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# EFFECT OF PLANTING DENSITY ON PHENOLOGY, GROWTH AND YIELD OF MAIZE (*ZEA MAYS* L.)

MOHAMMAD SHAFI[1*], JEHAN BAKHT[2], SAJJAD ALI[1], HAMAYOON KHAN[1]
MOHAMMAD AMAN KHAN[4] AND MOHAMMAD SHARIF[3]

[1]*Department of Agronomy,* [2]*Institute of Biotechnology and Genetic Engineering,*
[3]*Department of Soil & Environmental Sciences Khyber Pukhtunkhwa Agricultural University Peshawar Pakistan*
[4]*Department of Biotechnology QAU. Islamabad Pakistan*
[*]*Corresponding author E-mail: mshafi.aup@gmail.com*

**Abstract**

The present study investigated the effect of planting density on plant growth and yield of maize varieties. An experiment was conducted at Agricultural Research Farms Khyber Pukhtunkhwa Agricultural University Peshawar, Pakistan using randomized complete block (RCB) design with split plot arrangement having four replications. The experiment consist of four maize varieties viz., Azam, Pahari, Jalal-2003 and Sarhad white as main plot factor and three plant densities of 45000, 55000 and 65000 plants ha$^{-1}$ as sub plot factor. Analysis of the data indicated that planting density had a significant ($p<0.05$) effect on leaf area index, plant barrenness (%), plant height, ear length, number of grains ear$^{-1}$, grain weight ear$^{-1}$, 1000 grain weight, biological yield, stover yield, grain yield and harvest index and non-significant ($p>0.05$) on number of days to emergence, emergence m$^{-2}$, number of days to 50% tasseling and silking. Maximum leaf area index, barrenn plants, plant height, biological yield, stover yield, grain yield and harvest index was recorded from planting density of 65000 plants ha$^{-1}$. Maize varieties significantly ($p<0.05$) affected emergence m$^{-2}$, days to 50% tasseling, days to 50% silking, leaf area index, plant height, ear length, number of grains ear$^{-1}$, grain weight ear$^{-1}$, biological yield, stover yield, grain yield and harvest index. Maximum ear length was recorded from variety Azam. Maximum days to 50% tasseling and silking were recorded from Jalal-2003. Similarly, emergence m$^{-2}$, leaf area index, plant height, number of grains ear$^{-1}$, grain weight ear$^{-1}$, biological yield, stover yield, grain yield and harvest index was maximum in Sarhad white. The combined effect of Sarhad white with planting density of 65000 plants ha$^{-1}$ produced highest grain weight cob$^{-1}$, biological yield, stover yield, grain yield and harvest index.

## Introduction

Maize (*Zea mays* L.) is a very important cereal crop of the world including Pakistan. Maize is ranked third among cereal crops after wheat and rice. Maize is used as staple food. Maize is also used as feed for livestock. It is well recognized fact that inputs like improved varieties, irrigation, sowing time, plant population and balanced use of fertilizers each has an effective role in enhancing the yield of crop. In cereal crops maize presents the highest grain yield potential. In order to fully explore its capacity in grain production, it is necessary to understand how plants interact morphologically and physiologically in a community and to identify management practices which allow them to maximize the use of growth requirements in their environment. Plant density is one of the most important cultural practices which determine grain yield as well as other important agronomic attributes of this crop (Songoai, 2001). Maximum crop production can be achieved by development of improved crop varieties and suitable growing environment and soil with optimum plant population ha$^{-1}$. Optimum plant population is the pre-requisite for obtaining maximum yield (Trenton *et al.*, 2006; Gustavo *et al.,* 2006). In dense population most plants remain barren, ear and ear size remain smaller, crop become susceptible to lodging, disease and pest, while plant population at sub-optimum level resulted lower yield per unit area (Nasir, 2000). High plant population leads to lodging of maize plants (Trenton & Joseph, 2007). In case of high population, most plants bear barren ears, smaller ear in size, crop becomes susceptible to lodging and pest attack. In case of low plant density, yield per unit area is reduced because of lesser than optimum plants (Cardwell, 1982). The main objectives of this study were to investigate the effect of planting density and varieties on plant growth and yield of maize.

