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Response of maize (*Zea mays*) to different planting methods with limited irrigation at water sensitive growth stages

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ABSTRACT

In Indo-Gangetic Plains, ground water is the main source of irrigation. Maize (*Zea mays* L.) is the main rainy (*kharif*) season crop of the region after rice (*Oryza sativa* L.) and it is quite exhaustive crop in terms of nutrients and water as well. For efficient utilization of resources like nutrients and water and for maintaining sustainable yield at the same time of maize crop we need some agronomic alternatives. From the various alternatives, one promising alternative is by modifying the planting system along with limited water application at critical stages of crop. So by keeping all this in view, a field experiment was conducted to study the response of maize to bed system of planting with limited irrigation at water sensitive growth stages during 2017 and 2018 at ICAR-Indian Agricultural Research Institute, New Delhi. The experiment was laid out in a factorial randomized complete block design (FRCBD) with two crop establishment methods, i.e. narrow bed and broad bed planting and 5 levels of irrigation with 3 replications. Significantly higher grain yield was recorded in broad bed system of planting (4.37 and 4.57 t/ha) compared with narrow bed (4.23 and 4.38 t/ha) during 2017 and 2018, respectively. The highest grain yield was recorded where irrigation was applied at 25% depletion of available soil moisture (4.86 and 4.93 t/ha). It was concluded that sowing of maize on broad beds with irrigation in furrows at 25% depletion of available soil moisture resulted in higher growth, yield attributes and yield of maize compared to rest of the treatments.

Keywords: Crop establishment method, Growth, Irrigation, Maize, Yield

The dominant rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L.) (RW) system of Indo-Gangetic Plain (IGP) has contributed immensely to the food and livelihood security of the major mass of Indian population. But its future sustainability is questioned because of multiple issues. The major issues are natural resource degradation (Saharawat *et al.* 2010, Chauhan *et al*. 2012), rapidly decreasing water table (Sharma *et al*. 2012, Yadvinder-Singh *et al*. 2014) and deteriorating soil health (Parihar *et al*. 2016). To solve the above discussed issues to some extent, maize (*Zea mays* L.) can be a viable alternative to rice and a potential driver for diversification of RW system. Among the maize growing countries, India ranks 4th in area and 7th in production, representing around 4% of the world maize area and 2% of total production. During 2018–19 in India, the maize area has reached to 9.2 million ha (DACNET 2020). In India, maize is principally grown in two seasons, rainy (*kharif*) and winter (*rabi*). *Kharif* maize represents around 83% of maize area in India, while *rabi* maize correspond to 17% maize area. The stress prone ecology contributes towards lower productivity of *kharif* maize (2706 kg/ha) as compared to *rabi* maize (4436 kg/ha), which is predominantly grown under assured ecosystem (IIMR 2019). Bed planting provides opportunity for crop diversification through intensification of more efficient use of water (Jat *et al.* 2008) under rainfed as well as irrigated conditions because of optimum water storage and safe disposal of excess water. In light of the current pressure on increasing crop production, establishing a high yield and water-saving agricultural water use strategy to achieve highly efficient agricultural water use has become a priority for the sustainable development of agriculture in India. In these days, ground water table and availability of irrigation water keeps on decreasing. Under such situation the productivity of maize will decline which fails to provide sufficient food for ever growing population. For maintaining the sustainable yield of maize, there is a need to maintain sufficient moisture at least during critical stages of crop growth. Therefore, an experiment was conducted to study the response of maize to different planting methods with limited irrigation at water sensitive growth stages.

MATERIALS AND METHODS

The present field experiment was conducted during the rainy (*kharif*) season of 2017 and 2018 to study the response

