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Research Paper

Influence of irrigation and nitrogen levels on growth, yield attributes and yield of maize (*Zea mays*)

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ABSTRACT

A field experiment was conducted at the Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, during the winter (*rabi)* seasons of 2013 and 2014, to investigate the effect of nitrogen and water-management practices on potential yield of maize. The crop was subjected to 2 irrigation levels (cumulative pan evaporation: 0.80 and 0.50) and 5 staggered nitrogen levels (0, 50, 75, 100 and 125% of recommended dose of nitrogen (RDN). The experiment was laid out in a factorial randomized block design with 10 treatments and replicated thrice. Irrigation at IW : CPE ratio of 0.80 along with 250 kg N/ha (100% RDN) favourably increased the higher growth parameters, nutrient uptake, yield attributes and higher grain yield (7.31 t/ha) of maize. The crop did not respond significantly to further increase in nitrogen level up to 125% RDN (312 kg N/ha) over the 100% of recommended dose of nitrogen (250 kg N/ha). Better correlation coefficient of r^2 = > 0.95 was obtained with significant at P = 0.01 levels between growth parameters and yield attributes of maize. The same set of treatment resulted in higher net returns (64.3 × 10^3 ₹/ha) and benefit: cost ratio (2.89) than others.

Key words : Crop production, Growth parameters, Maize, Nitrogen, Water, Yield

Maize, a miracle crop is grown over a wide range of climatic conditions in semi-arid and sub-tropics on Indian continent. Water and nitrogen are the most important factors which play a major role in better growth and yield of maize (Hammad *et al.,* 2011). Formulation of water and nitrogen management practices is needed to ensure food productivity for the increasing world population and to address the growing concerns regarding the adverse environmental impacts of agricultural activities (Hammad *et al.,* 2012).

Water and nitrogen are 2 of the most critical inputs required to achieve the high yield potential of modern corn varieties. Under most agricultural settings, however, they are often scarce and costly. Large gaps remain between our empirical knowledge of the physiological changes observed in the field in response to nitrogen and water stresses (Humbert *et al.,* 2013).

In spite of increased production and productivity of maize in recent years, there is a continued increase in maize demand both normal maize and specialty corn from poultry-and food-processing industries respectively. To cope up with these challenges, there is need to supply sufficient quantity of quality hybrid seed and application of novel tools and techniques to further enhance the maize productivity. Owing to burgeoning growth rate of poultry, livestock, fish, and wet and dry milling industries, maize demand is expected to increase from current level of 16.72 to 45 m t by 2030 and its production is growing at a faster pace of about 6% against consumption growth rate of 4.7% (Kumar *et al.,* 2012). Therefore, optimization of these 2 inputs provides a favourable condition for better crop growth and higher productivity. Keeping this in view, an experiment was conducted to study the impact of variable water and nitrogen supply on growth and yield and economics of maize.

MATERIALS AND METHODS

The field experiment was conducted at the Tamil Nadu Agricultural University, Coimbatore, India during the winter (*rabi*) season of 2013 and 2014. The site (N' 11°0' 33.4" E76° 56' 25.7" and 430.5 mean sea-level) of the experiment is located in a subtropical belt. The soil was sandy clay loam and alkaline with *p*H 8.41. The soil was medium in organic carbon (0.62%), low in available nitrogen (186 kg/ha), medium in available phosphorus (13 kg/

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ha) and high available potassium (367 kg/ha). The soil-moisture retention is 24.3% at 0.33 bars and 10.2% at 15 bars. The farm experiences the mean annual 6 decades rainfall of 657 mm in 47 rainy days and the mean annual maximum and minimum temperatures of 31.5 and 21.4°C respectively. The relative humidity ranged from 61 to 91% in the forenoon and 14 to 68% in the afternoon.

