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Yield Response of Irrigated Maize (*Zea mays* L.) to Different Planting Architects in Loamy Soil of Upper Indus Basin

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Abstract

In maize, planting architects play a key role in achieving higher yield by providing improved soil conditions. The present study was conducted with an objective to investigate the yield response of hybrid maize to different architects. Four architects used were as follows: (1) 75 cm spaced ridges, planting on one side of the ridge with 15 cm plant spacing; (2) 90 cm spaced raised beds, planting on both sides of beds with 25 cm plant spacing; (3) 105 cm spaced raised beds, planting on both sides of beds with 21.25 cm plant spacing and (4) 120 cm spaced raised beds, planting on both sides of beds with 18.75 cm plant spacing. Results revealed that days to emergence, days of sailing and ear height did not respond to studied architects. Taller maize plants were recorded in ridge sowing. Higher ($P<0.05$) grain ear^{-1} (696), 1000-grain weight (324.8 g) and grain yield (12189 kg ha^{-1}) were recorded in architect-1. Among the bed structures, architect-3 produced taller plants (233 cm), and higher grain ear^{-1} (680), 1000-grain weight (296.4 g), and grain yield (11304.3 kg ha^{-1}). Therefore, in irrigated conditions of the upper Indus basin, ridge sowing is a better option for spring maize compared to bed sowing.

Introduction

Maize (*Zea mays* L.) is a standout cash crop in the Punjab province of Pakistan. The cultivation of maize hybrid coupled with improved and refined production practices has provided a landmark in the maize production in the country. The area under maize production witnessed a steady increase in the recent years. During 2016-17, the area under maize was 1334 thousand hectares which were 12% higher than previous years with a record high maize production of 6.10 million tons (16.3% higher than the previous year) [1]. Maize is a fast growing and high input-demanding crop that matures in 100-120 days hence require precise growing techniques. The suitable sowing method facilitates smooth root penetration and development resulting in better water and nutrient uptake [2]. Furthermore, proper planting patterns allow improved light penetration into the canopy, aeration and minimize above- and below-ground interspecific competition, which is translated into greater grain yield [2, 3].

The diverse planting patterns have been studied for maize that best suits the local growing conditions. Tillage based planting methods have shown a positive relationship between maize growth and yield [4]. Sowing maize on ridges and furrow irrigated raised beds are recommended planting architects in irrigated areas, especially in the upper plains of Indus basin in Punjab. In the ridge and bed preparation, soil porosity and permeability are improved while a deeper than normal seedbed is achieved [5]. Planting structures, including raised beds reduce seed mortality, enhance water and nutrient use efficiency, improve soil quality and decrease plant lodging compared to flat sowing [6]. The adaptability of these planting architects is on an increase, especially in Pakistan, Bangladesh and India, China and parts of Australia [7, 8]. Previous empirical studies in Punjab investigating the relative yield performance of maize on different planting architects, including flat land, ridges and raised beds, showed clear yield advantage of planting architects compared to flat sowing [9-12].

In Punjab, conventionally ridge sowing in done on 75 cm spaced ridges with plant spacing ranging from 15 cm to 30 cm depending upon genotype and climate [13]. Most of the studies hitherto conducted to investigate the yield response of maize to planting structure in the area comparing different planting methods explored the bed structure of size 120 cm wide beds with 30 cm furrow [14, 15]. None of the studies further investigate the bed structure beyond this dimension. Therefore, this study was designed to study the yield response of hybrid maize to planting architects involving bed structures of different dimensions and ridge structure.

Materials and Methods

Experiment site

Experiments were conducted at Maize and Millet Research Institute, (30°41 N and 73°6 E) Sahiwal, Pakistan during spring seasons of 2015 and 2016. The city is situated in the center of Punjab province and covers part of the upper Indus Basin. Soil of the site is loam with mean other characteristics of the top 15 cm and 30 cm soil layer as; saturation 38% and 39%, available P 0.79% and 0.42%, organic matter 0.78% and 0.42%, soil pH 8.4 and 8.1, and electrical conductivity 2.1 ds m^{-1} and 7.4 ds m^{-1}, respectively.

