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Research Communication

Yield components, yield and nutrient uptake pattern in maize (*Zea mays*) under varying irrigation and nitrogen levels

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ABSTRACT

A field experiment was conducted during the rainy season of 2015 on sandy-loam soil at ICAR–Indian Agricultural Research Institute, New Delhi, to study the effect of variable irrigation regimes and nitrogen rates on yield-contributing parameters, yield and nutrient uptake in maize (*Zea mays* L.) hybrid 'PEEHM 5'. Irrigating maize at 25% depletion of available soil moisture (DASM) improved the grain and stover yield by 26.7 and 15.4%, and 40.9 and 82.5% over irrigation at 75% DASM and rainfed crop respectively. Nutrient (N, P, K) uptakes in grain were significantly greater with irrigation at 25% DASM than 75% DASM and rainfed crop. The highest grain yield (4.35 t/ha) was obtained with 160 kg N/ha, while the stover yield was the highest with 240 kg N/ha. Uptake of N and K in grain increased significantly up to 160 kg N/ha; however, P uptake by grain increased significantly up to 120 kg N/ha. Further, the combination of irrigation at 25% DASM and 200 kg N/ha resulted in the highest grain yield (5.56 t/ha). Overall, maize crop may be irrigated at 25% DASM and supplied with 160 kg N/ha to obtain higher yield with major nutrient-enriched grains.

Key words: Irrigation, Maize, N-rates, Nutrient uptake, Yield attributes

Maize crop is adapted to a wide range of climatic and edaphic conditions (Sharma and Dass, 2012) and has highest yield potential among cereals. However, its productivity in India (2.6 t/ha) is about half of the global average productivity of 4.9 t/ha (FAOSTAT, 2015), mainly due to nutrient-and water-stresses. Maize hybrids are the exhaustive user of nitrogen (N) and respond to much higher quantity than the generally recommended rate of 120–150 kg N/ha. Several research reports have depicted sizable yield increments with increasing N-application rates beyond 200 kg N/ha. This necessitates the further standardization of N-rate for hybrid maize. Moreover, it is not only the amount of N available in the soil, but also the soil-moisture regimes that influence the availability and uptake of nutrient including N. A significant interaction between irrigation and N-rates was observed for grain yield and water-use efficiency (WUE) by Paolo and Rinaldi (2008). The available literature also indicates that application of N imparts water-stress tolerance in plants. The ever-growing water scarcity invokes to rethink and rationalize water and nutrient supply to maize crop in such a way that improves nutrient uptake, yield and water productivity of this crop. Although maize is relativity insensitive to water deficits during early vegetative growth because of minimal crop-water requirement (Farre and Faci 2009), but it is susceptible during flowering and grain-filling stages (Doerge 2008), thus water stress at these stages needs to be avoided. The irrigation strategies in maize have mostly been designed based on critical growth stages and climatic approaches (IW:CPE ratio), none of which accurately reflect the soil-moisture status before irrigation. Depletion of available soil moisture (DASM) can be the sound basis of deciding time and amount of irrigation, but gravimetric measurements of soil-moisture contents required for this method are cumbersome. The advent of soil profile-moisture sensors has made the use of DASM approach feasible. However, N × irrigation (DASM based) interaction effects on maize have not been studied adequately in India. Hence, the current field investigation was carried out to study the effect of variable water regimes and N-rates on yield-contributing components, yield and nutrient uptake

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in maize hybrid 'PEEHM 5'.

