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Productivity, quality and water expense efficiency of late *kharif* sown hybrid maize (*Zea mays* L.) under different irrigation regimes and nitrogen levels

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In the Indo-Gangetic plains of India, the continuous adoption of rice-wheat cropping system has led to a number of adverse effects including deterioration of soil health, severe ground water depletion and emergence of pest and weed infestation. The above factors have led to the need for replacing high water demanding rice with comparatively low water requiring maize crop (Jalota and Arora, 2002). In Punjab, late sown *kharif* maize (August sowing) has significantly lower maize borer infestation (Anon., 2012), higher grain and stover yields, net return and benefit: cost ratio compared to normal sowing in June and July (Panchanathan *et al*., 1992). In August sowing, as the crop progresses after knee-high stage, the temperature goes on falling causing a reduction in evapo-transpiration rate, so there is a possibility of less irrigation water requirement as compared to maize sown in other seasons. The performance of a plant in terms of its growth and yield mainly depends on plant water status which can be maintained at optimum level by following a proper irrigation schedule. Most of the work on irrigation is based on critical stages or soil moisture depletion without incorporating climatic parameters. IW/CPE ratio has been found to be a reliable, economical and practical basis for scheduling irrigation (Prihar *et al.,* 1976). Again, nitrogen is the most limiting factor of all the essential plant nutrients in Punjab soils owing to their low organic carbon content (Benbi and Brar, 2008). Not only the grain yield of maize but the quality of grains is also affected to a great extent by nitrogen availability. It has been reported that maize grown under limited water supply requires less nitrogen to achieve maximum grain yield than that required with well water supply (Moser *et al*., 2006) and increase in nitrogen supply could improve yield and irrigation water use efficiency (Mansouri *et al*., 2010). No concrete information is available on irrigation and nitrogen requirements of late sown *kharif* maize. Keeping this in view, a field experiment was carried out to evaluate the performance of late sown *kharif* hybrid maize under different irrigation and nitrogen levels. The field experiment was conducted at Students' Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana (30^{o} 54′N latitude and 75^{o} 48′E longitude at an altitude of 247 metre above the mean sea level) during late *Kharif* of 2009-10. Experimental soil was loamy sand in texture. Moisture content of 0-180 cm soil profile at 0.3 and 15 bar was 44.17 and 10.52 cm, respectively, with available soil water 33.65 cm. The average bulk density of 0-180 cm soil profile was 1.60 g cm^{-3}. The soil pH, electrical conductivity, organic carbon, available N, P and K were 8.1, 0.21 dS m^{-1}, 0.15 per cent, 185.6 kg ha^{-1}, 13.9 kg ha^{-1} and 154.6 kg ha^{-1}, respectively in the top 0-15 cm layer. The experimental site has been characterized by sub-tropical semi-arid climate with average rainfall of 705 mm. The experiment was laid out in split-plot design with four replications and treatments comprised of four irrigation regimes as main plot treatment [IW/CPE ratio 0.50 ($I_{0.50}$), 0.75 ($I_{0.75}$), 1.00 ($I_{1.00}$) and 1.25 ($I_{1.25}$)] and four nitrogen levels as sub-plot treatments [100(N_{100}) , 125 (N_{125}), 150 (N_{150}) and 175 (N_{175}) kg N ha^{-1}]. Nitrogen was applied as per treatments. P_2O_5, K_2O and zinc sulphate were applied @ 60, 30 and 25 kg ha^{-1}, respectively as recommended in the Punjab state (Anonymous, 2012). Urea, single super phosphate and muriate of potash formed the source for N, P and K, respectively. Entire quantity of P_2O_5, K_2O, zinc sulphateand one third of N was applied at sowing and remaining N was applied in two equal splits i.e. at knee high and pre-tasselling stages. The hybrid maize cultivar 'PMH1' was sown on August 25, 2009 after giving a pre-sowing irrigation. The sowing was done by dibbling two seeds per hill keeping row to row spacing of 60 cm and plant to plant spacing of 22 cm. Irrigation was scheduled when the cumulative pan evaporation (CPE) reached the level of 60, 75, 100 and 150 mm in case of $I_{1.25}$, $I_{1.00}$, $I_{0.75}$ and $I_{0.50}$, respectively. The irrigation water was measured with Parshall flume and depth of irrigation was 7.5 cm. The number of irrigations required during crop growing period was 3, 3, 2 and 1 at 1.2, 1.0, 0.75 and 0.50 IW/CPE, respectively, as given in Table 1. The total rainfall and open pan evaporation during the crop season were 216.4 mm and 364.9 mm, respectively and 73 per cent of the rainfall was received during first four weeks out of total 20 weeks of the crop season.