## Materials and Methods

The experiment was conducted at Agricultural Research Farms Khyber Pakhtunkhwa Agricultural University, Peshawar, Pakistan using randomized complete block (RCB) design with split plot arrangements with a sub plot size of 4m x 4.5m having four replications. Four varieties of maize viz., Azam, Pahari, Jalal-2003 and Sarhad white were allotted to main plots while three planting density of 45000, 55000 and 65000 plants ha$^{-1}$ to sub plots. All inputs and agronomic practices were carried out uniformly for experimental area. Plant population was adjusted by thinning at 4-5 leaf stage in each subplot.

**Procedures for data recording:** Days to emergence were counted from the date of sowing till when 50% seedling emerged in each sub-plot. Emergence m$^{-2}$ was recorded after complete emergence in three central rows in each subplot. The seedlings were counted in one meter row length and then converted to m$^{-2}$. Days to 50% tasseling and silking were recorded when more than 50% of the plants produced tassels and silks in each sub-plot. Leaf area index of five randomly selected plants were calculated by dividing leaf area plant$^{-1}$ in each sub plot by ground area covered by the plant m$^{-2}$. Un-productive plants in each sub plot were counted and barren plants percentage was worked out. Plant height was measured in cm at maturity by measuring plant height from ground level to the tip of the tassel of five randomly selected plants in each sub-plot and the average was worked out. Ear length of five randomly selected plants was measured in each sub-plot. To record number of grains ear$^{-1}$, five ears in each sub-plot were randomly selected and their average was worked out. Grains of five randomly selected ears were weighed separately to record grain weight ear$^{-1}$.

One thousand grains were taken randomly from each sub-plot and weighed by an electronic balance for 1000 grain weight. Each sub-plot was harvested at their maturity, tied into bundles separately, sun dried and weighed by spring balance and then converted to kg ha$^{-1}$. To record stover yield (kg ha$^{-1}$) data, each-sub plot was harvested at maturity, ears were removed and only dry stems were weighed after sun drying. Grain yield from three central rows in each sub-plot was recorded and converted into kg ha$^{-1}$. Harvest index was calculated as percent of a ratio of grain yield and biological yield.

**Statistical analysis:** All data are presented as mean values of three replicates. Data were analyzed statistically for analysis of variance (ANOVA) following the method described by Gomez & Gomez (1984). MSTATC computer software was used to carry out statistical analysis (Bricker, 1991). The significance of differences among means was compared by using Least Significant Difference test (Steel & Torrie, 1997).

## Result and Discussion

**Phenology and plant growth:** Days to emergence was on-significantly ($p>0.05$) affected by varieties, planting density and their interactions (Fig. 1). These findings are in agreement with Penuar & Sirrbie (1989) who reported that planting density has non significant affect on number of days to emergence. Emergence unit area$^{-1}$ is considered as an important parameter that determines the vegetative stand of a crop. Emergence unit area$^{-1}$ depends on various external and internal factors. Emergence m$^{-2}$ was significantly ($p<0.05$) affected by varieties, while non-significant ($p>0.05$) variations were recorded due to different planting density. Among varieties, Sarhad white showed maximum emergence m$^{-2}$ (Fig. 2) Significant differences among varieties in emergence m$^{-2}$ could be due to differences in their genetic make up. Statistical analysis of the data also showed that days to 50% tasseling and silking were significantly ($p<0.05$) affected by varieties. Plant population and their interaction with varieties were non-significant ($p>0.05$; Figs. 3 and 4). Jalal-2003 took more number of days to 50% tasseling and silking when compared with other varieties under study. It could be due to differences in genetic make up of these varieties. Hassan (1987) revealed that maize cultivars had significant differences in days to 50% silking. Park *et al.,* (1987) reported that plant density did not affect days to tasseling and silking. Leaf area is usually influenced by genotype, planting density, climate and soil fertility.