The field experiment was conducted during the rainy (*kharif*) season of 2015 at the ICAR-Indian Agricultural Research Institute; New Delhi (28°40' N, 77°12' E, 228.6 m above mean sea-level). General climate of the area is typical semi-arid and sub-tropical with hot dry summers and cool winters. The maize hybrid 'PEEHM 5' was planted on 22 July, 2015 and harvested during the last week of October. During the growing season, the mean weekly maximum, minimum temperature, relative humidity, sunshine hour/day and evaporation were 34.3°C, 23.0°C, 84.6%, 54.4%, 6.3 and 5.1 mm, respectively. The total rainfall (July to October) during crop-growth period was 348.9 mm, with effective rainfall of 237.7mm. The experimental field soil was sandy loam, having *p*H 7.6, low to medium in organic C (0.54%), low in available nitrogen (216 kg/ha), medium in available P (16.7 kg/ha) and available K (245 kg/ha). The experiment was laid-out in a 3 time replicated split-plot design. The treatments consisted of 24 combinations of 3 irrigation regimes, viz. Irrigation at 25% depletion of available soil moisture (DASM), irrigation 75% DASM and no irrigation (rainfed condition), allotted to main-plots and 8 N application rates, viz. N_0 (control), N_{40} (40 kg N/ha), N_{80} (80 kg N/ha), N_{120} (120 kg N/ha), N_{160} (160 kg N/ha), N_{200} (200 kg N/ha), N_{240} (240 kg N /ha), N_{300} (300 kg N /ha) in sub-plots. In all, there were 72 experimental plots of 4.2 m × 3 m size each. Six irrigations were given under 25% DASM and 3 under 75% DASM irrigation regime. Maize was planted at a spacing of 60 cm × 20 cm using seed rate of 20 kg/ha. Nitrogen in form of urea as per treatments, phosphate (60 kg P_2O_5) as single superphosphate (SSP), potash 40 kg K_2O as muriate of potash (MOP) were applied. Entire dosage of phosphate and potash and one-third dose of N were incorporated into soil basally at the time of final land preparation. The remaining two-thirds N was band placed in 2 equal splits–first at knee-high stage and the second just before tasseling stage.

At harvesting, 5 plants were sampled from the net plot from the plot-border of each plot to observe the yield attributes like cobs/plant, cob weight, grains/cob and 100-kernel weight. To determine grain yield, maize cobs from the net plots were harvested and sun-dried for 6 days and weighed. The cobs were dehusked, shelled, cleaned, dried in sun, weighed again and grain yield was adjusted at 14% moisture content. To determine stover yield, maize stalks were cut at ground level and weighed after 7-day sun-drying. The N, P and K contents in grain and stover were estimated using standard chemical analysis methods. Nutrient uptake (N, P and K) in grain and stover was estimated by multiplying N, P and K contents (%) in grain and stover with their respective dry-matter yields. The data were statistically analysed as per analysis of variance techniques (ANOVA) and critical differences were computed at 0.05 probability.

Irrigation regimes significantly affected the yield attributes, viz. kernels/cob, kernel weight/cob and cob weight. However, cobs/plant and 100-kernel remained unaffected. Applying irrigation at 25% DASM resulted in the highest number of kernels/cob (255.6) which was 29.4 and 17.2% higher than rainfed crop and irrigation at 75% DASM respectively. Similarly, higher kernel weight/cob and cob weight were found with irrigation at 25% DASM. This could be owing to the fact that irrigation at 25% DASM resulting in a greater number irrigations, might have resulted in a favourable soil environment and better solubilization, uptake and assimilation of soil and applied nutrients, finally culminating into higher crop growth and vigorous yield attributes. The 100-kernel weight is the trait that is largely genetically controlled and that may be the reason, it was not affected significantly by either of the treatments.

All the yield attributes of maize were influenced significantly by the varied nitrogen application rates, barring 100-kernal weight. Cobs/plant were the highest with the application 200 kg N/ha, which was significantly higher than 80 kg N/ha and lower N-levels; however, it was at par with 120 kg N/ha and other higher N-rates. Similar was the trend for number of kernels/cob and kernel weight/cob, except that the highest values were obtained at 160 kg N/ha. Cob weight consistently and significantly increased up to 160 kg N/ha, and further increase in N-rate to 240 and 300 kg N/ha reduced the cob weight significantly. The higher values of most of the yield attributes at 160 kg N/ha could be likely owing to ready availability, insufficient amount of N the most important plant nutrient needed for the overall growth and development of the plant and its further higher doses might have led to the deficiency of other essential plant nutrient leading to lower values of yield attributes.