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of maize to bed systems of planting with limited irrigation at water sensitive growth stages at ICAR-Indian Agricultural Research Institute (28º 40’N, 77º 11'E and about 228 m amsl) New Delhi. The experimental farm used in the present study was under a maize-wheat cropping system. The soil of the experimental field was sandy-loam in texture and alkaline in nature (*p*H 7.5), EC 0.39 dS/m, low in organic carbon (0.43%) and available nitrogen (234.8±22.5 kg/ha), and medium in available phosphorus (13.8±1.5 kg/ha) and potash (236.4±15.3 kg/ha). The experiment was laid out in a factorial randomized complete block design (FRCBD). The factor one having two bed (crop establishment) system, i.e. narrow bed and broad bed planting and factor two having 5 levels of irrigation at different stages with total 10 treatment combination and replicated thrice. These treatments were M_1, narrow bed and M_2, broad bed methods of planting and irrigation levels are as follows: I_1, 25% DASM (Depletion of available soil moisture); I_2, 25% DASM at tasselling, silking, grain filling and 50% during rest of time; I_3, 50% DASM at all stages; I_4, 50% DASM + K spray (KCL) at 40 DAS and at pre-tasselling; and I_5, 50% DASM + 2% Urea spray at 40 DAS and at pre-tasselling. The maize cv. PMH 1 seed were dibbled in single row on narrow bed spaced at 0.65 m (row to row) and in broad bed two rows 0.60 m apart. The recommended dose of nutrients @150: 26.2: 33.2 nitrogen: phosphorous: potassium kg/ha with 33% basal N was applied at the time of sowing and the rest of N was applied in two equal splits at knee high and tasselling stage in all the treatments uniformly and phosphorus and potassium was applied as basal dose at the time of sowing. The sources of nutrients were urea diammonium phosphate (DAP) and muriate of potash (MOP) for N P K respectively. The irrigation was applied in furrows in between the beds as per the treatment.

RESULTS AND DISCUSSION

Growth parameters

Maize is quite sensitive crop under extreme conditions like drought as well as flooded conditions. During first year of experiment from June 2017 to November 2017, high amount of rainfall was received and its distribution was also unequal. This condition created abnormal environment for maize growth, development which adversely affected its final yield, but in next season the distribution of rainfall was better compared to the previous year. This might help in maintaining optimum moisture for crop growth without causing much loss of nutrients from the soil which was expected more in previous year.

Plant height (cm): The increase in plant height linearly up to 90 DAS was recorded and after that there was no significant increase in plant height till maturity. Significant difference in plant height was observed in plant height during both the consecutive years, i.e. 2017 and 2018. In both the years under study, relatively more plant height was recorded in the crop sown on broad beds (248.5 and 251.3 cm) compared with narrow beds (233.2 and 240.9 cm) respectively. Amongst irrigation levels, the highest plant height was observed in I_1, i.e. where the irrigation water has been applied after 25% depletion of available soil moisture (265.3 and 270.2 cm) in both the years and this treatment was significantly better from rest of the irrigation treatments and lowest plant height was observed in I_4 (230.2 cm) in 2016 and I_5 in 2017 (231.0 cm). Overall non-significant differences were recorded in plant height during both the years of study. If we see the treatment combinations, the crop planted on broad beds with irrigation application after 25% depletion of available soil moisture (M_2I_1) resulted in highest plant (269.0 cm) height when compared with rest of the treatment combinations but on par with M_1I_1 (361.7 cm) and M_2I_2 (261.3 cm). The increase in plant height was due to availability of optimum soil moisture at 25% DASM during different growth stages of crop and broad bed provided sufficient area for good growth and development of maize via better root proliferation under limited irrigation as irrigation was given to furrows and plants were able to extract sufficient moisture because of lateral movement of water in beds. Similar results were also reported by Jehan B *et al.* (2012), Zhaoquan *et al*. (2018) and Huang C *et al*. (2022).

Leaf area (cm^2/plant): The increase in leaf area continuously up to 90 DAS and afterwards a decline was observed till maturity. Planting methods and irrigation treatments significantly affected the leaf area per plant, during both the years under study. Significantly higher leaf area was observed in broad bed sown maize crop (2670.1 and 2723.3 cm^2/plant) compared to the crop sown on narrow beds (2466.6 and 2539.7 cm^2/plant) in consecutive years respectively. In different irrigation levels, significantly more leaf area per plant was observed in I_1, i.e. 25% DASM, (depletion of available soil moisture) (2850.9 and 2908.2 cm^2/plant) in both the years compared to rest of the irrigation levels and lowest leaf area was observed in I_5 (2214.0 and 2313.7 cm^2/plant) in 2017 and 2018 respectively. The interaction effects found to be non-significant but highest leaf area was recorded in M_2I_1 (2949.2 and 2994.9 cm^2/ plant) in both the years respectively. Availability of optimum levels of moisture during various growth stages in I_1 resulted in higher leaf area due to more interception of sunlight, better growth and more photosynthesis. In contrary to this, I_4 and I_5 recorded less leaf area compared to rest of the treatments because of insufficient amount of moisture and poor crop vigour as water is very important component of photosynthesis. Similar findings were reported by Jehan B *et al.* (2012), Zhaoquan *et al*. (2018) and Huang C *et al*. (2022).