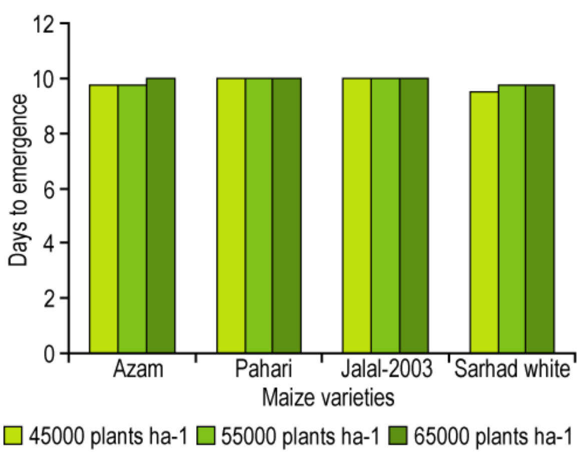


Fig. 1. Days to emergence of maize varieties as affected by different plant density.

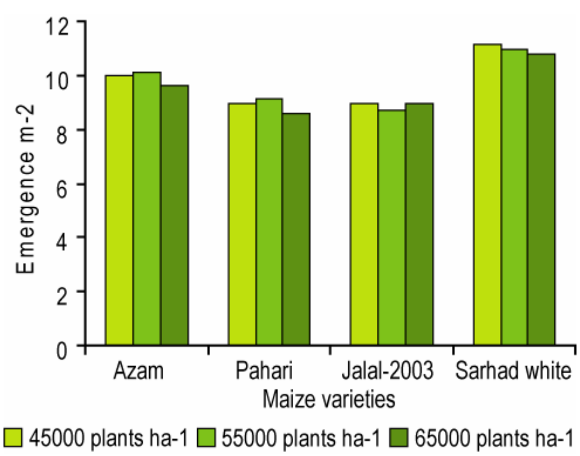


Fig. 2. Emergence m$^{-2}$ of maize varieties as affected by different plant density.

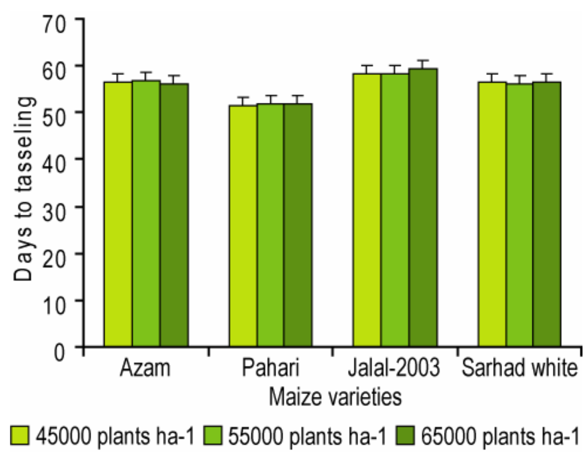


Fig. 3. Days to tasseling of maize varieties as affected by different plant density. Bars shows LSD at $p<0.05$.

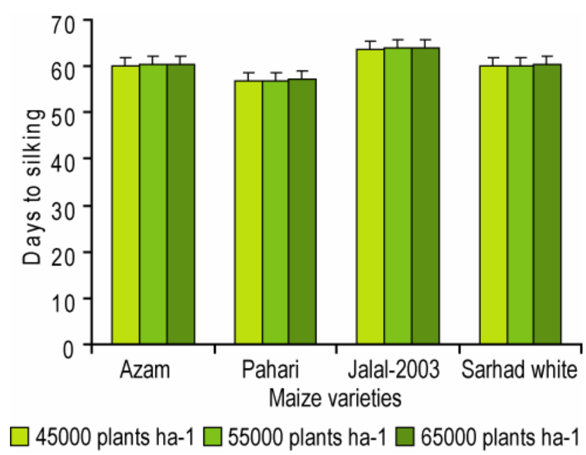


Fig. 4. Days to silking of maize varieties as affected by different plant density. Bars shows LSD at $p<0.05$.

