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Effect of irrigation regimes and nitrogen rates on photosynthetically active radiation interception, photosynthetic rate and dry matter partitioning in maize (*Zea mays*)

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Maize (*Zea mays* L.) constitutes the staple food for over 1.2 billion people worldwide (Prasanna *et al*. 2011). It also contributes substantially to ethanol production and deriving many other industrial products (Ghosh *et al*. 2016). India produces 24.4 Mt maize grain from an area of 9.4 Mha, with a low average productivity of 2.6 tonnes/ha (Economic Survey, 2014-15). Several environmental, cultural and genetic factors influence maize yield and quality. In the country, maize is largely grown under rainfed conditions often associated with erratic rainfall and long dry-spells that limit its productivity. Thus limited irrigation can help reduce the yield losses to a large extent. In general, scheduling irrigation is based on the IW: CPE ratio, which however, does not indicate water status in plant or soil. Applying irrigation taking into account the depletion of available soil moisture (DASM) in the root zone is more relevant and realistic approach. However due to growing paucity of water, it is desirable for farmers to apply less water than is required to get maximum yield as the yield reductions as a result of deficit-irrigation are far lower than the benefits coming from diverting the saved water for irrigating additional area.

Maize is an exhaustive feeder of N and responds to applied N upto a higher limit of 120–200 kg/ha (Dass *et al*. 2015). Higher amount of N alongwith adequate irrigation results in faster rate of leaf expansion, net photosynthetic rate (NPR) and increased radiation interception and radiation-use efficiency (Sinclair and Horie 1989, Connor *et al*. 1993) and finally higher productivity. A higher NPR enhances yield formation (Bene 2015). Since irrigation and N application play vital role in plant biomass production, physiological functions, photosynthetic efficiency and finally the economic yield, the current investigation was done to (i) assess the effect of different irrigation regimes and N-rates on PAR interception, and dry matter partitioning, and study the correlation of PAR interception and NPR with grain yield of maize.

The field experiment was conducted during rainy season of 2015 at the ICAR-Indian Agricultural Research Institute, New Delhi (28° 40' N, 77° 12'E and 228.6 m above mean sea level). The climate of the area is typical semi-arid and sub-tropical with hot dry summers and cool winters. The maize cultivar PEEHM 5 (Pusa Extra Early Hybrid Makka 5) was planted on 22 July, 2015 and harvested during the last week of October. During the growing season, the mean weekly maximum and minimum temperatures, relative humidity, sunshine (hrs/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. The experimental field soil was sandy loam in texture having pH 7.6, C 0.54% organic, N 216 kg/ha available, 16.7 kg/ha available P and K 245 kg/ha available. The experiment was laid-out in a three-time replicated split-plot design. The treatments consisted of 24-combinations of 3-irrigation regimes: Irrigation at 25% depletion of available soil moisture (DASM), 75% DASM and no-irrigation (rainfed condition) allotted to main-plots and eight N-rates: 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) allocated to 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 spacing of 60 cm × 20 cm using seed rate of 20 kg/ha. Entire dosage of P and K, and one-third dose of N were applied basally and remaining two-thirds quantity of N was band placed in two equal splits, at knee-high (KH) stage and at initiation of tasseling. Top-dressing of N was done when soil had adequate moisture.

The NPR in the top-most fully opened leaf was measured

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at KH and tasseling stages using infrared gas analyzer. Photosynthetically active radiation **(**PAR) was measured using Accu PAR LP-80 Ceptometer and the intercepted PAR was computed by deducting transmitted PAR from the Incident PAR. To determine dry mass accumulation (DMA) in different plant parts at harvest, five plants from the sampling rows were selected and cut at ground levels; leaves, stems and cobs were separated, air-dried for four days, thereafter dried in hot-air oven at 80^0C till constant weights were obtained, and their dry weights were recorded. Grain and stover yields were computed by harvesting crop (cobs and stalks) from the net plots. All data were analyzed using analyses of variance technique for a split-plot design using SAS software. Wherever F-value was significant, the critical difference (CD) values at the 95% level of probability were computed for comparing treatment means.