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Table 1: Details of irrigation applied during crop growing season

Treatments	Dates of irrigation	Number of irrigation	Total irrigation water applied (cm)
$I_{0.50}$	01 November (69)	1	7.5
$I_{0.75}$	17 October (54), 03 December (100/46)	2	15.0
$I_{1.00}$	09 October (46), 01 November (69/23), 20 December (117/48)	3	22.5
$I_{1.25}$	27 September (34), 23 October (60/26), 20 November (87/2	3	22.5

Note: Figures in parenthesis indicate days after sowing/days after previous irrigation

Table 2: Average monthly mean temperature, monthly rainfall and pan evaporation data during crop growing season

Month	**Average monthly mean temperature (°C)**	**Monthly rainfall (mm)**	**Monthly pan evaporation (mm)**
August	30.5	118.2	140.8
September	28.2	69.2	115.8
October	24.0	26.2	101.8
November	17.8	5.1	53.0
December	13.8	0	48.6
January'10	11.2	18.4	27.2

The crop was harvested manually on January 6, 2010 when more than 80 per cent of the cobs turned yellowish brown and grains became hard. Biometrical observations like cob length, cob diameter, grains per cob and barrenness of cob (unfilled portion) was measured from the six representative cobs selected randomly from each plot. Stover yield was monitored as cobs were picked and the remaining plant material including husk was sun dried, weighed and expressed as stover yield (q ha^{-1}). For grain yield, all the cobs from each net harvested plot were sun dried for fifteen days and shelled. The grain yield was adjusted to fifteen per cent moisture level and expressed as q ha^{-1}. Shelling percentage was calculated as the weight of grains expressed as percentage of whole cobs' weight. Grain yield expressed as percentage of total biomass yield was taken as harvest index. Protein, starch and oil content (%) in grains were determined by non-destructive method using instrument Foss Infratec^{TM} 1241 Grain Analyzer. Total sugar (as glucose) was estimated with Phenol Sulphuric acid method given by Dubois *et al.* (1956). Water expense was calculated by using the formula: Water expense = profile water use + effective rainfall + irrigation water applied. Water expense efficiency was expressed as the ratio of grain yield and water expense.

Yield attributes and yield

Effect of irrigation regimes and nitrogen levels on yield attributes and yield was significant (Table 3). Irrigation at $I_{1.25}$ and $I_{1.00}$ produced 370.4 and 365.4 grains per cob, respectively and these were statistically at par with each other but significantly higher than $I_{0.75}$ and $I_{0.50}$. The percent increase in number of grains per cob under $I_{1.25}$ over $I_{1.00}$, $I_{0.75}$ and $I_{0.50}$ were 1.4, 9.2 and 17.9, respectively. The increase in number of grains per cob might be due to lower barrenness of the cobs under higher irrigation regimes ($I_{1.25}$ and $I_{1.00}$) receiving 3 irrigations during growth period (Table 3). The reduction in barrenness of cobs at higher irrigation level might be due to better pollination and consequent to better filling of cobs due to optimum moisture availability. The maximum value of test weight (29.8 g) was also recorded under $I_{1.25}$, however, differences in test weight failed to attain the level of significance among irrigation treatments. Cob length and cob girth increased significantly as the number of irrigations increased in different treatments. Irrigation regime $I_{1.25}$ gave significantly higher shelling percentage (79.0%) in comparison to $I_{0.50}$ but it was statistically at par with $I_{1.00}$ and $I_{0.75}$. The grain yield was significantly increased up to $I_{1.00}$ irrigation level (81.2 q ha^{-1}), which produced 11.7 and 25.7 per cent higher yield than $I_{0.75}$ and $I_{0.50}$ (Table 3). Significantly higher grain yield under sufficiently irrigated regime can be attributed to the adequate turgidity which must have prevailed inside the plant and thereby helping in significantly better growth and development of the crop. During the reproductive stage, the well watered plants under $I_{1.00}$ must have been able to translocate the photosynthates efficiently from the source for the development of sink; sink size in the form of cob length and cob girth. Better pollination increased the number of grains per cob and reduced the cob barrenness (Table 3). Stover yield followed the same trend as those of grain yield. These findings are in conformity with those reported by Khan *et al*. (1996), Jat *et al.* (2008) and El-Tantawy *et al*. (2007).