The weather condition prevailed during the experimental periods. The rainfall received 17.6 mm in 1 rainy day and 10.5 mm in 1 rainy day, the mean maximum and minimum temperature were 33.4°C and 21.8°C and 31.6°C and 20.6°C, the relative humidity ranged from 78.7 to 38.4% and 83.1 (7.22 hr) to 42.2% (14.22 hr) during the winter (*rabi*) season of 2013 and 2014 respectively.

The crop was subjected to 2 irrigation levels and 5 staggered nitrogen levels. The experiment was laid out in a factorial randomized block design, with a gross plot size of 7 m × 6 m with 10 treatments, replicated thrice. The irrigation regimes were W_1, irrigation water: cumulative pan evaporation (IW : CPE) of 0.80 and W_2, IW: CPE of 0.50 (IW = 5 cm) and the nitrogen levels were N_0, no nitrogen; N_1, 50% recommended dose of nitrogen (RDN); N_2, 75% RDN; N_3, 100% RDN and N_4, 125% RDN.

The general recommended dose of fertilizers for hybrid maize is 250, 75, 75 kg N, P, K/ha as per the package of practice suggested by the Department of Agriculture, Government of Tamil Nadu. 'TNAU Maize hybrid CO 6' seeds were used for this study. A seed rate of 20 kg/ha was adopted with a spacing 60 cm × 25 cm. Seeds were dibbled on one side of the ridges @ 1 seed/hill. The field was irrigated immediately after sowing and life irrigation was given on the third day after sowing. Thereafter irrigation was given as per the treatment schedule based on IW : CPE ratio. As per the treatment schedule, nitrogen was applied in 3 splits, viz. 25% as basal, 50% at 25 days after sowing (DAS) and 25% at 45 DAS respectively. The entire dose of phosphorus was applied basal. The potassium was applied in 2 equal split doses, viz. basal and at 45 DAS. The N, P and K fertilizers were applied in the form of urea (46% N), single superphosphate (16% P_2O_5) and muriate of potash (60% K_2O) respectively. Application of atrazine @ 0.5 kg/ha as a pre-emergence herbicide on the third day after sowing followed by 2,4-D @ 1.0 kg/ha as post-emergence herbicide was followed on 20 DAS.

In each treatment plot, 5 random plants were tagged for recording biometric observations. Growth components were recorded at 30, 60 and 90 DAS. The height of the plant was measured from the ground level to the tip of the topmost leaf and mean of observations on 5 plants were arrived and expressed in cm. Leaf-area index was computed from the selected 5 plants by measuring the leaf length, breadth of the third open leaf from top and number of leaves/plant using the standard formula. Chlorophyll content of leaves was recorded by using the chlorophyll meter (SPAD-502). The readings were recorded on the uppermost fully expanded leaves in the 5 randomly chosen plants. The mean values were worked out and expressed as SPAD readings. Five plants at random were cut close to the ground level from the sampling row. The samples were initially air-dried in shade and then oven-dried at 65°C ± 5°C till the samples attained a constant weight and then weighed. The dry-matter production (DMP) was expressed in t/ha.

Yield attributes of maize were recorded at harvesting from the net plot area. The mean length of the cob from the bottom to top was measured expressed in cm. The mean girth of cob at its maximum girth was measured expressed in cm/cob. The mean number of grain rows/cob and a total number of grains in each row of the cobs were counted from the cobs obtained from sample plants. The weight of individual cob was recorded after drying and the mean weight was arrived at and expressed in g/cob. Five cobs were randomly selected from each plot and shelled. A sample of 100 grains was taken from each cob and weighed by using an electrical top pan balance and the mean weight was expressed in g. The cobs from net plot were harvested separately. The cobs were sundried, shelled, cleaned and grain yield was recorded for individual treatment at 14% seed moisture and expressed in t/ha. After harvesting of cobs, the stover in the net plot area was cut close to the ground level and left in the field for 3 days for sun drying. After drying, the weight of stover from each plot was recorded and expressed in t/ha.