Dry matter accumulation (g/plant): An increase in dry matter accumulation was recorded up to 90 DAS at faster rate and afterwards an increase was there but comparatively at slower rate till maturity (Table 1). Significantly higher dry matter accumulation was observed under broad beds (113.8 and 114.8 g/plant) compared to narrow beds (106.6 and 107.1 g/plant) in two consecutive years 2017 and 2018 respectively. Amongst the irrigation levels studied,

Table 1 Effect of different planting methods with limited irrigation regimes on growth parameters of maize

Treatment	Plant height (cm)		Leaf area (cm^2/plant)		Dry matter accumulation (g/plant)	
	2017	2018	2017	2018	2017	2018
(Narrow bed) M_1	233.2	240.9	2466.6	2539.7	106.6	107.1
(Broad bed) M_2	248.5	251.3	2670.1	2723.3	113.8	114.3
SEm±	3.2	3.0	25.1	34.9	1.3	1.9
CD (P=0.05)	9.4	8.8	74.5	103.6	3.8	5.5
I_1	265.3	270.2	2850.9	2908.2	117.1	117.5
I_2	249.8	250.7	2699.5	2794.9	114.7	115.0
I_3	237.3	245.5	2595.6	2608.3	111.2	111.7
I_4	221.5	233.3	2481.9	2532.5	107.3	107.5
I_5	230.2	231.0	2214.0	2313.7	100.8	101.7
SEm±	5.0	4.7	39.7	55.1	2.0	2.9
CD (P=0.05)	14.8	14.0	117.8	163.8	5.9	8.7
Interaction M × I						
M_1I_1	261.7	266.0	2752.5	2821.5	113.1	113.7
M_1I_2	238.3	240.0	2618.3	2784.4	111.0	111.3
M_1I_3	214.3	234.0	2463.1	2484.6	106.0	106.3
M_1I_4	216.3	233.0	2344.6	2375.9	104.0	104.3
M_1I_5	235.3	231.7	2154.5	2232.2	99.0	99.7
M_2I_1	269.0	274.3	2949.2	2994.9	121.0	121.3
M_2I_2	261.3	261.3	2780.7	2805.3	118.3	118.7
M_2I_3	260.3	257.0	2728.0	2732.0	116.3	117.0
M_2I_4	226.7	233.7	2619.1	2689.1	110.7	110.7
M_2I_5	225.0	230.3	2273.5	2395.1	102.7	103.7
SEm±	7.1	6.7	56.1	78.0	2.8	4.1
CD (P=0.05)	20.9	NS	NS	NS	NS	NS

Treatment details are given under Materials and Methods.

significantly higher dry matter accumulation per plant was observed in I_1, i.e. 25% DASM (117.1 and 117.5 g/plant) in both the years compared to rest of the irrigation levels and lowest dry matter accumulation was observed in I_5 (100.8 and 101.7 g/plant) in 2017 and 2018 respectively. The interaction effects found to be non-significant but highest dry matter accumulation was recorded in M_2I_1 (121.0 and 121.3 g/plant) in both the years respectively. Higher dry matter accumulation was due to more interception of sunlight which leads to more photosynthesis as sufficient available moisture resulted in higher leaf area and plant height and vigour which ultimately resulted in higher accumulation of dry matter. Similar findings were also reported by Jehan B *et al.* (2012) and Zhaoquan *et al.* (2018).

Yield parameters

Cob length (cm): Statistically the cob length between different planting systems did not showed significant outcomes in both the years under study, but relatively higher cob length was noted in broad bed planting (15.8 and 16.1 cm) system during 2017 and 2018, respectively (Table 2). In treatments comparing different irrigation regimes, significant differences in cob length were observed in consecutive years 2017 and 2018. Longest cob length was recorded in I_1 irrigation (17 and 17.7 cm) for both the year respectively and shortest cob length was recorded in I_4 (14.8 and 14.8 cm) and I_5 (15.3 and 15.2 cm) treatments respectively. Statistically on par interaction effect were observed and longest cob length (17.3 and 17.7 cm) was measured in the crop sown on broad beds with irrigation application after 25% depletion of available soil moisture (M_2I_1) during both the years respectively. Higher cob length was obtained as a result of favourable environment available for good crop growth in broad bed planting with optimum supply of moisture, leading to higher biomass, better plant vigour, higher leaf area, more assimilation of photosynthates and their portioning and transport to fruiting sites (sinks). Similar results were also reported by Jehan B *et al.* (2012) and Zhaoquan *et al*. (2018).