Maximum number of grains per cob (360.4), test weight (30.8 g) and cob length (17.7 cm) were recorded with N_{175} which was statistically at par with N_{150} but significantly better than N_{125} and N_{100} (Table 3). However, the cob girth increased significantly up to N_{175}. In general, barrenness of cobs decreased with increase in nitrogen dose. At N_{175} cob barrenness was 8.9 per cent which was at par with 9.2 per cent cob barrenness recorded under N_{150}.

Table 3: Yield attributes and yield of late *kharif* sown hybrid maize as influenced by irrigation regimes and nitrogen levels

Treatments	No. of grains cob^{-1}	Test weight (g)	Cob length (cm)	Cob girth (cm)	Barrenness (%)	Shelling percentage	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index (%)
Irrigation levels (IW/CPE ratio)									
$I_{0.50}$	314.2	27.9	14.9	10.3	12.4	76.2	64.6	125.6	30.6
$I_{0.75}$	339.2	28.9	15.9	11.4	11.3	77.8	72.7	136.2	31.7
$I_{1.00}$	365.4	29.5	16.6	12.6	9.2	78.8	81.2	150.7	32.1
$I_{1.25}$	370.4	29.8	17.2	13.1	8.4	79.0	83.1	155.0	32.2
LSD (0.05)	**24.0**	**NS**	**0.6**	**0.4**	**0.9**	**1.6**	**7.2**	**13.6**	**NS**
Nitrogen levels (kg ha^{-1})									
N_{100}	331.4	26.6	14.3	9.2	12.1	76.4	65.6	123.8	31.3
N_{125}	343.6	28.6	15.6	11.7	11.3	77.6	73.3	139.2	31.3
N_{150}	353.7	30.5	17.1	12.8	9.2	78.6	79.8	150.0	31.9
N_{175}	360.4	30.8	17.7	13.7	8.9	79.2	82.9	154.6	32.2
LSD (0.05)	**16.8**	**1.9**	**0.7**	**0.3**	**1.5**	**1.5**	**6.2**	**7.8**	**NS**
Interaction	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 4: Effect of irrigation regimes and nitrogen levels on grain quality, water expense and water expense efficiency of late *kharif* sown hybrid maize

Treatments	Nitrogen content in grains (%)	Protein (%)	Starch (%)	Total sugars (%)	Oil (%)	Total water expense (cm)	Water expense efficiency (kg ha-cm^{-1})
Irrigation levels (IW/CPE ratio)							
$I_{0.50}$	1.65	10.6	68.47	3.23	4.37	27.6	234.6
$I_{0.75}$	1.68	10.7	68.22	2.90	4.43	34.0	213.9
$I_{1.00}$	1.74	11.1	67.70	2.81	4.50	41.1	197.7
$I_{1.25}$	1.76	11.2	67.66	2.41	4.53	42.3	196.5
LSD (0.05)	**0.05**	**0.3**	**0.40**	**0.27**	**NS**	**-**	**-**
Nitrogen levels (kg ha^{-1})							
N_{100}	1.66	10.5	68.21	3.02	4.41	35.3	185.9
N_{125}	1.70	10.9	68.18	2.83	4.42	35.9	203.9
N_{150}	1.70	11.0	68.03	2.80	4.48	36.6	218.1
N_{175}	1.77	11.2	67.62	2.71	4.52	37.1	223.7
LSD (0.05)	**0.05**	**0.3**	**NS**	**NS**	**NS**	**-**	**-**
Interaction	**NS**	**NS**	**NS**	**NS**	**NS**	**-**	**-**