Water-use efficiency (WUE) in kg/ha-mm was calculated by dividing the kernel yield with respective total consumptive water use for the crop yield. Nutrient uptake by plant and available in soil was analyzed as per the standard procedure. The expenditure incurred from sowing to harvest was worked out and expressed in ₹/ha. Total income obtained from grain and stalk yields were calculated for individual treatments. Gross and net returns, benefit: cost ratio were worked out based on total variable cost and returns. The experimental data were statistically analyzed for the differential effect of treatments in maize and correlation studies were done by using SPSS (16.0).

RESULTS AND DISCUSSION

Growth parameters

Irrigation scheduled at IW : CPE ratio of 0.80 along with 125% of RDN resulted in significantly higher plant height and leaf-area index of maize (Table 1). This was followed by irrigation at IW : CPE of 0.80 ratio with 100% of RDN. Dry matter production was recorded higher under irrigation at an IW : CPE of 0.80 with 125%

RDN. This was comparable to same irrigation with 100% RDN at 30, 60 and 90 days after sowing (DAS). It might be owing to the increased frequency of irrigation and availability of adequate water throughout the growth period along with a higher dose of nitrogen application leading to increased nutrient uptake, higher photosynthetic rate and thereby the higher plant height, LAI and DMP. These findings are in line with those obtained by Hammad *et al.* (2012) and Kumar *et al.* (2015). Irrigation at an IW : CPE ratio of 0.5 with no-nitrogen application treatment recorded significantly lower value of the growth parameters of maize. This might probably be due to the fact that the moisture stress experienced by the crop under inadequate moisture levels and demand for the sufficient nitrogen requirement might have reduced plant growth at 30, 60 and 90 DAS.

The SPAD value responded significantly to different irrigation regimes and nitrogen levels. Irrespective of the treatments, the SPAD value increased up to the silking stage and gradually declined toward the senescence (Table 1). Irrigation scheduled at an IW : CPE ratio of 0.80 along with 125% of recommended dose of nitrogen recorded significantly increased SPAD value, followed by IW : CPE ratio of 0.80 with 100% of RDN at 30, 60 and 90 DAS. SPAD value reading is a measure of total chlorophyll content of leaves which indicates the greenness of leaves. As a green pigment, the chlorophyll content is one of the major factors that regulates photosynthetic capacity and gives an indirect estimation of the nitrogen content of the maize leaf. A higher dose of nitrogen and sufficient soil moisture in effect to frequent irrigation interval might have lead to higher transpiration rate. It automatically increased water absorption by root with higher nutrient mobility from soil to plant and increased the leaf chlorophyll content in turn to the greenness of the leaf in terms of SPAD value. Significantly lower SPAD value was recorded at irrigation at an IW : CPE ratio of 0.50 and without nitrogen application at 30, 60 and 90 DAS.

Nitrogen status in plant and soil

The nitrogen uptake was significantly influenced by irrigation regimes and nitrogen levels (Table 1). Among the treatments, irrigation scheduling at an IW : CPE ratio of 0.80 with 125% of RDN registered significantly higher nitrogen uptake. This was followed by irrigation at an IW : CPE ratio of 0.80 along with 100% of RDN at harvesting. Our results support the findings of Mallareddy and Padmaja (2014). Under the stressed condition, a combination of irrigation at an IW : CPE ratio of 0.5 with no-nitrogen application resulted in significantly lesser nitrogen uptake. The available nitrogen content in soils was higher under irrigation at an IW : CPE ratio of 0.80 along with

Table 1. Effect of irrigation and nitrogen levels on growth parameters of maize and N status in plant and soil (pooled data of 2 years)