Treatments and methodology

Sowing was done on February 17 in 2015 and on February 24 in 2016. During both the years, the land was fallow previously, which was preceded by summer maize crop. Well before planting, the land was ploughed and harrowed to prepare a fine seedbed. Plant spacing on the architects was adjusted to keep the plant population constant, i.e., 9 plants m^{-2}. The treatments consist of four planting architects as follows: [architect-1] 75 cm spaced ridges, planting on one side of the ridge with 15 cm plant spacing; [architect-2] 90 cm spaced raised beds (45 cm furrow, 45 cm bed plain), planting on both sides of beds with 25 cm plant spacing; [architect-3] 105 cm spaced raised beds (45 cm furrow, 60 cm bed plain), planting on both sides of beds with 21.25 cm plant spacing and [architect-4] 120 cm spaced raised beds, (45 cm furrow, 75 cm bed plain) planting on both sides of beds with 18.75 cm plant spacing. Bed and furrow height was 22.5 cm. Hence, row distance on the furrow side was 45 cm in all bed architects but from the row on same bed was 45 cm, 60 cm, 75 cm in architect-2, 3 and 4, respectively. These treatments correspond to the planting rectangularity (PR), the ratio of the longest distance between two plants to the shortest distance between plants, of 5, 3, 2.47 and 3.2, respectively [16]. Here longest distance was calculated by taking the average distance of rows while the shortest distance was within row plant distance.

In the field, treatments were laid out in a randomized complete block design with four replications and net plot size of 5 m × 5.25 m. Ridges and beds were made manually with the help of field tools. Each plot was hand-planted with two seeds per hill. Before planting, each plot received 100, 145 and 125 kg ha^{-1} of N, P and K in the form of urea, di-ammonium phosphate (DAP) and murate of potash (MOP), respectively. Later on 50 kg N ha^{-1} was applied at V_4 (four leaves with visible collar), V_8 (eight leaves with visible collar) and R_1 (silking) stage. To measure the total water applied cut-throat flume was installed at water inlet. During the growing season, a total of 630 mm ha^{-1} water was applied in 8 episodes when required.

Data regarding days to emergence was recorded till last seed emerged from the soil. Days to silking were recorded when crop reached at 50% silking. While data on the number of plants m^{-2}, plant height, and ear height was recorded at physiological maturity. From each plot, five random plants were selected and ears were harvested and threshed manually to count the average number of grain ear^{-1}. From such threshed ears, grain weight was estimated by taking the 1000-grain weight. Central four rows were completely harvested and threshed and grain weight was recorded, then converted on ha^{-1} basis.

Statistical analysis

Analysis of variance and least significant difference (LSD) tests among mean values were conducted by using the GLM procedure of SAS 9.1.3 (portable). F-test was carried out to check heterogeneity of variance for each variable. However, no such issue was detected. Resultantly analysis over year was carried out in which year was considered as a random effect while planting architect was considered as fixed effects. Significant year × architect effect was ignored as interaction effect was small compared to average main effect and ranking of architect remained stable over the years [17]. Least significant difference (LSD) test (P=0.05) was carried out to separate treatment means.

Results and Discussion

At the experimental site, climatic variables differed between the two years of study (Table 1). The year 2016 was hotter than 2015, especially higher maximum and minimum temperatures were recorded in the month of March 2016. However, the growing season (January-June) in the year 2015 received 23.67 mm more rainfall than 2016. Higher growing degree days were accumulated in 2016 throughout the growing season compared to 2015. Table 2 and 3 revealed that all the response measurements were affected by planting architects ($P<0.05$) except days to emergence, days to silking and ear height. Higher grain yield during 2016 may be attributed to more accumulated growing degree days (Table 1) and a higher number of grain ear^{-1} (Table 3). In this study, planting architect did not affect days to emergence. Similar results have been reported by Bakht et al. [18] who reported that days to emergence did not vary significantly among different planting methods.

