Research Article

Maize Yield Performance Under Planting Patterns and Row Spacing in Semi-Arid Zone of Pakistan-Mardan

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Abstract | A field study was conducted to investigate the effect of different planting patterns and row spacing on maize yield in the semi-arid zone of Pakistan–Mardan. The experiment was set in Randomized Complete Block Design (RCBD) with three replicates. Effect of five planting patterns i.e. P_1 (Flat planting, row spacing 60 cm), P_2 (Ridge-Furrow planting, row spacing 60 cm), P_3 (Ridge-Furrow planting, row spacing 75 cm), P_4 (Bed planting, row spacing 60 cm, in double rows planting, bed width 60 cm) and P_5 (Bed planting, row spacing 75 cm, double row planting, bed width 60 cm) was investigated using Malakand maize variety. The beds and ridges height were kept 15 cm while plant-plant distance of 20 cm was maintained for all the patterns. From statistical results of the data, it was observed that flat pattern P_1 produced significantly ($P<0.05$) higher grain (7568.7 kg ha^{-1}) and biomass (17571.2 kg ha^{-1}) yield as compared to P_5 that produced 6160.85 kg ha^{-1} grain and 11340.65 kg ha^{-1} biomass. The planting pattern P_2 is par with P_1 produced 6944.5 kg ha^{-1} grain yield and 16500.7 kg ha^{-1} of biomass. No significant effect was found in yield among P_2, P_3 and P_4. Similarly, no statistically significant difference was observed in days taken to 50% seedling emergence, leaf area (LA) and plant height (PH) among the different planting patterns. In order to maximize maize yield, it is recommended that maize should be raised on flat pattern keeping row spacing 60 cm.

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Introduction

Maize (*Zea mays* L) belongs to grass family of Poaceae, genus Zea and specie *Z. mays* (Tian *et al*., 2009) and ranks second in among the cereal crops ensuring global food security (Yoshida, 1972). In the world maize is the most speedy growing cereal crop and has maximum yield as compared to other cereal crops (Murdia *et al*., 2016). For an agricultural country like Pakistan, maize is a main source of food and fodder. Concerning the area maize gets third (3rd) position after wheat and rice (Zamir *et* *al*., 2013). According to a research study (Tahir *et al*., 2008) Punjab and Khyber Pakhtunkhwa are the two major maize producing provinces of Pakistan producing 98 % of the gross national production. In Khyber Pakhtunkhwa maize is one of the valuable crops, contributing to more than half of the country maize production (Aziz *et al*., 2007). Maize grows on different types of soils with varying combination of clay, silts and sand. However, for optimum production soils having medium-size texture with maximum water holding capacity, high organic matter and well drained capabilities are requisite (Nazir *et al*., 1994).

Maize grain can be used as a source of food for humans and animals and source of fodder for animals (Gurman *et al*., 2008). Globally, it provides 33.3 percent nutrition for human beings and 66.6 percent to animals (Pandey and Koirala, 2017). According to research (Yoshida, 1972) studies maize is one of the least tolerant crops to high plant densities. Using different sowing methods and row spacing can change the yield. During the last decade the maize production in Pakistan has been declined although new heirloom cultivar has been introduced despite increased use of fertilizer and pesticides. There is great potential to rise the per acre production of existing varieties through improved cultural practices. These includes adequate use of fertilizer, proper irrigation, preventing weed infestation and pest attack, selection of suitable cultivars for a given set of environments, suboptimal crop density, and cropping pattern. The last two will have no financial impact on the resources the grower if investigated under the local environmental conditions.