Net intercepted PAR of maize at KH and tasseling stages was significantly altered by N-rates (Table 1), while the effect of irrigation and also the irrigation × N interaction effect were non-significant at KH stage. This could likely be due to occurrence of enough rainfall during early stage of crop growth. However, ideal soil moisture conditions created by regular irrigations at 25% DASM led to the highest PAR interception (910 µmol/m^2/s) at KH stage. At tasseling stage, a higher overall PAR interception was observed as both N-rates, irrigation levels and their interaction effect depicted a distinct effect on PAR interception. At KH stage, 300 kg N/ha recorded the highest PAR interception (1091 µmol /m^2/s) which was 71.4% higher than control, however at tasseling stage, the value was the highest (1503 µmol/m^2/s) with 200 kg N/ha. Irrigation × N-rates interaction effect revealed that the combination of 25% DASM and 300 kg N/ha resulted in the highest amount of intercepted PAR (1658 µmol/m^2/s). Mahesh *et al.* (2015) also reported that light interception at different growth stages was higher with 300 kg N/ha, compared to lower N-rates. The PAR interception depends upon the LAI, thus higher PAR interception under ideal soil moisture condition (25% DASM) and higher N-rates could be due to increased leaf area and biomass accumulation. But under rainfed and prolonged water stress (75% DSAM) conditions, the moisture stress led to the less vegetative growth resulting into low PAR interception.

Applying irrigation at 25% DASM resulted in significantly higher NPR (15.2 and 22.3% at KH and tasseling stage, respectively) over rainfed crop (Table 1). Photosynthetic inhibition is one of the primary detrimental effects of water stress, thus lower NPR in rainfed crop and the crop irrigated at longer interval (75% DASM) in the current study could be due to possible moisture stress. Among N-rates, the highest NPR (27 µmol CO_2/m^2/s) was recorded with 300 kg N/ha at KH, whereas at tasseling it was highest with 200 kg N/ha (31.3 mol CO_2/m^2/s). The higher NPR at higher N- rate might be due to higher PAR interception as there is a proportional relationship between the carbon capture and reduction by plant and the amount of absorbed PAR by plant canopies (Monteith 1977). N-deficiency promotes increment in abscisic acid, causing stomatal closure and a reduction in photosynthesis (Ologundudu and Adelusi 2013).

Irrigating maize at 25 or 75% DASM resulted in

Table 1 Effect of irrigation regime and N-rates on net intercepted PAR and net photosynthetic rate and dry matter partitioning maize

Treatment	Intercepted PAR (µmol/m^2/s)		NPR (µmol CO_2 /m^2/s)		Dry matter partitioning in different plant parts (g/plant)		
	KH stage	Tasseling stage	KH stage	Tasseling stage	Leaf	Stem	Cob
Irrigation							
25% DASM	910	1454	25.7	30.7	54.4	193.5	90.0
75% DASM	892	1228	23.9	28.3	56.0	140.0	87.8
Rainfed	839	1232	22.3	25.1	49.9	119.9	77.5
SEm ±	0.02	55	0.89	1	1.44	2.52	0.44
CD (P=0.05)	NS	153	2.48	2.77	4.13	6.99	1.22
N-Rates							
N_0	602	933	17.2	21.0	25.2	79.1	67.6
N_{40}	708	1169	19.6	24.4	36.1	82.3	73.7
N_{80}	808	1280	22.9	27.2	45.8	129.4	82.0
N_{120}	888	1349	24.9	29.1	54.3	166.6	89.7
N_{160}	934	1423	26.4	30.6	65.0	182.4	95.9
N_{200}	979	1503	26.9	31.3	68.4	184.8	94.0
N_{240}	1032	1418	26.5	30.6	66. 6	192.8	89.1
N_{300}	1091	1363	27.0	30.4	66.1	191.6	88.5
SEm ±	22	38	1.14	1.24	2.45	2.06	0.41
CD (P=0.05)	44	77	2.30	2.50	4.94	4.16	0.84

Table 2 Interaction effect of irrigation regimes and N-rates on dry matter partitioning in different plant parts (g/plant)