Leaf area index was significantly ($p<0.05$) affected by planting density and varieties, while their interactive effect was non-significant ($p>0.05$; Fig. 5). Our results indicated that highest leaf area index was observed in planting density of 65000 plants $ha^{-1}$ when compared with other treatments. These results are in agreement with Franc & Martina (2000) who reported that leaf area index increased with increasing plant population from 4.5 to 13.5 plants $m^{-2}$. They further investigated that higher plant population may increase leaf area index to more than 5. Highest leaf area index was recorded by Sarhad white when compared with other varieties. Varietal characteristics and efficient utilization of available resources also influence leaf area index. These results agree with those reported by Park *et al.,* (1989). Plant population and varieties had a significant ($p<0.05$) effect on plant height (Fig. 6) Maximum plant height was recorded from the treatment of 65000 plants $ha^{-1}$. Minimum plant height was attained by 45000 plants $ha^{-1}$. Taller plants were attained by Sarhad white, whereas shorter by Pahari. These results are in agreement with Sharma & Adamu (1984) who reported that plant height was maximum at highest population. Yaday & Warsi (1986) also confirmed these results who reported that plant height decreased with low planting density and *vice versa*. Hassan (2000) revealed that plant height increased with increasing plant density from 47600 to 71400 plants $ha^{-1}$.

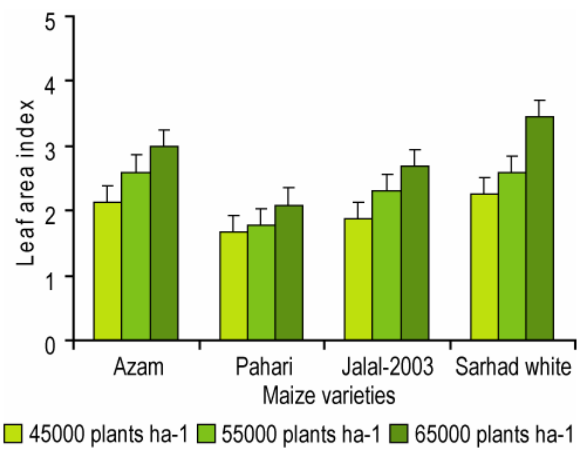


Fig. 5. Leaf area index of maize varieties as affected by different plant density. Bars shows LSD at $p<0.05$.

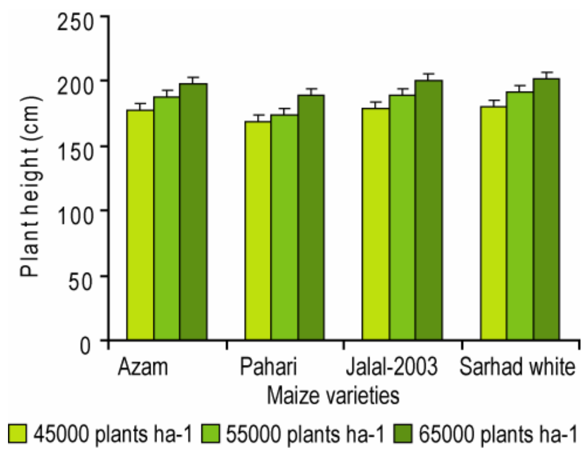


Fig. 6. Plant height of maize varieties as affected by different plant density. Bars shows LSD at $p<0.05$.