The density of maize plants influences plant architecture, growth and developmental patterns, and carbohydrate production. Many modern maize varieties do not tiller well at low densities and often produce only one ear per plant (Abuzar *et al*., 2011). While high population, on the other hand, increases interplant competition for light, water, and nutrients, which may be detrimental to final yield because it stimulates apical dominance, induces barrenness, and ultimately reduces the number of ears produced per plant and kernels set per ear, 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). The review of literature shows that in different world regions, the optimal sowing density for maximum maize yield is different. According to a study in the eastern part of the American Corn Belt, a planting density of 98,800–104,500 plants ha^{-1} is considered optimal for yield (Stanger and Lauer, 2006). Another study conducted in chine suggest a planting density of 90,000 plant ha^{-1} (Huang *et al*., 2012). In semi-arid regions, the research studies recommend planting densities of 67,000–70,000 plants ha^{-1} for maximum corn yield (Lamm *et al*., 2008) and (Al-Kaisi and Yin, 2003). Despite extensive research on maize planting densities, no single recommendation exists that takes into account all environmental factors. There is no as such specific value and it depends on the environmental factors, soil condition and nutrients status, cultivar, planting pattern and harvest time (Sangoi *et al*., 2002; Kucharik, 2008; Burken *et al*., 2013). Another research study investigated the ridge and furrow planting pattern effects on canopy structure and grain yield of maize. The results showed that planting pattern having high photosynthetic capacity resulted in higher grain production (Liu *et al*., 2018). According to (Kaufman, 2013) by changing the spacing of plants within a row one can changes the light available to the plant, thus can change the crop production.

Keeping this in view, this study was conducted to evaluate the maize crop yield by changing both the planting patterns and row spacing for maximum yield potential under the local conditions of Peshawar Valley.

Materials and Methods

A field test was performed with summer maize in 2019, in District Mardan, Lundkhwar (34°24′28″N, 71°56′34″E, 391 m Altitude), of Khyber Pakhtunkhwa province located in North of Pakistan. Mardan is a semi-arid zone of Pakistan with a mean annual precipitation of 559 mm. Maximum rainfall occurs in August, with an average of 132 mm. Hottest month is June, with an average temperature of 42°C while, January is considered as the coldest month with a mean temperature of 10 °C. The climatological data was collected from a nearby water and power development authority (WAPDA) department, Sugar Crops Research Institute, Mardan, Khyber Pakhtunkhwa, Pakistan weather stations. Precipitation and temperature data of the research area during the study period is presented in Figure 1.

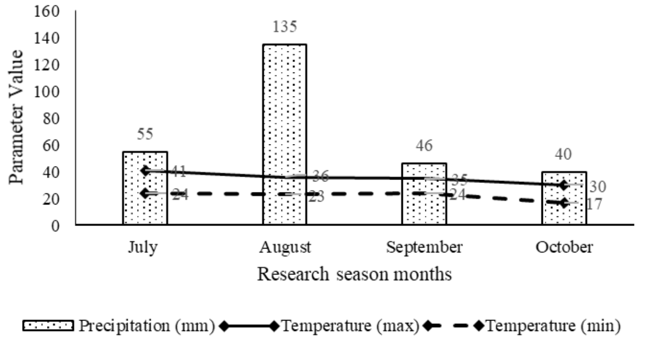

Figure 1: *Precipitation, mean maximum and minimum temperatures at the research site, Mardan.*

Figure 2: *Soil sampling and texture analysis.*

A hydrometer method (Rashid *et al*., 2001) of soil texture analysis was used to investigate the soil type of the experimental area at 15, 30 and 45 cm soil depths Figure 2. Before sowing the experimental field was irrigated beyond the field capacity. After attaining proper soil moisture, the tillage operation (ploughing by cultivator and then rotavator, to break soil clods) was done to get the desired tilth for a fine seed bed Figure 3. The field was leveled using the conventional bull planking. Five different planting patterns were set in the experimental area. Each pattern was replicated three times. A two feet dikes and water course were made. The net size of each plot was 42.69 m^2 (length 7.01 m, width 6.09 m). Flat pattern (P_1) row spacing 60 cm, Ridge-Furrow (P_2) row spacing 60 cm, Ridge-Furrow (P_3) row spacing 75 cm, Bed (P_4) row spacing 60 cm and Bed (P_5) (Figure 4) keeping row spacing 75 cm were evaluated using maize hybrid Malakand seed in July 2019.