Treatment	Leaf			Stem			Cob		
	25% DASM	75% DASM	Rainfed	25% DASM	75% DASM	Rainfed	25% DASM	75% DASM	Rainfed
N_0	27.7	25.6	22.2	83.9	86.8	66.4	74.0	65.7	63.0
N_{40}	37.0	37.9	33.3	90.9	87.1	68.9	86.9	74.0	60.1
N_{80}	47.2	47.8	42.6	143.5	129.3	115.4	91.6	84.2	70.3
N_{120}	48.1	67.5	47.2	189.0	152.6	158.1	99.0	92.5	77.7
N_{160}	66.6	72.2	56.1	239.8	154.3	153.	97.1	102.7	87.9
N_{200}	71.2	68.5	65.6	254.8	165.6	134.0	93.4	97.1	91.6
N_{240}	67.5	65.6	66.6	279.1	167.5	131.9	87.9	93.4	86.0
N_{300}	70.1	62.9	65.3	266.6	176.9	131.3	89.7	92.5	83.3
		SEm ±	CD (P=0.05)		SEm ±	CD (P=0.05)		SEm ±	CD (P=0.05)
Two sub-plot means at the same main-plot treatment		4.24	8.56		3.52	7.2		0.72	1.45
Two main-plot means at the same or different sub-plot treatments		4.46	9.71		4.18	9.59		0.8	1.8

significant improvement in DMA in all plant parts, leaf, stem and cob, compared to rainfed crop. Among N-rates, the highest dry matter in leaf was recorded with 200 kg N/ha, in stem with 240 kg N/ha and in cob with 160 kg N/ha (Table 1). This indicates that higher N–rates increased plant biomass to a greater extent than the sink-size. The interaction effects of irrigation regimes and N-rates revealed that crop irrigated at 75% DASM and fertilized with 160 kg N/ha produced the highest dry matter in leaf that was similar to leaf-dry matter produced by the plants fertilized with 160 kg N/ha and higher N-rates under irrigation at 25% DASM. The highest dry matter in stem was found in plants irrigated at 25% DASM and fertilized with 240 kg N /ha that was similar to dry matter recorded with 300 kg N/ha under the same irrigation regime and significantly higher than all other irrigation regime × N-rate combinations. More or less similar interaction effect of irrigation regimes and N-rates were observed on cob weight (Table 2).

Both PAR interception and NPR at both the stages were positively correlated with grain yield. However, the correlation of PAR interception with grain yield at tasseling stage was stronger than at KH-stage except under rainfed condition. Irrigation regimes influenced significantly the strength of these correlations (Fig 1, 2); under ideal soil moisture conditions (irrigation at 75% DASM), the correlation was strongest ($R^2 = 0.75$) followed by irrigation at 50% DASM ($R^2 = 0.68$) and weakest for rainfed crop ($R^2 = 0.55$), the same trend was found at the KH stage also. This indicates that there was sufficient biomass accumulated by maize crop using rain water stored in the root zone, which resulted in fairly good amount PAR interception in initial stage, but later on the water stress due to no-(rainfed condition) and-restricted irrigation (50% DASM), limited grain setting, decreased cob weight, and the finally grain yield got severely affected. This led to poorer correlation of grain yield with PAR interception under water stress conditions. In case of correlation between net photosynthetic rate and grain yield, it was found better under well irrigated conditions at both KH and tasseling stages. The negative effect of water stress on correlation of NPR with yield was greater for the same reasons as for PAR interception; NPR was satisfactory, but it did not translate into grain formation and final yield.

