

Enhancing productivity of spring maize (*Zea mays*) through planting methods, varieties and irrigation levels in Punjab

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ABSTRACT

A field experiment was conducted during the spring seasons of 2010 and 2011 at Ludhiana to enhance the productivity of spring maize through cultivars, planting methods and irrigation scheduling. The experiment was conducted in 3 times replicated factorial split-plot design, where main-plots received 9 combinations of three varieties viz. 'JH 3956', 'PMH 2' and 'JH 3459' and 3 methods of planting viz. freshly prepared beds, ridges and flat plots while sub-plots received 3 irrigation levels based on IW:CPE ratios viz. 1.2, 0.9 and 0.6. Crop planted on southern slope of east-west laid beds and ridges recorded 18.0–18.1% higher grain yield, 19.7–21.2% higher irrigation water productivity (IWP) and 37.8–38.6% higher net returns over variable costs in comparison to flat planted crop. Cultivar 'JH 3956' produced 12.7% higher grain yield, similar IWP and 25.7% higher returns as compared to 'PMH 2', which in turn recorded 7.9% higher grain yield, 6.5% higher IWP and 17.6% higher returns than that of 'JH 3459' cultivar. The IWP was recorded the highest in IW:CPE ratio of 0.6 while the grain yield and economic returns was the highest with irrigation at 0.9 IW:CPE ratio.

Key words: Beds, Flat, Irrigation scheduling, IW:CPE ratio, Maize cultivars, Ridges

The state of Punjab is well known for its higher agricultural productivity (28.5 mt in 2012–13) and contributions towards the national buffer stock of food grains (25.1% rice and 33.6% wheat in 2012–13). This is only because of intensive cultivation of the rice–wheat cropping system which has also resulted in several adverse effects (Sidhu and Chhiba 2008) on soil and fresh ground water. The ground water is the main source of irrigation and its continuous withdrawal to meet the high irrigation demand of rice–wheat system is causing its rapid depletion which is a cause of concern. Such concern demand crop diversification and replacement of rice (*kharif* crop) with crops like maize which has low irrigation requirement. But cultivation of maize in *kharif* season has its own limitations like comparatively lower yield, frequent attack of insect-pests and higher incidence of diseases which results in lower net returns. So, cultivation of maize in spring season (February to May) is picking up and large acreage has been put under it because it overcame the listed limita-

tions. The spring planted crop faces wide range of temperatures starting from very low which may be sub zero (end January–mid February) to very high temperature which may go above 40°C (April–May). The reproductive phase of spring maize in the region is often associated with hot and dry weather (May–June) when evaporation rates are as high as 8 to 10 mm/day and water stress even for a short period at this stage can adversely affect the grain yield as maize yields are most sensitive to water stress, especially at flowering and pollination stages (NeSmith and Ritchie, 1992). Keeping in view the high temperatures and low relative humidity, farmers often over-irrigate the crop which results in low water productivity of the crop. Thus, there is dire need to formulate various strategies for improving the water and economic productivity of otherwise highly profitable crop. Various agronomic practices like planting methods and irrigation scheduling can help in mitigating the climatic vagaries during the crop season by changing the micro-environment of the surroundings. The southern slopes of east-west laid ridges generally have higher temperature due to more entrapment of solar radiations thereby planting on southern slope can promote germination and growth during earlier stages. Since the genetic characteristics of different crops/cultivars vary for their response to high temperature

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and water-stress conditions, it becomes essential to monitor the performance of different cultivars under variable micro-climate and water-management conditions.

Keeping these considerations in view, a study was carried out to find the most suitable planting and irrigation option for obtaining higher yield, water and economic productivity of maize during spring season in north-western plains of Punjab.