Figure 3: *Field preparation and plots making.*

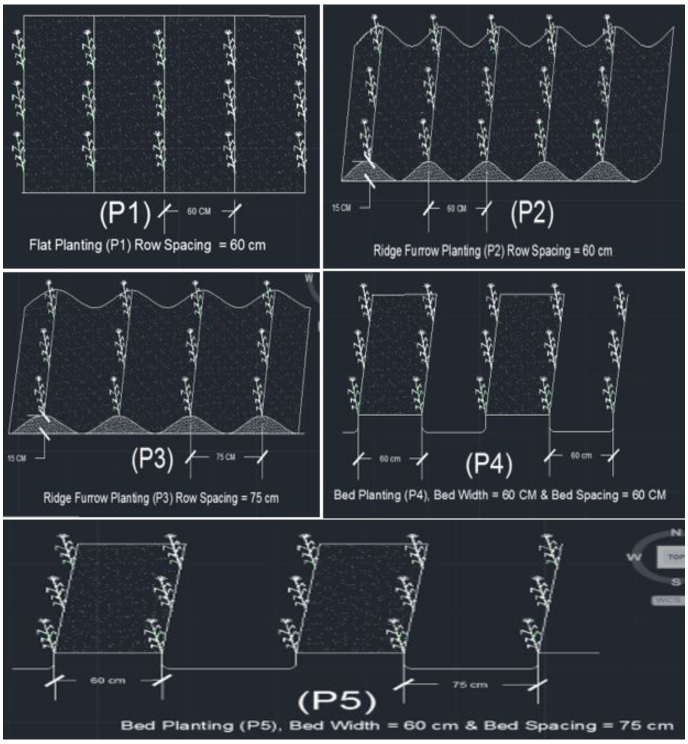

Figure 4: *Sketch of five different planting patterns.*

The patterns were set in a randomized complete block design (Figure 5). All the furrows formed were of the uniform slopes. To stop the sidewise flow of water the plots were bordered with a two feet wide dikes. The bed width was kept constant i.e. 60 cm in each case. In beds planting was done with two rows. The plots were well managed. The weeds, diseases and pests were well controlled throughout the replications. On July 8, 2019 the maize hybrid, Malakand seeds (70+) were sown, by using a conventional maize planter. Plant-plant distance was 20 cm for all the treatments. After ten days of sowing the gaps were filled to maintain the optimum number of plants per pattern. Similarly, thinning was done in over population areas. The NPK (Nitrogen, Phosphorus and Potassium) was applied to the field. At the time of sowing phosphorus [$(NH_4)_2HPO_4$], 150 kg ha^{-1} and potash (K_2SO_4) at 125 kg ha^{-1} were given to the field. NPK was applied as 110:90:75 kg ha^{-1}. First dose of NPK was given to the field before first irrigation, then 20 days after sowing (DAS) and before tasseling. An herbicide Gingwei (Atrazine, Mesotrione 50 g lit^{-1}) was applied after twenty (20) days of emergence. Whether required a hand weeding was done. Following maize parameters were evaluated:

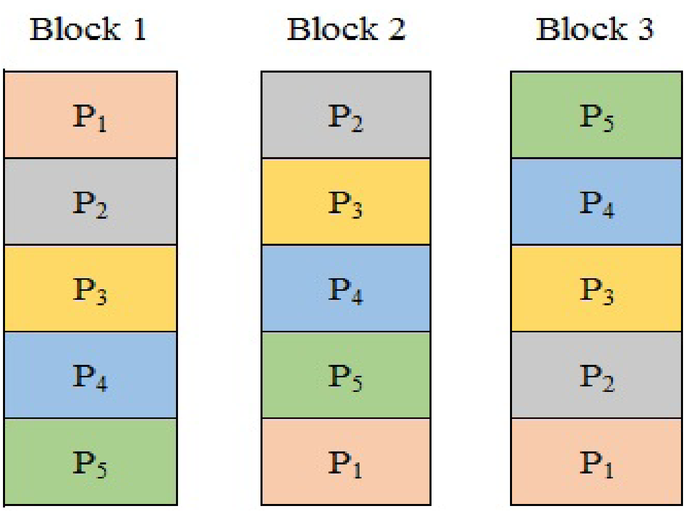

Figure 5: *Schematics of randomly assigned treatments replicated three times.*

Days taken to 50% seedling emergence

Seedling emergence is the basis for optimum plant density and finally crop yield (Kaur, 2016). To determine the effect of sowing methods on seedling emergence; the number of days from sowing date till 50% seedling emergence were recorded.

Plant height (m)

60 days after sowing date, three plants from the central rows of each plot were selected. The height was measured using measuring tape from the ground level up to the last unfolded leaf of the stem. Mean value of the selected plants was computed and were expressed in meter (m) (Kaur, 2016).

Leaf area (cm^2)

When half of the leaf has turned yellowed i.e. when the plant leaves reached its full length and width (80 DAS), three (3) average plants from the center plants of each pattern were selected, to calculate the leaf area (Figure 6). The following formula was used for calculating the leaf area (Liu *et al*., 2018).

$$LA = L \times W \times 0.75 \quad \dots (1)$$

Where; LA = Leaf area of the plant (cm^2); L = Length of the leaf (cm); W = Maximum width of the leaf (cm); Maize crop factor = 0.75

Figure 6: *Measuring plant height and leaf area.*

Actual grain yield (kg ha^{-1})

When the plants reached the degree of physiological maturity (35% moisture in kernels) before proceeding towards the hand-harvesting, plants (ears) were pre-dried standing in the field for ten (10) days. After the pre-drying period all the plants were harvested. By hand the husks were removed from the ears. All the ears were exposed to sunlight for five days. The ears were then threshed separately at 25% moisture content. Each pattern kernels were separately collected. The impurities (earth, husks and cobs pieces) mixed with the grains were removed. To find the actual yield of each pattern, all the kernels were dried in the open atmosphere and then weighed. The grain yield was determined at 14% moisture (Lucia and Assennato, 1994).

$$Grain\ Yield\ (kg\ ha-1) = \frac{Pattern\ grain\ yied(kg) \times 10{,}000}{Pattern\ size\ (m2)} \quad ...(2)$$

Biomass production (kg ha⁻¹)

Three representative plants from the center rows of each plot were selected. The plants were cut at soil level and dissected into parts i.e. ear, ear leaves, tassels, other plant leaves and stem. The fresh biomass weight was determined. All these components were then oven dried at 80 °C for two days and then weighed to determine biomass yield (kg/ha). The term biomass here indicates total yield i.e. grain yield plus dry matter produced by a pattern.

$$Biomass\ Yield\ (kg\ ha-1) = \frac{Pattern\ biomass\ (kg) \times 10{,}000}{Pattern\ size\ (m2)} \quad ...(3)$$

Data was analyzed according to completely randomized block design (Gomez and Gomez, 1984) using statistical software Statistix 10. Data was first subjected to the software for analysis of variance (ANOVA). Then a pair wise comparison of the different pattern means was investigated by the least significant difference (LSD) test at probability level of 5%.

Results and Discussion

Days taken to 50% seedling emergence

Number of days taken to 50 percent emergence in the entire plot was observed in order to investigate whether there is any significant difference of planting pattern and row spacing on the seedling emergence rate. The data regarding the days to 50% seedling emergence are given in Table 1. The Figure 7 illustrates that minimum number (4 days) to 50 percent seedling emergence was experienced in pattern P_1 as compared to P_3, P_4 and P_5. The pattern P_3, P_4 and P_5 took the same number (4.7 days) to 50% emergence. However, results of the data (Table 1) revealed that there is no statistical difference among the mean number of days taken to 50% emergence by different patterns.