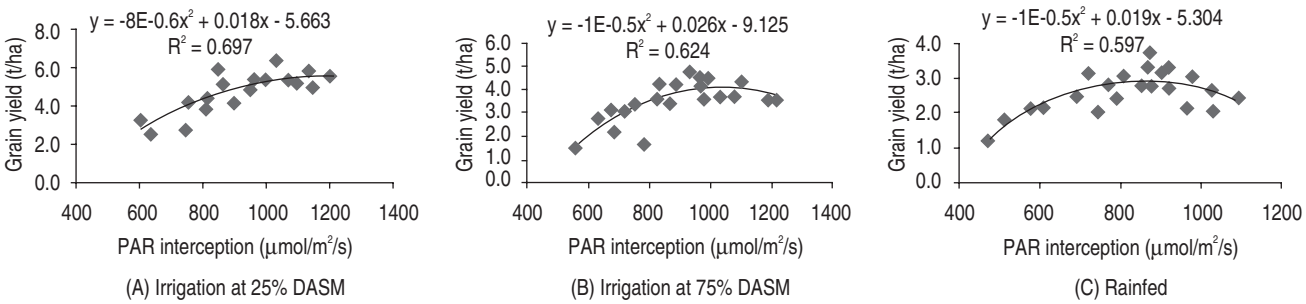

Fig 1 Correlation between PAR interception at KH stage and grain yield

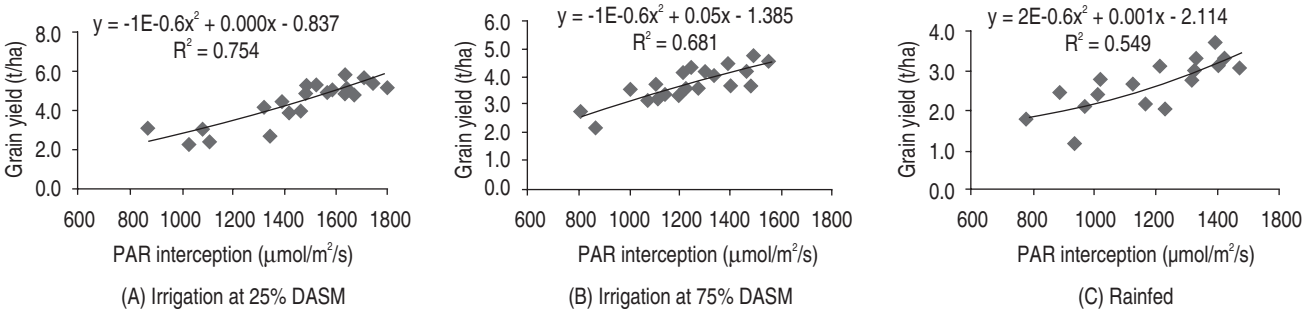

Fig 2 Correlation between PAR interception at tasseling stage and grain yield

SUMMARY

The results of the study showed that irrigating maize at 25 and 75% DASM led to higher NPR, PAR interception, dry mass accumulation in different plant parts over rainfed crop. Among N-rates, the higher values of NPR and PAR interception were observed at 200–300 kg N/ha. Both PAR interception and NPR were positively correlated with grain yield, the correlation being stronger under better soil moisture condition. Overall, the findings demonstrated that maize crop may be irrigated at 25% DASM and fertilized with 160–200 kg N/ha to enhance physiological and agronomic potential of maize for its higher yield. However, under scarce water availability conditions, the crop may be irrigated at 75% DASM and fertilized with 120–160 kg N/ha.

REFERENCES

Bene E. 2015. Correlation between the sowing date and the yield of maize on chernozem soil, in connection with the leaf area index and the photosynthesis. *International Journal of Biological, Biomolecular, Agricultural, Food and Biotechnological Engineering* **9**(8): 952–7.

Connor D J, Hall A J and Sadras V O. 1993. Effect of nitrogen content on the photosynthetic characteristics of sunflower leaves. *Australian Journal of Plant Physiology* **20**: 251–63.

Dass A, Shivkumar B G, Dhar S and Kumar K. 2015. Soil and plant based precision N management in *rabi* maize (*Zea mays* L.) in north-Indian alluvial plains. *Annals of Agricultural Research* **36**(4): 358–63.

Ghosh A P, Dass A, and Kaur R. 2016. Effect of growing environments and chlorophyll meter based management on productivity and profitability of maize cultivars in alluvial plains of north-India. *Indian Journal of Ecology* **43**: 66–71.

GOI. 2015. Economic Survey, 2014-15. *Economic Survey-Vol II.* Department of Economic Affairs, Ministry of Finance, Government of India, 78.

Mahesh N, Rani P L, Sreenivas G and Madhavi A. 2015. Resource use efficiency of *kharif* maize under varied plant densities and nitrogen levels in Telangana state, India. *International Journal of Current Microbiology and Applied Sciences* **4**(7): 632–9.

Monteith J L.1977. Climate and the efficiency of crop production in Britain. *Philosophical Transactions of the Royal Society of London* **B281**: 277–97.

Ologundudu A F and Adelusi A. 2013. Effect of nitrogen nutritional stress on some growth parameters of *Zea mays* L. and *Vigna unguiculata*. *Notulae Scientia Biologicae* **5**(1): 79–85.

Prasanna B M, Mazumdar S, Chakraborti M, Hossain F, Manjaiah K M, Agrawal P K, Guleria S K and Gupta H S. 2011. Genetic variability and genotype × environment interactions for kernel iron and zinc concentrations in maize (*Zea mays*) genotypes. *Indian Journal of Agricultural Sciences* **81**: 704–11.

Sinclair T R and Horie T. 1989. Leaf nitrogen, photosynthesis and crop radiation use efficiency: A review. *Crop Science* **29**: 90–8.