MATERIALS AND METHODS

The field experiments were conducted at research farm of Punjab Agricultural University, Ludhiana, (30°54'N, 75°48' E, 247 m above the mean sea-level) during spring (January to May) season of 2010 and 2011. The site is situated in the central plain region of Punjab under Trans-Gangetic agro-climatic zone of India. The average rainfall of the area is around 700 mm, 80% of which is received during July to September and the rest during November to April. The normal (long time average) maximum and minimum temperatures vary from 18.9°C and 5.3°C in January to 39.9°C and 25.6°C in June respectively. Maximum air temperature during 2 seasons ranged between 8.6–12.5°C (January) and 44.0–45.4°C (May–June) and minimum air temperature was between 3.0–3.8°C (January) and 29.8–32.0°C (June). The total rainfall from January to June was 197.4 and 85.8 mm and open pan evaporation was 1131.8 and 1091.3 mm during the two years, respectively, as compared to normal rainfall of 187.7 mm (25.6% of annual rainfall) and normal pan evaporation of 1086.6 mm. The soil of the experimental site was loamy sand in texture throughout 180 cm profile depth. The bulk density of soil profile varied from 1.57 to 1.61 with slight increase till 180 cm depth. The soil was slightly alkaline and non-saline in 0–30 cm profile. The soil was low in organic carbon content (1.3 g/kg). It was low in available (KMnO₄ extractable) nitrogen (174.6 kg/ha), medium in available (0.5 N NaHCO₃ extractable) phosphorus (14.0 kg/ha) and potassium (147.6 kg/ha). The experiment comprised of 27 treatments combinations, which was laid out in split-plot design (factorial) with three replications. Treatments combination of planting methods (raised bed, ridge and flats) and varieties 'JH 3956', 'PMH 2' and 'JH 3459' were allotted to main-plots and irrigation levels viz. IW : CPE of 1.2, 0.9 and 0.6 to sub-plots. Each treatment plot was surrounded by 0.6 m buffer strip on all the sides. A pre-sowing irrigation was applied to the field vacated after paddy harvesting. The raised beds and ridges were prepared with the help of tractor operated bed maker and ridger. The width of the top of the bed was 37.5 cm with furrow width of 30 cm and depth of 15 cm. The ridge to ridge distance was 60 cm with furrow depth of 25 cm. Maize varieties were sown on 30 January and 6 February

during 2 years, respectively as per the treatments. Two seeds/hill were dibbled in east-west lines in flat plots and at mid height of southern slope of the raised beds and ridges laid in east-west direction. The row to row spacing was 67.5 cm and plant to plant spacing was 13.3 cm in case of beds, whereas on ridges and flats the spacing was 60 and 15 cm. Thinning of crop was done at thirty days after planting (DAP) keeping one plant per hill to maintain uniform plant population in all the treatments. The irrigations were applied as per the treatments. The amount of irrigation water was kept constant at 7.5, 6.0 and 5.0 cm in flat, ridge and bed plots, respectively. All other cultivation practices were followed as per the recommendations for maize production by Punjab Agricultural University. Leaf area index (LAI) was recorded by using the Sun Scan Canopy Analyzer. Dry-matter accumulation (DMA) was recorded by harvesting two representative randomly selected plants from each plot, then sun- and oven- drying at 60°C to a constant weight. The data on various parameters was subjected to analysis of variance (ANOVA). The comparison of treatment means was made by critical difference (CD) at P_e 0.05.

RESULTS AND DISCUSSION

Growth attributes

Periodic leaf area index (LAI): The ridge and bed plots recorded significantly higher LAI as compared to flat plots during all the periodic observation i.e. from 30 days after planting (DAP) to crop harvesting (Fig. 1). However, LAI was similar on ridges and beds at all the growth stages. At 30 DAP, ridges and beds recorded 8.6 and 4.6% higher LAI than flat plots, respectively. Similar trend in LAI was observed at other periodic observations. LAI increased with crop growth to attain maximum value at 90 DAP and then started to decline till harvesting of crop. The LAI was 9.3 and 8.9% higher on ridges and beds than on flats at the time of harvest. The southern slopes of ridges and beds entrap higher amount of radiations which help the seedlings to grow vigorously during initial growth stages when temperatures are lower than the optimum range. The optimum moisture-aeration balance in ridges and beds could have created better root zone environment for uptake of water and nutrients leading to better crop growth and higher number of leaves which was presented in terms of higher LAI in ridges and beds as compared to flat plots.