The cob barrenness recorded under N_{150} was statistically lower as compared to that observed under N_{125} (11.3%) and N_{100} (12.1%). Grain yield was significantly higher up to N_{150} level (79.8 q ha^{-1}), which was at par with N_{175} (82.9 q ha^{-1}). Application of nitrogen resulted in better development of sink size as indicated by cob length and cob girth. Better pollination under adequately supplied nitrogen conditions reduced the barrenness and helped to develop the sink capacity i.e. the number of grains per cob which was well filled as indicated by test weight and higher shelling percentage (Table 3). Stover yield followed the same trend as those of grain yield. Similar observations were also recorded by some earlier workers (Rana and Choudhary, 2006; Khanday and Thakur, 1991; Ramu and Reddy, 2007).

Quality parameters

Maximum protein content (11.2%) in maize grains was observed under $I_{1.25}$ which was significantly better than $I_{0.75}$ and $I_{0.50}$ but statistically at par with that recorded under $I_{1.00}$ (Table 4). The higher protein content under $I_{1.25}$ and $I_{1.00}$ might be due to more production and translocation of assimilates to the sink as it is evident from significant increase in nitrogen content of grains with increase in irrigation regime (Table 4). Starch content in maize grains decreased with increase in irrigation level. Significantly higher starch content was observed under $I_{0.50}$ as compared to $I_{1.00}$ and $I_{1.25}$ whereas it was statistically at par with that recorded under $I_{0.75}$. Here it may be pointed out that under low level of irrigation, accumulation of carbohydrates was more resulting in more starch and low protein content. Like starch, total sugar content of maize grains also decreased significantly with increase in irrigation frequency. Lower irrigation regime of $I_{0.50}$ recorded maximum (3.23 per cent) total sugar while minimum was recorded under $I_{1.25}$. Increased sugar under moisture stress is an established phenomenon of stressed plants to accumulate these osmolytes to combat drought stress. Contrary to protein content, the total sugar exhibited a reverse trend. The decrease in total sugar at higher irrigation regime might be due to enhanced synthesis of protein at the expense of sugar and derivation of carbon skeleton from sugar for synthesis of amino acids. The results are in agreement with the findings of Bharthi *et al*. (1997) and Setter and Parra (2010). Quality parameters *viz*., oil, starch and total sugar content (%) of maize grains was not affected significantly by different nitrogen levels (Table 4). However, application of nitrogen at the level of N_{175} produced maximum protein content (11.2%) in grain which was comparable with that of N_{150} (11.0%) but significantly better than N_{125} (10.9%) and N_{100} (10.5%). This may be attributed to the maximum total nitrogen content of grains accumulated and extended benefit with congenial biochemical relations at higher nitrogen levels as reported by Kamalakumari and Singaram (1996).

Water use studies

Total water expense was computed by taking moisture content from 0-180 cm soil profile (Table 4). Among irrigation levels, total water expense followed the trend $I_{1.25} > I_{1.00} > I_{0.75} > I_{0.50}$. The irrigation regime $I_{1.25}$ recorded lowest water expense efficiency (196.5 kg ha-cm^{-1}) in spite of the best grain yield recorded under this treatment due to highest value (42.3 cm) of total water expense. Highest value of water expense efficiency was observed under $I_{0.50}$ (234.6 kg ha-cm^{-1}). Khan *et al.* (1996) also recorded higher value of water expense at IW/CPE ratio 1.00 as compared to IW/CPE ratio 0.75, 0.50 and control (with any irrigation).

Among different nitrogen levels, water expense increased with successive increase in nitrogen doses. It might be due to better growth of crop under higher nitrogen levels in terms of grain yield, stover yield and other growth parameters resulting in more water use under these treatments. Maximum water expense efficiency was observed under N_{175} (223.7 kg ha-cm^{-1}) while the lowest was under N_{100} (185.9 kg ha-cm^{-1}).

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