Cob grain weight (g): Grain weight obtained from five cobs showed significant differences in planting systems during 2017 but it could not reach to significant level during the year 2018. Higher grain weight was recorded with broad bed planting (322.3 and 323.1 g) during both the years under

Table 2 Effect of different planting methods with limited irrigation regimes on yield parameters of maize

Treatment	Cob length (cm)		5 cobs grains weight (g)		100 grain weight (g)	
	2017	2018	2017	2018	2017	2018
(Narrow bed) M_1	15.4	16.2	311.7	326.1	24.6	25.8
(Broad bed) M_2	15.8	16.1	322.3	332.1	25.9	26.6
SEm±	0.2	0.2	3.4	3.3	0.6	0.3
CD (P=0.05)	NS	NS	10.2	NS	NS	NS
I_1	17.0	17.7	347.5	359.5	29.1	29.1
I_2	16.0	16.7	330.7	350.0	27.6	27.3
I_3	15.3	15.8	317.2	331.2	25.3	25.3
I_4	14.8	15.3	299.3	309.2	22.7	24.9
I_5	14.8	15.2	290.5	295.7	21.7	24.2
SEm±	0.4	0.4	5.4	5.3	0.9	0.5
CD (P=0.05)	1.1	1.1	16.1	15.6	2.8	1.4
Interaction M × I						
M_1I_1	16.7	17.7	335.0	352.3	28.7	28.3
M_1I_2	16.0	17.0	325.0	348.3	27.3	27.3
M_1I_3	15.0	16.0	306.0	325.3	24.7	24.7
M_1I_4	14.7	15.3	302.7	313.3	21.5	24.5
M_1I_5	14.7	15.0	290.0	291.3	20.7	24.0
M_2I_1	17.3	17.7	360.0	366.7	29.4	29.9
M_2I_2	16.0	16.3	336.3	351.7	27.8	27.3
M_2I_3	15.7	15.7	328.3	337.0	26.0	25.9
M_2I_4	15.0	15.3	296.0	305.0	23.9	25.2
M_2I_5	15.0	15.3	291.0	300.0	22.7	24.4
SEm±	0.5	0.5	7.7	7.4	1.3	0.7
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Treatment details are given under Materials and Methods.

study. In different irrigation regimes, highest grain weight was recorded in I_1 irrigation (347.5 and 359.5 g) for both the year respectively and lowest was recorded in I_5 (390.5 and 395.7 g) for respective years. The interaction effects obtained were non-significant. Highest grain weight (360.0 and 366.7 g) was obtained in the crop sown on broad beds with irrigation application after 25% depletion of available soil moisture (M_2I_1) during both the years respectively, compared to rest of the treatment combinations. Higher grain weight was due to more congenial environment in broad beds with optimum supply of moisture, leading to higher biomass, better leaf area which leading to more assimilation of photosynthates and their partitioning to sinks hence bold grains with more weight (Table 2). These results were on par with Jehan B *et al.* (2012), Zhaoquan *et al*. (2018) and Kingra *et al.* (2021).

100 grain weight (g): Although higher 100 grain weight was recorded with broad bed planting (25.9 and 26.6 g) system but the data pertaining to 100 cob grain weight (Table 2) showed non-significant differences in planting system during 2017 and 2018. In contrary to that significant differences in test weight were observed under different irrigation regimes during both the years. Highest test weight (29.1 and 29.1 g) was recorded in I_1 irrigation and lowest was recorded in I_5 (21.7 and 24.2 g) in the respective years. The interaction effects obtained did not reached to the significant levels. In combination of treatments, highest test weight was recorded in M_2I_1 (29.4 and 29.9 g) in both the years under study, compared to rest of the treatment combinations. Higher test weight obtained on broad beds with optimum moisture levels resulted in higher biomass, leaf area, photosynthates and their translocation to sinks and ultimately resulted in less chaffy grain filling (Table 2). Similar results were also reported by Huang C *et al*. (2022).

