corn belt. J. Prod. Agric. 10: 293-300.

Revilla, P., P. Velasco, M.I. Vales, RA.A. Malvar and A. Ordas. 2000. Cultivar heterosis between sweet and Spanish field corn. J. American Soc. Hort. Sci. 125: 684-688.

Sangoi, L. 2001. Understanding plant density effect on maize growth and development: an important issue to maximize grain yield. Ciencia Rural. 31: 159-168.

Staggenborg, S.A., D.L. Fjell, D.L. Devlin, W.B. Gordon, L.D. Maddux and B.H. Marsh. 1999. Selecting optimum planting date and plant population for dry land corn in Kansas. J. Prod. Agric. 12: 85-90.

Stoskopf, N.C. 1981. Understanding crop production. Reston publishing Co., Inc, Reston, Virginia. Pp.131.

Taran, S.A., M.S. Kakar and R.A. Bugti. 1998. Performance of maize varieties / hybrids under irrigated condition of Balochistan. Sarhad J. Agric. 14: 113-116.