Kaur (2016) have experienced 4.3, 4.4 and 5.1 number of days in bed, ridge and flat sowing methods respectively to 50% seedling emergence. Bakht et al. (2011) have noted better seedling emergence in ridge as compared to flat sowing. This difference in days to 50% seedling emergence might be due to high mortality rate in bed planting pattern. Therefore, to maintain proper plant population densities they were refilled after one week.

Table 1: *Effect of planting patterns and row spacing on physiological and agronomic parameters of summer maize.*

Treat-ments	Days to 50% emergence	Plant height (m)	Leaf area (cm²)	Grain yield (kg/ha)	Biomass yield (kg/ha)
P_1	4.0^a	2.45^a	585.28^a	7564.59^a	17561.62^a
P_2	4.3^a	2.42^a	542.06^a	6940.7^{ab}	16491.75^{ab}
P_3	4.7^a	2.34^a	551.22^a	6550.78^{ab}	14421.7^{ab}
P_4	4.7^a	2.29^a	572.90^a	6238.83^{ab}	14576.01^{ab}
P_5	4.7^a	2.36^a	597.80^a	6160.85^b	11340.65^b
CV (%)	11.56	4.4	7.59	11.05	18.43

Means sharing the same letter (s) do not differ significantly at 5% level of probability.

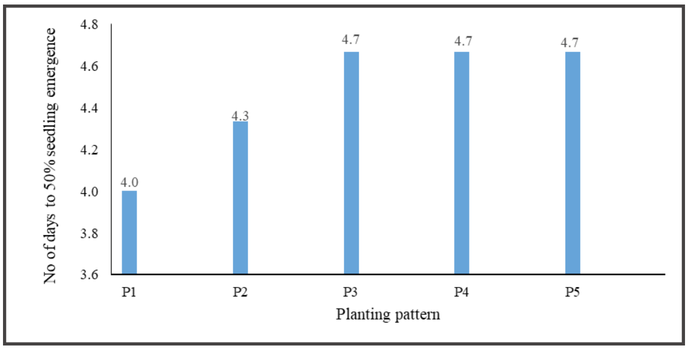

Figure 7: *Effect of planting pattern and row spacing on days to 50% seedling.*

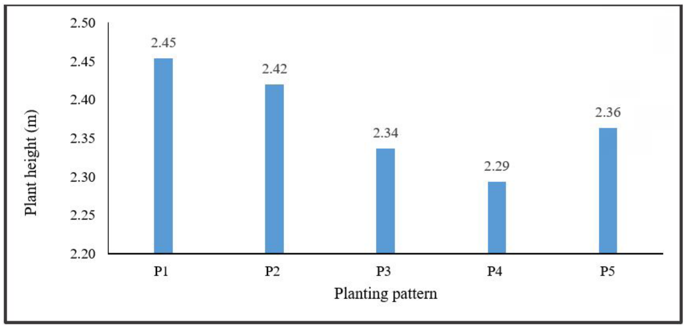

Figure 8: *Effect of planting pattern and row spacing on plant height.*

Plant height (m)

Plants have different heights however; it can be modified by using different agronomic manipulations. After analysis of the recorded data it was concluded that planting pattern and row spacing of maize crop has no significant (P<0.05) effect on the plant height. It was observed that maximum (2.45 m) plant height was produced by the flat pattern P_1 followed by P_2 (2.42 m) while P_4 produced minimum (2.29 m) height (Figure 8). Statistically no variations were found in plant height regarding the planting pattern (Table 1).

Akman (2002) had observed the same effect that by increasing the plant density the plant height increases but the ear length and diameter decreases. Gozubenli *et al*. (2004) have performed a two-year experiment, in order to investigate the best planting pattern (using single and twin rows) as well as planting density. They concluded that maximum plant height (186.6 cm and 189.5 cm) were produced by higher plant densities (90000 plant ha^{-1} and 120000 plant ha^{-1}). Khan *et al*. (2012) performed a field work to assess the effect of different planting methods on phosphorus uptake, rooting system, crop growth and grain yield of maize hybrids. They planted three maize hybrids using three different patterns, flat method (row spacing 75 cm), ridge sowing method (ridges 75 cm apart) and bed sowing method (120-30 cm apart beds). They observed greater phosphorus uptake, root growth and yield in ridge planting method.