At 30 DAP, 'JH 3459' recorded 9.1 and 10.5% higher LAI as compared to 'JH 3956' and 'PMH 2' cultivars, respectively. 'JH 3459' variety has genetic character of better vigour and growth during initial crop stages. At 45 and 60 DAP, all the cultivars recorded statistically similar values of LAI. However, at 90 DAP and other succeeding observations till harvest, the cultivar 'JH 3956' recorded

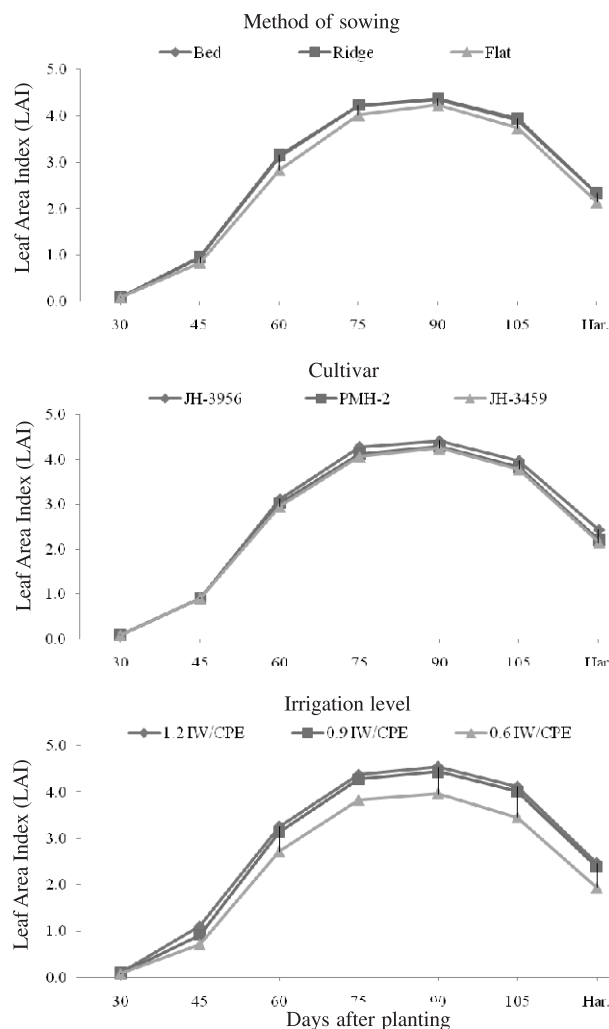


Fig. 1. Periodic leaf area index (LAI) of spring maize as influenced by method of planting, cultivar and irrigation level (pooled data of 2 years)

significantly higher LAI than ‘PMH 2’ and ‘JH 3459’, latter two being statistically at par. At harvest, cultivar ‘JH 3956’ recorded 10.4 and 13.0% higher LAI than ‘PMH 2’ and ‘JH 3459’ respectively.

The plots irrigated at IW: CPE of 1.2 recorded significantly higher LAI at all the stages of observation. The magnitude of reduction in value of LAI was less when IW: CPE ratio was reduced from 1.2 to 0.9, but it was quite higher when lowered from 0.9 to 0.6 at all the periodic observations. IW : CPE ratio of 1.2 was statistically at par with ratio of 0.9% but recorded 27.8% higher LAI than ratio of 0.6 at the time of crop harvest. Well watered conditions under IW : CPE ratio of 1.2 and 0.9 helped the plants to develop good source size and capacity by keeping the plant cells fully turgid resulting in better growth and LAI to capture higher proportion of solar radiations.