**Yield and yield components:** Plant barrenness percentage represents the capacity of a crop to produce more non-productive plants. Plant barrenness percentage was significantly ($p<0.05$) affected by plant population while the effect of varieties and their interactions was non significant ($p>0.05$). Maximum barren plants were counted in planting density of 65000 plants $ha^{-1}$ and minimum in plant population of 45000 plants $ha^{-1}$ (Fig. 7). This may be due to limitation of reproductive partitioning in highest plant density. At low plant population the reproductive sink capacity of individual plant are greater as compared to high plant population. Significant differences among plant population have been reported by Das & Kashyapi (1984). They concluded that increasing the plant population of maize more earless stalks (barren plants) were produced. Our results also revealed that plant population and varieties had a significant ($p<0.05$) effect on ear length (Fig. 8). Highest plant population had a negative impact on ear length. Ear length was more in planting density of 45000 plants $ha^{-1}$ when compared with other treatments. This may be due to the fact that available nutrients, moisture, space and light become limited in high plant population due to high competition of soil resources between plants. Ultimately plants produced relatively small ears. Maximum ear length was observed in case of variety Azam and minimum from Pahari. Similar results were reported by Chakor & Awasthi (1983); Esechie (1992) and Hassan (2000). They observed that ear length decreased with increase in plant population.

Number of grains $ear^{-1}$ contributes to the economic yield as well as represent the productive efficiency of any cereal crop or crop variety. Grains $ear^{-1}$ (Fig. 9) was significantly ($p<0.05$) affected by planting density and varieties while their interactions were non-significant ($p>0.05$). Highest plant density negatively affected number of grains $ear^{-1}$. With increasing plant population, number of grains $ear^{-1}$ decreased in a linear manner. Maximum number of grains $ear^{-1}$ was observed at plant density of 45000 plants $ha^{-1}$ when compared with other treatments. Among varieties, highest number of grains $ear^{-1}$ was recorded for Sarhad white while minimum by Pahari. This could be due to the fact that in high planting density, photosynthetic capability of plants was reduced due to the low light interception that negatively affected number of grains $ear^{-1}$. These results are in line with Esechie (1992) and Zada (1998) who found that the number of grains $ear^{-1}$ decreased with increasing plant density. Significant ($p<0.05$) variations were noted for grain weight $ear^{-1}$ due to planting density and varieties. Highest grain weight $ear^{-1}$ was reported from the treatment of plant population of 45000 plants $ha^{-1}$ and lowest from 65000 plants $ha^{-1}$ (Fig. 10). It may be due to source sink relationship and competition among maize plants for nutrients. These results are in agreement with Sharma & Adamu (1984) who reported that grain weight $ear^{-1}$ was highest at lowest plant population. The data also indicated that maximum grain weight $ear^{-1}$ was produced by Sarhad white whereas minimum was recorded from Pahari. These results agree with the findings of (Penuar & Sirrbie, 1989).

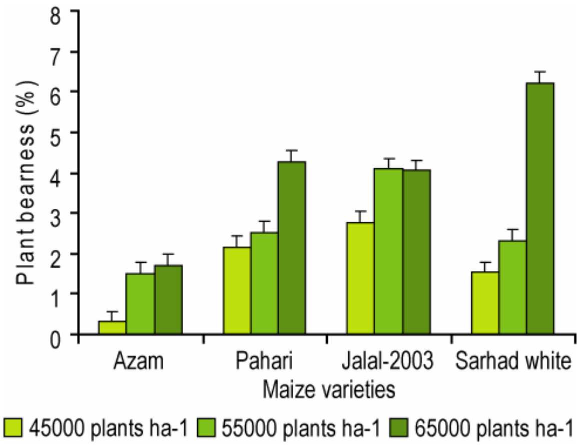


Fig. 7. Plant bearness of maize varieties as affected by different plant density. Bars shows LSD at $p<0.05$.

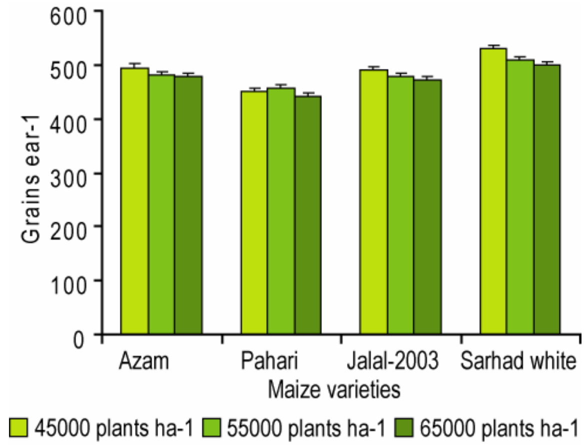


Fig. 9. Grain ear-1 of maize varieties as affected by different plant density. Bars shows LSD at $p<0.05$.