Grain yield increased with the increase of N-level up to 160 kg N/ha and further increase in N-dose caused a gradual decline likely due to deficiency of nutrients other than N and consequent diversion of plants energy towards vegetative growth under excess N-application. The highest grain yield (4.35 t/ha) obtained with 160 kg/ha N fertilization rate was 100.5% higher than the control, 8.2% higher than immediate lower N-level (120 kg/ha), and 3.2, 9.3 and 16.6% higher than the yield obtained with higher N levels, 200, 240 and 300 kg N/ha respectively. Stover yield also followed the identical trend, but it was the highest when N was applied at 240 kg/ha. Higher doses of nitrogen are known to enhance vegetative growth of the plant. The higher vegetative growth at 240 kg/ha, but dis-

Table 1. Effect of irrigation regimes and nitrogen rates on yield attributes, yield and nutrient uptake in maize

Treatment	Cobs/ plant	Kernels/ cob	100-kernals weight (g)	Kernel weight/cob (g)	Cob weight (g)	Yield (t/ha)		N-uptake(kg/ha)		P-uptake (kg/ha)		K-uptake (kg/ha)	
						Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
Irrigation													
25% DASM	1.20	256	23.0	63.4	96.4	4.60	9.56	79.3	66.3	9.6	9.5	27.8	117.8
75% DASM	1.20	219	22.3	53.0	94.1	3.63	8.28	57.3	51.2	9.0	8.2	21.7	94.1
Rainfed	1.17	198	20.7	44.6	83.5	2.52	6.78	40.8	36.3	6.2	6.7	13.5	86.7
SEm±	0.025	5.82	0.65	1.85	1.38	0.17	0.2	2.96	1.84	0.33	0.14	0.83	2.67
CD (P=0.05)	NS	16.68	NS	5.30	3.96	0.47	0.57	8.22	5.27	0.95	0.41	2.37	7.65
N-rates (kg/ha)													
0	1.07	167	21.5	39.1	73.4	2.17	4.99	27.9	16.2	5.7	5.0	11.9	59.6
40	1.10	195	22.0	46.8	78.9	2.71	6.20	39.1	26.1	7.0	6.2	14.7	76.0
80	1.17	223	22.1	53.0	87.9	3.50	7.30	48.6	38.7	8.3	7.3	19.5	90.3
120	1.25	235	22.3	57.3	96.1	4.02	8.29	64.1	50.5	9.6	8.2	22.2	103.5
160	1.29	247	22.4	60.4	103.3	4.35	9.45	75.9	64.0	10.1	9.4	25.5	118.8
200	1.30	245	22.0	58.6	100.9	4.21	9.91	74.7	71.0	9.3	9.9	26.3	118.6
240	1.28	241	22.0	57.5	95.5	3.98	9.91	70.5	72.7	8.5	9.9	24.7	117.2
300	1.29	237	21.7	56.8	94.7	3.72	9.63	72.2	71.2	7.5	9.6	23.1	112.3
SEm±	0.036	5.6	0.73	1.38	1.87	0.16	0.36	2.33	2.97	0.37	0.36	1.11	4.63
CD (P=0.05)	0.102	16.0	NS	3.97	5.35	0.45	1.04	6.68	8.51	1.07	1.05	3.19	13.25
Irrigation × N interaction	*	NS	NS	NS	*	*	NS	*	*	NS	NS	*	NS

DASM, depletion of available soil moisture; *significant; NS, non-significant

proportionate diversion of dry matter form source to sink might have resulted in the higher stover yield and lower grain yield at higher N-application rates.