Periodic dry matter accumulation (DMA): The pooled

data regarding periodic DMA (Fig. 2) reveal that the ridges and beds recorded significantly higher DMA as compared to flats during all the periodic observations i.e. from 30 DAP to crop harvesting. However, DMA was similar on ridges and beds at all the growth stages. At 30 DAP, ridges and beds recorded 17.1% and 14.3% higher dry-matter (DM) than in flat plots. Similar trend in DMA was observed at other periodic observations. The DMA was 19.9 and 17.0% higher on ridges and beds than on flats at the time of harvest. Since the raised beds and ridges were formed from the soil excavated for creating furrows, this surface soil being rich in nutrients (both applied and inherent) resulted in increased fertility of soil in beds and ridges. This along with better root zone environment led to higher LAI and higher photosynthesis in crop on beds and ridges. All these factors led to significantly higher dry matter production and accumulation under ridge and bed methods of planting than in flats.

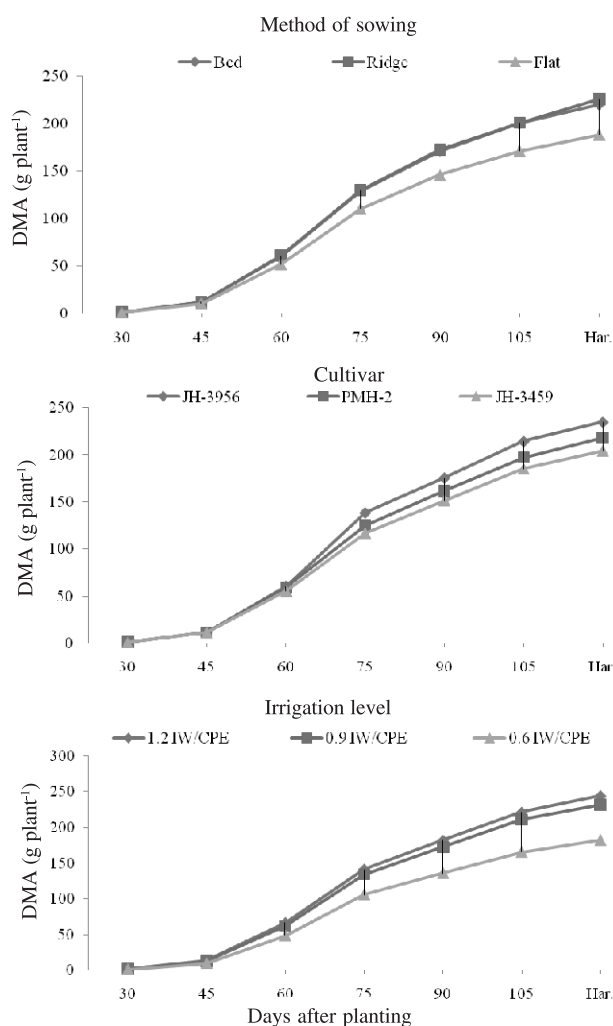


Fig. 2. Periodic dry-matter accumulation (DMA) (g/plant) of spring maize as influenced by method of planting, cultivar and irrigation level (pooled data of 2 years)

At 30 DAP, 'JH 3459' accumulated 7.1% and 6.1% higher DM as compared to 'PMH 2' and 'JH 3956' cultivars, respectively. At 45 DAP, all the cultivars were similar with respect to DMA. However, at 60 DAP, the cultivars 'JH 3956' and 'PMH 2' recorded significantly higher DM than 'JH 3459', former two being statistically at par. Unlike at 60 DAP, 'JH 3956' recorded higher DMA than 'PMH 2' which in turn recorded higher DM than 'JH 3459' at 75 DAP and the same trend continued till the crop harvest. At harvest cultivar 'JH 3956' recorded 7.5% higher DMA than 'PMH 2' which in turn recorded 6.8% higher DMA than 'JH 3459'. The late maturity of cultivar 'JH 3956' by 6–7 days as compared to the other two cultivars could have helped to accumulate higher amount of dry matter at harvest.