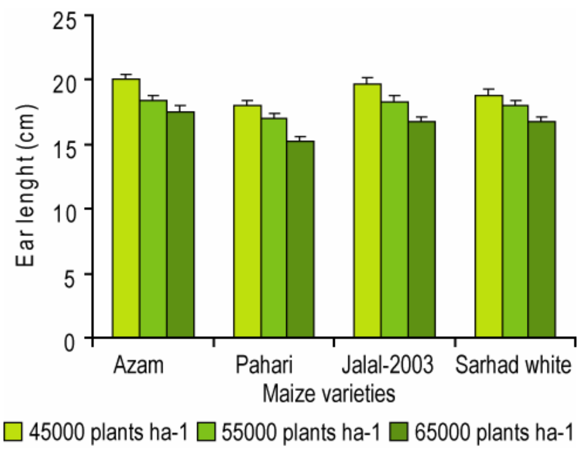


Fig. 8. Ear length of maize varieties as affected by different plant density. Bars shows LSD at $p<0.05$.

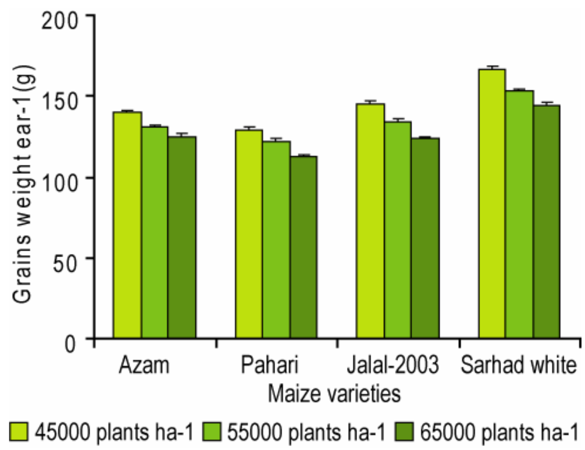


Fig. 10. Grain weight ear-1 of maize varieties as affected by different plant density. Bars shows LSD at $p<0.05$.

Fig. 11 indicated that planting density had significantly ($p<0.05$) affected thousand grain weight while varieties and their interaction with plant density was non-significant ($p>0.05$). Increasing planting density had a negative impact on thousand grain weight. Increasing plant population decreased thousand grain weights. Maximum thousand grain weight was produced by planting density of 45000 plants ha$^{-1}$ when compared with other treatments. The probable reason could be due to minimum light interception and high competition for moisture and nutrients which resulted in low photosynthate accumulation. These results are consistent with the findings of Dunque & Yayao (1992) who reported that increasing crop density has reduced thousand grain weights. Similarly, it was reported by Akbar (1998) that thousand grain weight decreased by higher density of 125000 plants ha$^{-1}$. Several other studies (Jovin & Veskovic, 1997; Hassan, 2000; Nasir, 2000) confirmed these results. Grain yield or economic yield is an important characteristic and ultimate objective for which most of crops are grown. It depends upon various factors such as soil status, environmental factor, plant population and plant characteristics. Significant ($p<0.05$) variations were observed in grain yield due to plant population, varieties and their interaction. Plant population of 65000 plants ha$^{-1}$ had significantly ($p<0.05$) enhanced the grain yield ha$^{-1}$ (Fig. 12). The reason of increased grain yield may be due to net crop assimilation rate and more number of ears unit$^{-1}$ areas. Our results are supported by Chakor & Awasthi (1983) who reported that the crop planted in 75 cm apart rows with population of 60,000 plants ha$^{-1}$ gave the highest yield. Yaday & Warsi (1986) reported that sweet corn grown at 60,000, 70,000 and 80,000 plants ha$^{-1}$ gave grain yields of 3.18, 3.59, 3.85 tons ha$^{-1}$ respectively. These findings are in line with Hassan (1987) and William & Kurt (2002 a and b). Several other studies reported that plant population is a key factor for attaining maximum grain yield (Narwal *et al.*, 1989; Esechie, 1992; Akbar, 2002). Among varieties, maximum grain yield was produced by Sarhad white. In case of interaction, highest grain yield was recorded by Sarhad white with planting density of 65000 plants ha$^{-1}$ when compared with other treatments. These findings are supported by Khan *et al.,* (1993) who reported highest grain yield of 6817 kg ha$^{-1}$ was produced by maize cultivar Sarhad white and followed by maize variety Azam.