Grain and stover yields were significantly influenced by both irrigation regimes, nitrogen- application rates and their interaction. Scheduling irrigation at 25% DASM (4.6 t/ha) resulted in 26.7 and 15.4%, and 40.9 and 82.5% higher grain and stover yields over irrigation at 75% DASM and rainfed crop respectively, might be owing to higher values of yield attributes with the former irrigation regime. The interaction effects of irrigation and nitrogen showed that grain yield was the highest when irrigation was given at 25% DASM and N was applied at the rate of 200 kg/ha. This was mainly owing to higher number of cobs/plant under this treatment. Better soil moisture and nutrient availability including N, under treatment combination of irrigation at 25% DASM and 200 kg N/ha could have resulted in the highest growth, yield components and finally grain yield. In an obvious contrast to number of cobs/plant, cob weight was the highest with irrigation at 75% DASM and 160 kg N/ ha, which was, however, at par with cob weight obtained with same level of irrigation and 200 kg N/ha, irrigation at 25% DASM and N-fertilization at 120 kg/ha or 160 kg/ha (Table 2).

Nutrient (N, P, K) uptakes in grain as well as stover were significantly greater under well- watered conditions (irrigation at 25% DASM) compared to water-stressed conditions (irrigation at 75% DASM and no-irrigation or rainfed crop) except P uptake in grain. Total N uptake (grain+ stover) was 34.2 and 88.7%, total P-uptake 10.5 and 47.6% and total K uptake 25.7 and 45.4 % higher when irrigations were applied at 25% DASM compared to irrigation at 75% DASM and no-irrigation (rainfed crop). Better nutrient solubility leading to better availability of nutrients in soil solution and consequent higher uptake by plants and higher grain and stover yields contributed to higher N, P and K uptakes under irrigation at 25% DASM. Djaman *et al.* (2013) also reported that higher irrigation level resulted in a significant increase in plant-nutrient uptake.

Nutrient uptakes were influenced significantly by nitrogen application rates also. Uptake of N and K in grain increased significantly up to 160 kg N/ha. Further increase in N-rate up to 300 kg N/ha decreased the N uptake; however, K uptake increased marginally with increase in N level to 200 kg/ha, but decreased when N dose was raised beyond 200 kg N/ha. Grain-P uptake also increased up to 160 kg N/ha, but the increase was significant up to 120 kg N/ha only. Al-

Table 2. Interaction effect of irrigation regimes and nitrogen rates on grain yield (t/ha) of maize

N-rates (kg/ha)	Irrigation regimes		
	25% DASM	75% DASM	Rainfed
0	2.67	2.15	1.71
40	3.30	2.59	2.24
80	4.27	3.46	2.78
120	5.07	4.01	2.99
160	5.35	4.47	3.24
200	5.56	4.35	2.73
240	5.37	4.17	2.43
300	5.24	3.87	2.07
	SEm±	CD (P=0.05)	
Two sub-plot means at the same main-plot treatment	0.38	0.77	
Two main-plot means at the same or different sub-plot treatments	0.39	0.85	

DASM, depletion of available soil moisture

most similar trends were seen for N, P and K uptakes in stover; however, N and P uptakes were the highest with 240 kg N/ha. These variations in nutrient uptakes are attributed largely to the variations in grain-and stover-yields, which were highest at 160 and 200 kg N/ha, respectively.

Irrigation regime × N rate interactions revealed that the highest N uptake was under the treatment where irrigation was given at 25% DASM and N was applied at the rate of 160 kg/ha (75.9 kg/ha, 172% higher than control) and 240 kg/ha (72.8 kg/ha, 349.2% higher than control) for grain and stover N uptake, respectively. The highest total (grain + stover) N uptake, and grain and total K uptakes were observed at 25% DASM × 240 kg N/ha. This might be owing to higher biomass production under ideal soil-moisture condition (irrigation at 25% DASM) and higher N dose of 240 kg/ ha led to considerable increment in N-and K-accumulation.

Overall, the results of the investigation revealed that irrigating maize crop at 25% DASM and fertilizing it with 160 kg N/ha resulted in higher yield attributes, yield and nutrient uptakes. Thus, it is suggested that hybrid maize should be irrigated at 25% DASM and supplied with 160 kg N/ha to obtain higher yield with higher uptake of major nutrients.

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