The plots irrigated at IW: CPE of 1.2 recorded significantly higher DMA at all the stages. The DMA at harvest was 5.5% higher in plots irrigated with IW: CPE ratio of 1.2 than in plots irrigated with ratio of 0.9 which in turn recorded 27.1% higher DMA than IW: CPE ratio of 0.6. Decrease in DMA in IW: CPE 0.6 irrigation regime can be attributed to closure of stomatal apertures to reduce transpiration losses under water deficit situations (Mutava *et al.*, 2011) leading to lower gaseous exchange and CO₂ assimilation ultimately resulting in lower DMA as compared to higher irrigation levels. Lower number of leaves per plant and LAI under 0.6 IW: CPE ratio also support the lower amount of DMA in stressed plants as compared to well watered plants under IW: CPE ratio of 0.9 and 1.2. Nutrient availability is reduced under water stressed conditions and high temperature stress affects the photosynthesis process adversely which further lead to low DMA (Wang *et al.*, 2008; Farre and Faci, 2006). Well watered conditions under IW: CPE ratio of 1.2 and 0.9 helped the plants to develop good source size and capacity by keeping the plant cells fully turgid resulting in better growth and LAI to capture higher proportion of solar radiations for accumulating significantly higher quantity of dry matter.

Yield attributes

Cob barrenness: Cob barrenness was not significantly affected by different planting methods and cultivars (Table 1). Significantly lower percentage of cob barrenness was recorded in highest irrigation level. IW: CPE ratio of 1.2 recorded 8.9% less cob barrenness over IW: CPE ratio of 0.9, which in turn recorded 56.0% less cob barrenness over irrigation ratio of 0.6. Stress during pollination and thereafter must have caused desiccation of pollens and abortion of zygote (Ratalino Edreira *et al.*, 2013) leading to higher barrenness and lowered the number of grains/ear in stressed plants leading to reduced grain yield.

100-grain weight: Planting methods did not differ significantly for 100-grain weight (Table 1). Cultivar 'PMH 2' had boldest grains followed by that of 'JH 3956' and 'JH 3459', respectively. The 100-grain weight of 'PMH 2' was 6.4% and 21.7% higher than that of 'JH 3956' and 'JH 3459', respectively, whereas it was 14.4% higher in 'JH 3956' as compared to 'JH 3459'. Irrigation levels of 1.2 and 0.9 IW : CPE ratio were at par with respect to hundred grain weight but recorded a respective increase of 5.4% and 4.7% over 0.6 IW : CPE ratio. Lower assimilate production due to low LAI, stomatal closure and/or high level of endogenous abscisic acid during above period might have limited 100 grain weight in water stressed plots. Lower kernel weight in water stressed plots indicates that plants were unable to meet the demand of growing kernels which may be due to reduced assimilate production or storage during grain filling as is clear from the significantly lower values of various growth attributes like DMA which have a bearing on sink size and capacity.

Harvest index: Crop planted on ridges, beds and in flats recorded statistically similar value of HI (Table 1). Differences in harvest index between cv. 'PMH 2' and cv. 'JH 3459' were not significant but HI of both the cultivars was significantly inferior to that of 'JH 3956'. Cultivar 'JH 3956' recorded 6.0 and 6.3% higher value of HI over 'PMH 2' and 'JH 3459', respectively. IW: CPE ratio of 0.9 recorded 4.8% higher value of harvest index over ratio of 0.6 but increasing irrigation level from 0.9 to 1.2 was not able to produce corresponding increase in harvest index so the latter 2 were at par with respect to harvest index. The effects of deficit irrigation on grain yield were greater than total biomass due to which lower harvest index is reported under deficit irrigation (Tyagi *et al.*, 1998).

Productivity

Grain yield: The grain yield of maize under ridge and bed did not differ significantly from each other but it was 18.1% and 18.0% higher than in flat plots, respectively (Table 1). More frequent irrigations in ridges and beds during the higher temperature period may have helped the crop to maintain optimum temperature conditions. Larger source size as indicated by statistically higher LAI and DMA along with better micro-climatic conditions during the crop reproductive stage in ridges and beds is responsible for the development of larger sink size and capacity, which is shown in terms of less cob barrenness or higher number of grains in ridges and beds. Better source and sink development and congenial micro-environment under ridge and bed method of planting resulted in better translocation of not only reserved but also concurrent photosynthates for filling the sink to its capacity for higher grain yield as compared to flat plots.