Treatments	Plant height (cm)			Leaf-area index			SPAD value			DMP (t/ha)			N uptake at harvesting (kg/ha)	Available N in soil at harvesting (kg/ha)	N balance in soil (kg/ha)
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS			Gain/loss
W_1N_0	39.3	119	123	1.26	3.36	3.23	29.9	33.5	30.0	0.38	4.73	7.3	89	92	-94.0
W_1N_1	56.6	171	177	1.68	4.77	4.58	46.3	50.9	48.3	0.53	7.13	11.3	128	127	-58.8
W_1N_2	64.2	185	191	1.82	5.10	4.94	50.9	55.4	52.5	0.56	8.01	12.6	150	177	-9.1
W_1N_3	71.3	204	212	2.00	5.57	5.40	55.6	60.7	57.5	0.62	8.88	14.0	168	242	55.6
W_1N_4	78.8	224	233	2.19	6.05	5.85	60.1	66.1	62.9	0.64	9.28	14.6	185	307	120.8
W_2N_0	35.2	107	110	1.17	3.15	2.98	25.6	29.5	27.1	0.33	4.33	6.2	71	109	-76.9
W_2N_1	46.0	133	139	1.33	3.77	3.60	36.7	40.4	38.0	0.41	5.55	8.4	99	159	-26.9
W_2N_2	49.5	148	156	1.44	4.13	3.99	40.2	45.0	41.9	0.45	6.27	9.8	115	230	43.6
W_2N_3	57.1	165	173	1.62	4.60	4.44	44.8	50.2	47.0	0.50	7.09	11.2	129	297	111.5
W_2N_4	62.8	184	191	1.79	5.06	4.89	49.4	55.3	52.0	0.53	7.48	11.9	146	364	177.9
Mean	56.1	164	171	1.63	4.55	4.39	44.0	48.7	45.7	0.50	6.87	10.7	128	210	-
SEm±	2.0	5	6	0.05	0.14	0.13	1.4	1.7	1.7	0.02	0.24	0.4	5	7	-
CD (P=0.05)	5.8	15	16	0.14	0.40	0.39	4.0	4.9	4.8	0.04	0.69	1.2	15	19	-

W_1, IW : CPE ratio 0.80; W_2, IW : CPE ratio 0.50; N_0, no nitrogen; N_1, 50% recommended dose of nitrogen (RDN); N_2, 75% RDN; N_3, 100% RDN; N_4, 125% RDN the application of 125% of RDN. This was followed by 100% of RDN. A similar trend was observed for nitrogen balance in the soil.

Yield attributes

The yield attributes such as cob length (cm), cob girth (cm), rows/cob, grains/row, cob weight (g) and 100-grain weight (g) were influenced by irrigation regimes and nitrogen levels (Table 2). The yield attributing characters of maize were recorded higher under irrigation scheduled at an IW : CPE ratio of 0.80 along with 100% of RDN treatment and this was on par with 125% of RDN, because higher availability of nutrients and frequent irrigation resulted in better translocation of assimilates from source to sink. Better crop growth and higher nutrient uptake increased the leaf gas exchange parameters like photosynthetic rate, stomatal conductance and better transpiration rate might have influenced the yield attributes favorably. Hammad *et al.* (2011) made similar observations. Yield attributes were significantly reduced by irrigation when scheduled at an IW : CPE ratio of 0.5 along with no-nitrogen application. The lower LAI, DMP, less nutrient uptake and decreased photosynthetic rate due to the water stress and insufficient nitrogen status resulted in the poor conversion of the source to sink and thereby reduced yield attributes of maize.

The Pearson correlation coefficients between growth parameters and yield attributes at different plant growth stages of 60 and 90 DAS were significantly influenced by irrigation regimes and nitrogen levels (Table 3). The relationship between growth parameters, viz. plant height, LAI, SPAD value and dry-matter production had better correlated with yield attributes. Especially all the growth parameters expressed high or positive correlation with significance at the P=0.01 level with yield attributes with a correlation coefficient of r^2 = > 0.95 both at 60 and 90 DAS.