A higher number of plants m^{-2} ($P<0.05$) were recorded at architect-4 where 18.75 cm spaced plants were sown on 120 cm wide raised beds (PR = 3.2) though statistically not different from architect 1 and 3. However, plants m^{-2} in architect-2 (PR = 3) were 5% and 4% lower ($P<0.05$) than architect-4 and 1, respectively. The variation might have been aroused due to lodging (data not recorded) in architect-2 owing to narrower row spacing produced weak and thinner plants. Contrarily Khan et al. [11] found no difference in plant m^{-2} among different planting architect. Plant height responded to planting architects ($P<0.05$). Taller maize plants ($P<0.05$) were observed in architect-1 (PR = 5) followed by architect-3 (PR = 2.47). Similarly, Khan et al. [11] and Bakht et al. [18] also reported taller plants in ridge sowing compared to bed planting. On bed structures, plant height decreased as rectangularity increased from 2.47 which can be attributed to greater interspecific competition for resources at lower rectangularity that resulted in taller plants. The data further reveal that plant height did not respond to variation in plant population as shortest plants were recorded from plots where plants m^{-2} were high (architect-4). This result was contradictory to that of Huang et al. [19] who reported 2-3 cm taller plants in 60000 plants ha^{-1} compared to 90000 plants ha^{-1}. This contradiction might be attributed to the relatively little differences of plant population among the treatments in our study as plant population varied from 87500 plants ha^{-1} to 83300 plants ha^{-1} among all architects. Days to silking did not respond to planting architect ($P>0.05$). This result is congruous with Tanveer et al. [9] who recorded no difference in days to silking under different planting architects, i.e., ridge and bed planting.

During the year 2016, 4.9% higher ($P<0.05$) grains were produced compared to 2015 which might be due to the high degree days accumulated during 2016. Number of grains ear^{-1} varied ($P<0.05$) in response to planting architect. Architect-1 (PR=5.00 on ridges) recorded the highest number of grain ear^{-1} this was statistically not different from

Table 1 Monthly rainfall, average temperature (T) and growing degree days (GDD) received at Yousufwala-Sahiwal during the spring season in 2015 and 2016.

Month	2015			2016		
	Rainfall (mm)	Average T (˚C)	GDD (˚C d^{-1})	Rainfall (mm)	Average T (˚C)	GDD (˚C d^{-1})
January	7.08	12.27	79	5.4	12.33	114
February	17.31	17.07	198	0.0	17.04	214
March	24.58	20.5	325	25.6	23.88	423
April	22.5	28.98	570	10.4	28.93	568
May	1.4	32.91	710	3.00	34.07	749

Table 2 Source of Variation for plants m^{-2}, days to emergence, days to silking, plant height (cm), ear height (cm), grain ear^{-1}, 1000-grain weight (g) and grain yield (kg ha^{-1}).

Source of Variation	DF	Plants m^{-2}	Days to emergence	Days to silking	Plant height	Ear height	Grains ear^{-1}	1000-grain weight	Grain yield
Year	1	0.6487	0.8847	<.0001	<.0001	0.0042	0.0103	0.3563	0.0344
Planting architect	3	0.0384	0.3711	0.4321	<.0001	0.2135	0.0303	<.0001	<.0001
Year × planting architect	3	0.2112	0.7190	0.0178	0.0235	0.0457	0.600	0.4019	0.2317

Table 3 Effect of different planting architects on plants m^{-2}, days to emergence, days to silking, plant height (cm), ear height (cm), grain ear^{-1}, 1000-grain weight (g) and grain yield (kg ha^{-1}) of maize (means are average of 2015 and 2016).