'JH 3956' recorded 12.7% and 21.6% higher grain yield than that of 'PMH 2' and 'JH 3459', respectively. 'PMH 2' also recorded 7.9% higher grain yield than that of 'JH 3459'. Higher DMA in 'JH 3956' can exhibit a larger source size to support larger sinks. This along with better capacity to supply accumulates from source to sink as evident from significantly better HI (Table 1) led to higher grain yield in 'JH 3956' as compared to other two cultivars. Active photosynthesis resulting from longer duration along with higher LAI, might also have contributed towards higher grain yield in 'JH 3956' as compared to 'JH 3459' and 'PMH 2'. The yield advantage in late maturing hybrids is largely attributed to longer period of radiation interception along with an increase in the leaf area of later hybrids (Tsimba *et al.*, 2013). Higher DMA in 'PMH 2' than in 'JH 3459' was mainly due to genetic differences like higher stem thickness although both these cultivars had almost similar plant height, LAI and life span. Malhi *et al.* (2006) reported higher DM and 8.4% to 13.3% higher grain yield in 'PMH 2' as compared to 'JH 3459' during Kharif season under flat planting.

The IW: CPE ratio of 0.9 resulted in 33.2% higher grain yield than that with 0.6 IW : CPE ratio. Increasing irrigation level above 0.9 IW : CPE ratio did not further increased the grain yield significantly. Grain filling was also reduced due to early maturity in 0.6 IW : CPE irriga-

tion level. Shortening of grain-filling period because of heat stress resulting in reduction in amount of light captured by crop canopy is considered to be a main reason for reduction in grain yield. Stress during grain filling period affects the grain weight due to stomatal closure leading to lower rate of concurrent photosynthesis and lower rate of translocation of photosynthates to the grains which ultimately reduces the yield (Rattalino Edreira *et al.*, 2012). Grain yield reductions due to heat stress in maize are mainly related to lowering of HI and to a lesser extent to variations in final shoot mass (Rattalino Edreira *et al.*, 2013).

Irrigation water productivity (IWP): The total amount of irrigation water applied in ridge and bed plots was nearly same to that applied in flat plots as the irrigation was applied on the basis of IW: CPE ratio. The amount of water applied per irrigation was less in ridges (6 cm) and beds (5 cm) than in flat plots (7.5 cm) but the number of irrigations was higher than the flat plots (Table 2). There was marked increase in IWP of crop on beds and ridges than in flats which was mainly due to higher grain yield obtained from ridges and beds as compared to flat. The IWP in ridge and bed plots was 21.2 and 19.7% higher than the flat plots, respectively (Table 1).

The cultivar 'JH 3956' had comparatively longer duration and it matured 6–7 days later than the other two cul-

Table 1. Yield parameters, grain yield, irrigation water productivity and economics of spring maize as influenced by method of planting, cultivars and irrigation regime (pooled data of 2 years)

Treatment	Cob barrenness (%)	100-grain weight (g)	Harvest index (HI) %	Grain yield (t/ha)	Total irrigation water applied (cm)	Irrigation water productivity (kg/ha-mm)	Variable cost ($\times 10^3$ ₹/ha)	Gross returns ($\times 10^3$ ₹/ha)	Returns over variable cost ($\times 10^3$ ₹/ha)
<i>Methods of planting</i>									
Bed	6.89	22.9	28.7	8.33	58.9	15.2	34.3	71.5	37.2
Ridge	6.84	23.0	28.7	8.34	59.0	15.4	34.2	71.6	37.4
Flat	7.38	22.6	28.5	7.06	60.0	12.7	33.6	60.6	27.0
CD (P=0.05)	NS	NS	NS	0.27	-	0.5	-	2.3	2.3
SEm \pm	0.14	0.2	0.1	0.90		0.1		0.7	0.7
<i>Cultivar</i>									
'JH 3956'	6.80	23.3	29.8	8.75	64.0	14.8	34.1	75.2	41.1
'PMH 2'	7.51	24.8	28.1	7.77	57.5	14.8	34.0	66.7	32.7
'JH 3459'	6.81	20.4	28.1	7.20	56.7	13.9	34.0	61.8	27.8
CD (P=0.05)	NS	0.82	0.3	0.27	-	0.5	-	2.3	2.3
SEm \pm	0.14	0.2	0.1	0.90		0.1		0.7	0.7
<i>Irrigation regime (IW: CPE ratio)</i>									
1.2	4.60	23.3	29.0	8.85	81.8	11.0	34.3	76.1	41.8
0.9	5.05	23.1	29.2	8.50	60.4	14.3	34.1	73.0	38.9
0.6	11.47	22.1	27.8	6.38	36.6	18.2	33.8	54.7	20.9
CD (P=0.05)	0.53	0.5	0.4	0.44	-	0.5	-	2.6	2.6
SEm \pm	0.15	0.1	0.1	0.15		0.1		0.8	0.8