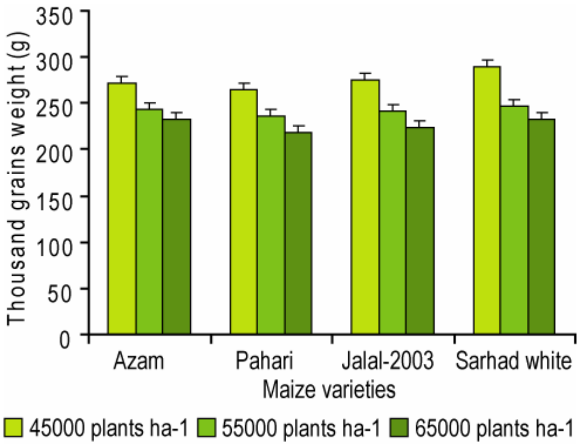


Fig. 11. Thousand grain of maize varieties as affected by different plant density. Bars shows LSD at $p<0.05$.

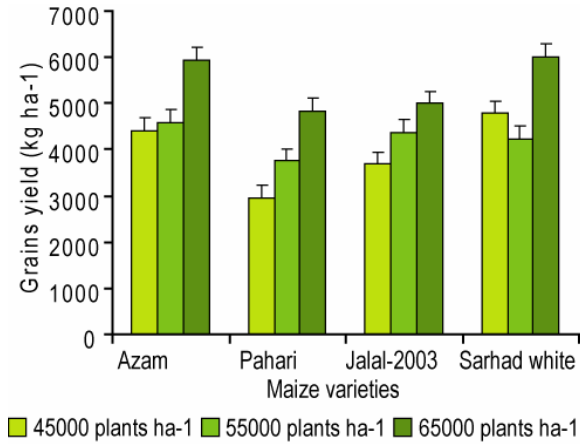


Fig. 12. Grain yield of maize varieties as affected by different plant density. Bars shows LSD at $p<0.05$.

Biological yield is a major contributor to total output of any crop and dependent upon crop management, type of variety and various other factors. Plant population, varieties and interaction between varieties and plant population had significantly (p<0.050 affected biological yield (Fig. 13). Highest biological yield was recorded from the treatment of 65000 plants $ha^{-1}$. Mean values of the data also showed that maximum biological yield was produced by Sarhad white and minimum by Pahari. Akbar *et al.,* (2002) reported that biological yield was significantly ($p<0.05$) increased at 180000 plants $ha^{-1}$. These results are consistent with the findings of Plensicar & Kustori (2005) who reported that maximum biological yield was found at higher planting density. Stover yield (Fig. 14) was significantly ($p<0.05$) affected by plant population, varieties and their interaction. Highest stover yield was recorded from the treatment of 65000 plants $ha^{-1}$ and lowest from the treatment of 45000 plants $ha^{-1}$. In case of varieties, maximum stover yield was produced by Sarhad white. Similarly, maximum stover yield was produced by Sarhad white at planting density of 65000 plants $ha^{-1}$. Park *et al.*, (1989) reported that increasing plant density linearly increased stover yield. Harvest index is the partitioning of dry matter by plant among biological and economic yield. Planting density, varieties and their interaction had a significant effect ($p<0.05$) on harvest index (Fig. 15). Highest harvest index was observed in the treatment of 65000 plants $ha^{-1}$ and lowest in 45000 plants $ha^{-1}$. Similarly, maximum harvest index was recorded from Sarhad white when compared with other varieties. In case of interaction, highest harvest index was observed in Sarhad white at plant density of 65000 plants $ha^{-1}$. The reasons for such results could be better utilization of available nutrients by maize plants in highest plant population as compared to lowest plant population. In lowest plant population, weeds also compete with crop for nutrients. Similarly grain become a dominant sink at their maturity stage and the entire photo-assimilate deposited in the grains as compared to other parts of the plant. Highest plant population produced more grain and thus resulted in maximum harvest index. Ahmad & Khan (2002) reported that increase in plant density significantly increased harvest index.