Yield

The grain and stover yields of hybrid maize were influenced by irrigation regimes and nitrogen levels (Table 2). Irrigation scheduled at an IW : CPE ratio of 0.80 with 100% RDN (250 kg N/ha) resulted in the highest grain yield, and this was on a par with application nitrogen 125% RDN. Grain yield did not respond significantly further to applied nitrogen when the level was increased to 312 kg/ha (125% RDN). Higher grain yield of hybrid maize with higher nitrogen levels responding in line with the law of diminishing returns. Our results confirm the findings of Rehman *et al.* (2010), who recorded the highest maize grain yield with application of 250 kg N/ha. This might be owing to comparatively higher LAI, DMP and

Table 2. Effect of irrigation and nitrogen levels on yield attributes and yield, water use, water-use efficiency (WUE) and economics of maize (pooled data of 2 years)

Treatment	Cob length (cm)	Cob girth (cm)	Grain rows/ cob	Grains/ row	100-grain weight (g)	Cob weight (g)	Grain yield (t/ha)	Stover yield (t/ha)	Harvest index	Water use (mm)	WUE (kg/ha-mm)	Total cost	Gross returns	Net returns	Benefit: cost ratio
												(× 10³ ₹/ha)			
W_1N_0	11.1	10.8	11.8	20.5	26.7	124	2.82	6.01	0.32	377	7.5	31.1	38.4	7.3	1.24
W_1N_1	14.7	12.4	13.4	28.5	32.2	184	4.96	8.84	0.36	377	13.2	32.6	67.2	34.6	2.07
W_1N_2	16.5	13.6	13.8	31.5	34.0	210	5.96	9.66	0.38	377	15.8	33.3	80.5	47.2	2.42
W_1N_3	19.0	15.4	15.4	35.8	38.1	258	7.31	10.51	0.41	377	19.4	34.1	98.3	64.3	2.89
W_1N_4	18.1	14.8	15.0	34.6	37.8	243	7.10	11.26	0.39	377	18.8	34.8	95.8	61.0	2.75
W_2N_0	11.0	10.2	11.0	18.7	24.4	114	2.18	5.09	0.30	252	8.6	30.1	29.8	–0.4	0.99
W_2N_1	12.7	11.4	12.6	24.1	28.3	148	3.47	7.11	0.33	252	13.8	31.6	47.2	15.6	1.50
W_2N_2	14.1	11.8	12.8	26.9	30.7	172	4.27	7.65	0.36	252	17.0	32.3	57.9	25.5	1.79
W_2N_3	16.4	13.5	13.8	31.5	34.3	213	5.30	8.87	0.37	252	21.0	33.1	71.6	38.6	2.17
W_2N_4	15.6	13.0	13.6	29.8	33.4	201	5.18	9.10	0.36	252	20.6	33.8	70.1	36.3	2.08
Mean	14.9	12.7	13.3	28.2	32.0	187	4.85	8.41	-	-	-	-	-	-	-
SEm±	0.4	0.3	0.3	0.8	0.8	7	0.25	0.29	-	-	-	-	-	-	-
CD (P=0.05)	1.1	0.9	0.9	2.4	2.4	20	0.71	0.82	-	-	-	-	-	-	-

W_1, IW : CPE ratio 0.80; W_2, IW : CPE ratio 0.50; N_0, no nitrogen; N_1, 50% recommended dose of nitrogen (RDN); N_2, 75% RDN; N_3, 100% RDN; N_4, 125% RDN

Table 3. Pearson correlation coefficient between growth parameters and yield attributes and yield of maize

Yield attributes/ growth parameters	60 DAS				90 DAS			
	Plant height	LAI	SPAD value	DMP	Plant height	LAI	SPAD value	DMP
Cob length	0.953**	0.955**	0.959**	0.976**	0.956**	0.957**	0.958**	0.974**
Cob girth	0.950**	0.950**	0.950**	0.970**	0.952**	0.953**	0.947**	0.967**
Grains rows/cob	0.958**	0.957**	0.964**	0.973**	0.961**	0.958**	0.962**	0.974**
Grains/row	0.956**	0.958**	0.970**	0.978**	0.961**	0.960**	0.968**	0.980**
100 grain weight	0.970**	0.969**	0.976**	0.983**	0.973**	0.972**	0.973**	0.986**
Cob weight	0.957**	0.958**	0.964**	0.977**	0.960**	0.960**	0.962**	0.976**
Grain yield	0.976**	0.976**	0.977**	0.992**	0.978**	0.978**	0.976**	0.991**
Stover yield	0.991**	0.991**	0.995**	0.995**	0.992**	0.992**	0.995**	0.997**