tivars, thereby it (63.98 cm) received 11.3 and 12.8% higher amount of irrigation water as compared to 'PMH 2' and 'JH 3459', respectively (Table 1). The corresponding increase in grain yield produced by 'JH 3956' was also higher thereby it recorded 6.5% higher IWP than that of 'JH 3459' but was at par with 'PMH 2' which produced lower grain yield (84.9 kg/ha) but with less amount of irrigation water due to shorter life span.

The plots irrigated with IW: CPE ratio of 0.6 resulted in 27.3% higher IWP than in plots irrigated with IW: CPE ratio of 0.9 which in turn recorded 30.0% higher IWP than plots irrigated with 1.2 IW: CPE ratio (Table 1). The amount of irrigation water applied in plots with IW : CPE ratio of 0.6 was 64.9% less as compared to IW: CPE ratio of 0.9 which was further 35.3% less than the plots irrigated with 1.2 IW:CPE ratio. Farre and Faci, 2006 also reported higher consumptive use in case of well irrigated crop as compared to stressed crop. The increased amount of irrigation water in higher IW: CPE ratios lowered IWP as compared to lower ratio of IW: CPE.

Economic productivity: The variable cost incurred in ridge and bed plots was nearly same which was little higher than the flat plots. It was mainly due to the cost involved in construction of ridges and beds which required one extra operation with tractor operated ridge or bed maker after normal field preparation as compared to flat plots which required normal field preparation only. The grain yield was quite higher in ridge and bed plots so were the gross returns. The returns over variable cost were 38.6 and 37.8% higher in ridge and bed plots as compared to flat plots, respectively (Table 1).

Cultivar 'JH 3956' recorded a little higher variable cost as compared to other two cultivars which recorded almost similar variable cost. This was mainly due to longer crop duration of the former cultivar and cost involved on various operations like irrigation during this extended period increased its variable cost. Cultivar 'JH 3956' recorded higher grain yield so the gross returns were 12.7 and 21.6% higher and returns over variable cost were 25.7 and 47.7% higher over the cultivars 'PMH 2' and 'JH 3459', respectively. 'PMH 2' also recorded 17.6 % higher returns over variable cost in comparison to 'JH 3459' (Table 1).

Lower irrigation levels incurred low variable cost as the number of irrigations applied in these treatments was less so involved less labour. But the returns over variable cost were also less in lower irrigation levels as the gross returns were less due to lower grain yield. IW: CPE ratio of 1.2 recorded 7.4% higher returns over variable cost as com-

pared to IW: CPE ratio of 0.9 which in turn recorded 86.0% higher returns over variable cost in comparison to 0.6 IW: CPE ratio.

Based on the study it is concluded that spring season maize planted on southern slopes of the east-west laid ridges and beds ridges improved the productivity in terms of grain yield, irrigation water and net monetary returns. The cv. 'JH 3956' performed better in terms of harvest index (HI), grain yield, irrigation water and economic productivity. Irrigation regime of 0.9 IW: CPE ratio seems to be optimum from water saving, grain yield and economic productivity point of view.

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