Leaf area (cm^2)

Plant leaf area is one of the important growth parameters. The recorded data (Table 1) revealed that planting pattern has no significant (P<0.05) effect on leaf area of maize plant. However, maximum (597.80 cm^2) leaf area was produced in pattern P_5 followed by P_1 (585.28 cm^2) while minimum (542.06 cm^2) was observed in P_2 (Figure 9).

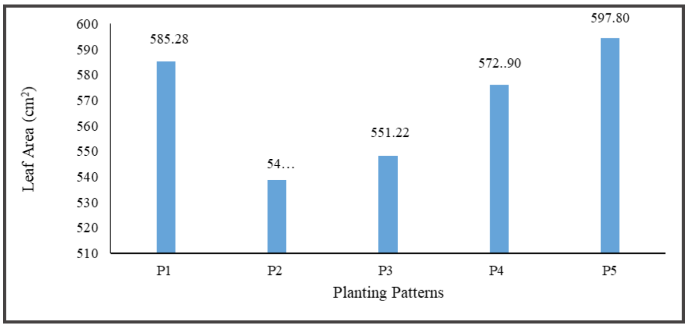

Figure 9: *Effect of planting pattern and row spacing on leaf area.*

Savita *et al*. (2011) had also experienced the similar effects after conducting a field experiment. They observed maximum leaf area in bed planted crop as compared to flat and ridge sowing methods. Khan *et al*. (2012) had worked to evaluate the effect of varying planting methods on crop growth and yield of different maize hybrids. Compared to flat method they observed maximum leaf area in bed and ridge pattern after 90 days of sowing.

Grain yield (kg ha^{-1})

It was observed (Figure 10) that planting pattern P_1 produced maximum (7564.6 kg ha^{-1}) grain yield. P_2 (6940.7 kg/ha), P_3 (6550.78 kg ha^{-1}) and P_4 (6238.83 kg ha^{-1}) produced statistically same yield after P_1. Minimum (6160.9 kg/ha) grain yield was found in pattern P_5.

Gozubenli *et al*. (2004) have found the similar findings after conducting a two-year experiment, to determine optimum plant density and planting pattern. They experienced that grain yield was increasing with increasing plant density up to 90000 plant ha^{-1}. Acciares and Zuluaga (2006) has conducted a two years experiments to study the effect of maize row spacing on maize grain yield and weeds above ground. They have tested three maize hybrids and two row width (0.7 m and 0.35 m). They experienced maximum maize grain yield in narrow (0.35 m) row arrangement than in wide (0.7 m) row spacing. Ahmad and Chudhry (2008) has performed two seasons (spring and kharif) experiment. They found that ridge planting with one row and flat sowing with earthing up both performed better in both the seasons. In spring the flat sowing yield 5236 kg/ha while in summer 6287 kg ha^{-1} were recorded. Similarly, 4343 kg per hectare and 5270 kg per hectare were observed for ridge sowing with single row in spring and kharif seasons respectively. Another researcher Mashingaidze *et al*. (2009) has suggested that narrowing the row spaces reduces weeding requirements and increases the crop (maize) yield. Ali *et al*. (2017) has experienced those different hybrids require variable plant population densities. Increasing the plant density grain yield per plant decreases but per unit area increases. Rehman *et al*. (2011) has experienced after conducting a field experiment, that highest grain yield can be achieved using medium dose of NPK in ridge sowing method.