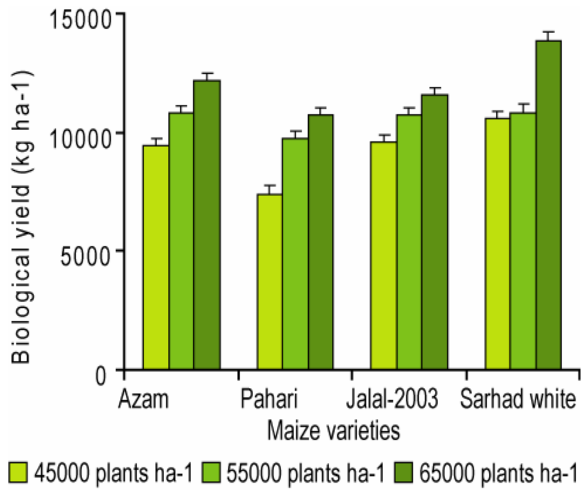


Fig. 13. Biological yield of maize varieties as affected by different plant density. Bars shows LSD at $p<0.05$.

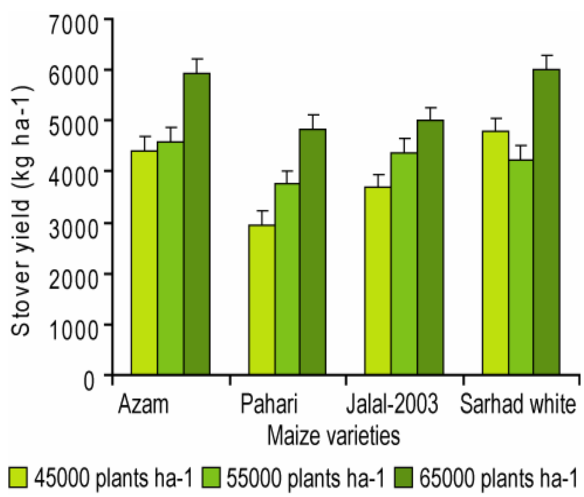


Fig. 14. Stover yield of maize varieties as affected by different plant density. Bars shows LSD at $p<0.05$.

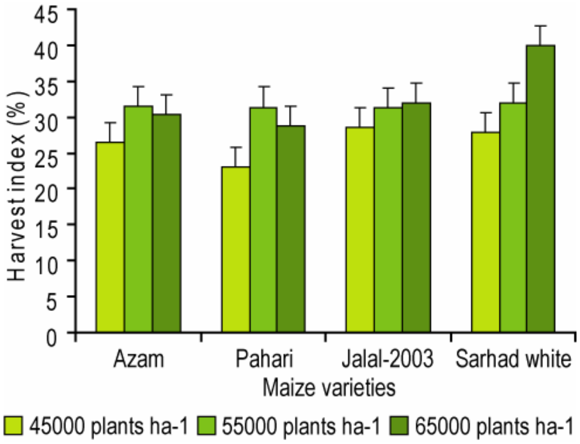


Fig. 15. Harvest index of maize varieties as affected by different plant density. Bars shows LSD at $p<0.05$.

## Conclusion

It can be concluded from the data of the present experiment that the growth and yield of variety Sarhad white was better than the other varieties under test when sown at plant population of 65,000 plants $ha^{-1}$.

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