Grain yield (t/ha): Significant differences were observed in grain yield of maize sown in different planting systems as well as with different irrigation regimes. In different planting system, higher grain yield was observed in broad bed (4.37 and 4.57 t/ha) compared to narrow bed (4.23 and 4.38 t/ha) system of planting in both the respective years. Relatively more grain yield was obtained with optimum moisture levels, i.e. I_1 (4.86 and 4.93 t/ha) compared with rest of the treatments and lowest grain yield (3.91 and 4.02 t/ha) was obtained with I_5 treatment during 2017 and 2018, respectively. Interaction effect of different planting method and irrigation regimes was found to be non-significant. But the best treatment combination was observed in M_2I_1 which recorded ever highest grain yield (4.99 and 5.07 t/ha) in 2017 and 2018 respectively. The lower grain yield and other growth parameter of maize during 2017 was due to high rainfall with high intensity during critical period. Higher grain yield obtained was because of the favourable microclimatic conditions available for the bed sown crop under optimum supply of moisture. The good amount of loose soil available in case of broad beds provide sufficient space for better growth in both above and below the ground, leading to better plant vigour, higher leaf area, higher crop biomass, better translocation of photosynthates to grains and ultimately resulted in higher grain yield (Table 3). Similar results were also reported by Jehan B *et al.* (2012), Zhaoquan *et al*. (2018), Kaur *et al.* (2020), Sen *et al*. (2020) and Huang C *et al*. (2022).

Biological yield (t/ha): Significant differences were observed in grain yield of maize when sown in two planting systems under different irrigation regimes. Under different planting systems, comparatively higher biological yield was obtained in broad bed sown crop (8.97 and 9.07 t/ha) compared to narrow bed (8.54 and 8.58 t/ha) system of planting in the respective years. Higher biological yield was observed in higher level of irrigation, i.e. I_1 (9.28 and 9.40 t/ha) compared to rest of the treatments and lowest biomass yield was observed in treatment I_5 (8.20 and 8.26 t/ha) during 2017 and 2018, respectively. The interaction effects were observed non-significant. But the best treatment combination was observed in M_2I_1 which recorded ever highest biological yield (9.59 and 9.81 t/ha) in 2017 and 2018 respectively. Higher biomass yield was due to getting favourable environment in broad bed with optimum supply of moisture provided sufficient space for growth in both above and below the ground, leading to higher leaf area which turns to high biomass production (Table 3). The finding was on par with Zhaoquan *et al*. (2018), Kaur *et al*. (2020a & b) and Huang C *et al*. (2022).

High rainfall intensity with unequal distribution leads to greater economic losses of crops as a general and specifically maize which is highly susceptible to both the extremes for water may be due to water logging or prolonged dry spells. Based on above experiment it is concluded that broad bed method of planting is highly beneficial for maize crop as it saved the irrigation water during limited irrigation supply

Table 3 Grain yield and biological yield as influenced by different planting methods with limited irrigation regimes

Treatment	Grain yield (t/ha)		Biological yield (t/ha)		Harvest Index	
	2017	2018	2017	2018	2017	2018
(Narrow bed) M_1	4.23	4.38	8.54	8.58	0.50	0.51
(Broad bed) M_2	4.37	4.57	8.96	9.07	0.49	0.50
SEm±	0.04	0.05	0.12	0.14	0.01	0.01
CD (P=0.05)	0.12	0.14	0.36	0.41	0.02	0.03
I_1	4.86	4.93	9.28	9.40	0.52	0.53
I_2	4.43	4.79	9.17	9.26	0.49	0.52
I_3	4.27	4.42	8.74	8.81	0.49	0.50
I_4	4.02	4.21	8.38	8.42	0.48	0.50
I_5	3.91	4.02	8.20	8.26	0.48	0.49
SEm±	0.06	0.08	0.19	0.22	0.01	0.02
CD (P=0.05)	0.18	0.23	0.57	0.65	0.03	0.05
Interaction M × I						
M_1I_1	4.73	4.79	8.97	8.99	0.53	0.53
M_1I_2	4.33	4.69	8.94	8.97	0.49	0.52
M_1I_3	4.16	4.34	8.55	8.62	0.49	0.51
M_1I_4	4.06	4.18	8.20	8.25	0.50	0.51
M_1I_5	3.87	3.90	8.04	8.08	0.48	0.48
M_2I_1	4.99	5.07	9.59	9.81	0.52	0.52
M_2I_2	4.54	4.89	9.40	9.54	0.48	0.51
M_2I_3	4.38	4.51	8.92	8.99	0.49	0.50
M_2I_4	3.98	4.24	8.55	8.58	0.47	0.49
M_2I_5	3.96	4.13	8.36	8.44	0.47	0.49
SEm±	0.09	0.11	0.27	0.31	0.02	0.02
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Treatment details are given under Materials and Methods.

and at the same time non-stagnation of excess water during high rainfall situations. Further irrigation application at 25% DASM is beneficial for getting better plant vigour, good growth and higher grain yield of maize.

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