Factor	Level	Plants m^{-2}	Days to emergence	Days to silking	Plant height (cm)	Ear height (cm)	Grain ear^{-1}	1000-grain weight	Grain yield (kg ha^{-1})
Planting architect	Architect-1	8.71 a	5.75	75.8	240 a	134.8	696 a	324.75 a	12188.8 a
	Architect-2	8.33 b	5.63	76.0	229.6 bc	132.6	668.3 b	291.1 b	10131.8 c
	Architect-3	8.61 ab	5.38	75.5	233 b	135.5	680.8 ab	296.37 b	11304.3 b
	Architect-4	8.75 a	5.38	76.1	226 c	134.7	659.1 b	281.9 c	9919.1 c
	$LSD_{0.05}$	0.307	NS	NS	3.83	NS	24.53	10.14	562.34
Year	2015	8.61	5.56	77.4 a	208.2 b	139.5 a	659.1 b	294.1	10403 b
	2016	8.58	5.5	72.2 b	256.1 a	129.3 b	693.2 a	298.0	11369 a
	$LSD_{0.05}$	NS	NS	0.820	8.88	8.93	19.49	NS	732.21

Values in the column sharing the same letter are not significantly different at 0.05 probability using the LSD test. Architect-1: 75 cm spaced ridges, planting on one side of the ridge with 15 cm plant spacing, Architect-2: 90 cm spaced raised beds (45 cm furrow, 45 cm bed plain), planting on both sides of beds with 25 cm plant spacing, Architect-3: 105 cm spaced raised beds (45 cm furrow, 60 cm bed plain), planting on both sides of beds with 21.25 cm plant spacing, A 120 cm spaced raised beds, (45 cm furrow, 75 cm bed plain) planting on both sides of beds with 18.75 cm plant spacing.

architect-3 (PR = 2.47). Production of similar number of grains at maximum rectangularity under study, i.e., PR = 5 and lower, i.e., PR=2.47 hints little role of planting rectangularity in grain ear^{-1} in maize. However, grain ear^{-1} did not vary within the architects involving bed structures, i.e., architect-2, 3 and 4. Similar to our study, the significant effect of planting method on grain ear^{-1} has been reported by Khan et al. [11], Zamir et al. [10] and Mahmood et al. [20]. They further reported higher grain ear^{-1} in ridge sown maize than bed sown. However, Bakht et al. [18] and Verhulust et al. [21] reported the non-significant effect of planting method on grain ear^{-1}. A higher number of grains in ridges might be attributed to the more favorable canopy structure in architect-1 and 3 that facilitated the processes that led to grain formation. Ear height remained unaffected (P>0.05) by planting architects.

Grain weight is one of the crucial yield determining factors in maize. Grain weight varied (P<0.05) in response to planting architect. The weight of 1000 grains for ridge sowing was 324.75 g which was the highest (P<0.05) among the treatments. This might be due to planting structure favorable for better root growth and penetration in the soil, allowing plants with better moisture and nutrient uptake coupled with better canopy structure with improved light penetration resulting in a better photosynthetic activity that later translated in heavier grains [22]. Similarly, Khan et al. [11] reported heavier maize grains in ridge sowing and also found a positive correlation between number of lateral roots, root length and grain yield. Among the bed architects, architect-2 and architect-3 produced the similar 1000-grain weights. These results are in accordance with the findings of Raymond et al. [23]. The yield is the economic part of the crop and is a function of yield contributing components. In 2016, 9.2% higher grain yield was recorded than 2015. Ridge architecture produced highest (P<0.05) grain yield compared to other architects. Among the bed structures, architect-3 (PR = 2.47) produced higher (P<0.05) grain yield. Grain yield from ridge sowing was 14% greater than the average yield from all bed structures. Conducive growing conditions in ridge structures and its impact on yield contributing characters of maize lead to greater yield. In our study, the pronounced effect was witnessed in days to silking, grain ear^{-1}, and grain weight that cause higher yield in ridge sowing. Results are congruous with Khan et al. [11], Abdullah et al., [25], Amin et al., [13] and Rasheed et al., [2003].

Conclusions

Yield and yield contributing characteristics were affected by planting architects. Number of plants m^{-2} at silking, plant height, grain ear^{-1}, grain weight and grain yield were affected by different planting structures. Ridge sowing proved to be better planting architect of maize compared to bed architects within studied dimension. However, if maize is to be planted on beds, they should be constructed with 105 cm inter-bed space (45 cm furrow, 60 cm bed top) and planting should be done on both sides of the bed. However, further studies to investigate the ridge and bed structures of different dimensions for other soil types in the region are warranted.

Conflict of Interest

The authors have no conflict of interest.

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