**Correlation is significant *P*=0.01 level; LAI, leaf-area index; DMP, dry matter production

the highest values for yield attributes resulted from higher nitrogen application. Significantly higher grain yield under sufficiently irrigated regime could be attributed to the adequate turgidity which must have prevailed inside the plant and thereby helped in significantly better growth and development of the crop. During the reproductive stage, the plants under IW : CPE ratio of 0.80 must have been able to translocate the photosynthates efficiently from the source to sink, as also reported by Aulakh *et al.* (2012). Under moisture-and nitrogen-stressed condition when irrigation was scheduled at an IW : CPE ratio of 0.5 along with no-nitrogen application the maize grain yield significantly reduced 70% as compared to irrigation scheduled at an IW : CPE ratio of 0.80 along with 100% of recommended dose of nitrogen

Higher stover yield of maize was recorded under irrigation scheduled at an IW : CPE ratio of 0.80 along with 125% of recommended dose of nitrogen to that comparable at 100% RDN at same irrigation level (Table 2). Increased aerial growth parameters like plant height, LAI, leaf chlorophyll content (SPAD reading), DMP and increased photosynthetic rate owing to the adequate soil moisture and higher nitrogen availability would have resulted in enhanced stover yield. Significantly reduced stover yield of maize by irrigation at an IW : CPE ratio of 0.50 with no-nitrogen application.

Higher harvest index (HI) was recorded under irrigation at an IW : CPE ratio of 0.80 along with 100% of RDN was recorded higher harvest index (Table 2). Since the optimum or sufficient plant water status and higher nitrogen application were conducive for maximum translocation of photosynthates to the kernel and increased harvest index.

Irrigation data on different irrigation regimes revealed that the total water applied under the furrow irrigation at an IW : CPE ratio of 0.80 was 377 mm and 252 mm/ha water was applied at irrigation at an IW : CPE ratio of 0.50. The water-use efficiency generally lowers under irrigation at an IW : CPE ratio of 0.80 compared to irrigation scheduled at an IW : CPE ratio of 0.50. Within irrigation regimes, among the nitrogen levels application of nitrogen 100% RDN (250 kg N/ha) had higher water-use efficiency compared to the other nitrogen levels. This result also supported the findings of Mallareddy and Padmaja (2014).

Economics

Economic viability of crop management is the foremost criteria in transforming new investigations to farmers' field. The results revealed that the highest gross returns (₹), net returns (₹) and benefit: cost ratios were recorded higher under irrigation at an IW : CPE ratio of 0.80 along with application of 100% RDN. This might be owing to improvement in growth parameters, yield attributes and yield recorded under this treatment (Table 2).

The following conclusions were drawn from the results obtained in the present investigation. Thus, irrigation at an IW : CPE ratio of 0.80 along with application of 250 kg N/ha (100% RDN) favourably increased the higher growth parameters, nutrient uptake and yield attributes and higher grain yield. The maize crop did not respond significantly to further increase the fertilizer level up to 125% RDN (312 kg N/ha) over the 100% of recommended dose of nitrogen (250 kg N/ha). This treatment also had higher water use and lesser water-use efficiency compared to irrigation at an IW : CPE ratio of 0.50. The better correlation coefficient of r^2=>0.95 obtained with significant at *P*=0.01 levels between growth parameters and yield attributes of maize. The same set of treatment gave higher net returns and benefit: cost ratio also.

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