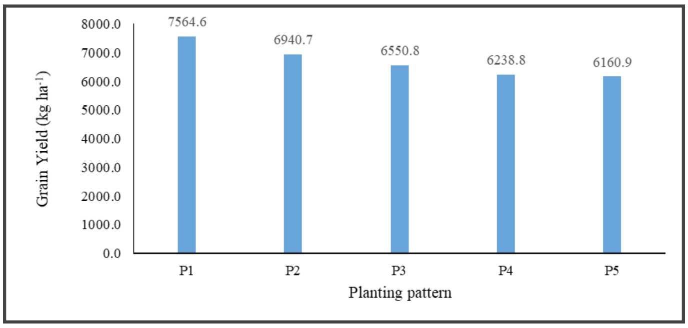

Figure 10: *Effect of planting pattern and row spacing on grain yield.*

Biomass production (kg ha^{-1})

After evaluating the biomass data, it was observed that planting pattern has significant (P<0.05) effect on biomass production. It was observed that maximum (17561.62 kg ha^{-1}) biomass was produced by the flat planting pattern P_1 followed by the pattern P_2 (16491.75 kg ha^{-1}) while minimum (11340.65 kg/ha) biomass was resulted in bed planting method P_5 (Figure 11). Both the methods P_1 and P_5 had significantly affected the biomass production as given in Table 1. However, patterns P_2, P_3, P_4 and P_5 have statistically no difference. Similarly, there is no statistical difference in the biomass production of P_1, P_2, P_3 and P_4 planting pattern (Table 1).

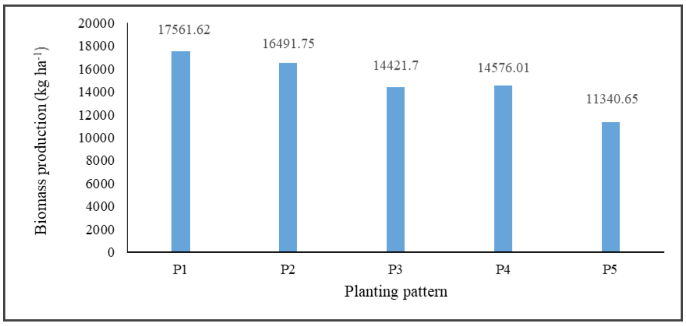

Figure 11: *Effect of planting pattern and row spacing on biomass yield.*

Kaufman (2013) Suggests that the light available to the plant can be changed by changing the spacing of plants within a row. Increasing the spacing reduces the competition of neighboring plants and the total plant yield can be increased. By increasing the plant population, the spacing between plants within a row decrease. This increases the interplant competition as a result reduction in yield occurs. Another researcher Cusicanqui and Lauer (1999) have performed a field study to analyze the influence of plant density and maize hybrids on corn forage yield and quality. They used two hybrids (low and high quality) and sown in the experimental area in five (5) different plant densities starting from 44500-104500 plants/ha at six (6) different locations. They concluded that by increasing the plant density (from 44500-104500) the dry matter yield also increased (1.7 to 4.1 Mg ha-1). This shows that plant densities have positive impact on the forage production however, adverse impact on grain production. Akbar *et al*. (1996) had suggested that 100000 plants ha^{-1} be the most proper sowing density.

Conclusions and Recommendations

From the study it can be concluded that planting pattern does not affect significantly the growth and yield parameters as compared to row spacing (60 cm and 75 cm), as it changes the plant densities. Moreover, the flat and ridge planting pattern with row spacing 60 cm is recommended for better grain and biomass yield. This recommended approach will not only improve the grain production but also has great potential for reducing the farm labor and carbon footprint in term of fuel saving.

Acknowledgments

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Novelty Statement

This study contributes to productivity enhancement of maize crop heirloom cultivar through researched cultural practices related to planting patterns and row spacing.

Author's Contribution

Shakir Ali: Conducted experiment, data collection, data analysis.
Abdul Malik: supervised the field work, designed experiment.
Zia Ul Haq: Field coordination, provided inputs in designing of experiment.
Tariq M Khalil: Data analysis, Writing- Reviewing and Editing.
Ijaz Ahmad Khan: Guided regarding editing the manuscript.

Conflict of interest
The authors have declared no conflict of interest.

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