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Review/Overview

Productivity and water use efficiency of no-till winter (*rabi*) maize (*Zea mays*) as influenced by drip-fertigation

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ABSTRACT

A field trial was conducted for 4 consecutive winter seasons from 2007–08 to 2010–11 on sandy-loam soil to compare the effect of irrigation and nitrogen levels through drip system against conventional irrigation and fertilizer application method in winter (*rabi*) maize (*Zea mays* L.) grown in no-till condition at Warangal, Andhra Pradesh. The drip irrigation at 75% pan evaporation (PE) recorded higher kernel yield (7.37 t/ha) which was 39 and 8% more than that obtained with drip irrigation at 50% PE and furrow irrigation at 1.0 irrigation water: cumulative pan evaporation (IW:CPE) ratio respectively. Water-use efficiency was the maximum with drip irrigation at 50% PE (26.6 kg/ha-mm), while the nitrogen-use efficiency (50.3 kg kernel/kg nitrogen), production efficiency (65.4 kg/ha/day), N uptake (100.4 kg/ha), net returns (₹ 36,856/ha) and benefit: cost ratio (1.5) were higher with the scheduling of irrigation at 75% PE through drip irrigation. Application of 150 kg N/ha was found to be optimum, which showed kernel yield of 6.67 t/ha, production efficiency of 59.2 kg/ha/day, net returns of ₹30,400/ha and benefit: cost ratio of 1.2.

Key words : Crop production, Drip irrigation, Fertigation, Maize, Nitrogen-use efficiency, No till, N uptake, Production efficiency, Water-use efficiency

Maize has become most important crop in Andhra Pradesh, grown for food, feed and industrial purposes, in an area of 2.8 lakh ha with a productivity of 5.32 t/ha (CMIE, 2011). Water, being the prime natural resource, very often becomes costly and a limiting input particularly in semi-arid tropics and needs to be judiciously used to reap the maximum benefit of other inputs. Maize is one of the efficient field crops in producing higher dry matter per unit quantity of water (Viswanatha *et al*., 2002). Drip irrigation provides the efficient use of limited water with increased water-use efficiency. Besides water, maize also exhibits good response to nitrogen (Reddy *et al.,* 2012). Drip irrigation and fertigation are the latest methods to supply water and nutrients in the root zone of plant and thereby increasing productivity. Adoption of micro-irrigation might help in increasing productivity of crop, irrigated area and water use efficiency (Bhalerao *et al.,* 2011). At present, furrow irrigation is mainly practiced for maize crop. Being a crop of high water and nitrogen requirement, drip irrigation and fertigation offers good scope for enhancing the yield as well as factor productivity in maize. Hence present investigation was conducted to find out the suitable irrigation schedule and nitrogen dose for winter (*rabi*) maize under drip irrigation in Telangana region of Andhra Pradesh.

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MATERIALS AND METHODS

A field experiment was conducted for 4 consecutive years during the winter season of 2007–08 to 2010–11 at Regional Agricultural Research Station, of the N.G. Ranga Agricultural University, Warangal, Andhra Pradesh. The soil was sandy loam having pH of 8.0 and electrical conductivity (EC) of 0.2 dS/m, medium in available organic carbon (0.42%), low in available nitrogen (250 kg/ha), medium in available P_2O_5 (24.8 kg/ha) and low in available K_2O (216 kg/ha). Field capacity, permanent wilting point and bulk density were 13%, 5.6% and 1.4 g/cm^3 respectively, over the soil depth of 60 cm. The experiment was laid out in a split-plot design, comprising nine treatment combinations with 3 irrigation schedules: I_1, drip irrigation at 75% pan evaporation (PE); I_2, drip irrigation at 50% PE and; I_3, furrow irrigation at irrigation water cumulative pan evaporation (1.0 IW:CPE) ratio as main plots and 3 doses of nitrogen: N_1, 120 kg, N_2, 150 kg and N_3, 180 kg/ha as sub-plots and replicated thrice. Maize hybrid, 'Dekalb Super 900 M' was used for the study at a spacing of 60 cm × 20 cm. It was dibbled manually under no-till condition after the harvest of rainy (*kharif*) season soybean at a depth of 5 cm @ one seed/hill on 19, 21, 16 October and 2 November during 2007, 2008, 2009 and 2010 respectively. Atrazine @ 2.5 kg/ha was sprayed immediately after sowing to control the weeds. The plot size was 9.6 m × 6.0 m. Thinning and gap filling were done 10 days after sowing. Two common irrigations of 60 mm each were given, one at pre-sowing after the harvest of soybean for good germination and second at day 6 after sowing for crop establishment. Drip system was established keeping 120 cm between 2 lateral lines. The lateral line of 16 mm diameter was laid between 2 maize rows and another lateral line came after 2 rows of maize. The inline dripper distance was 50 cm with a discharge of 4 litres per hour (Lph). The system was operated under a pressure of 1.2–1.5 kg/cm^2. The irrigation treatments were imposed based on the pan evaporation and rainfall received during the crop-growth period taking into account of pan evaporation (mm) mentioned in table 1. Drip system was operated on every alternate day. The source of irrigation water is open well fitted with 3 HP electrical motor. Quantity of water applied in furrow irrigation (I_3) was measured with water meter fixed to the system by taking into account of area and depth of irrigation (IW) (60 mm). Scheduling of irrigation was started whenever the cumulative pan evaporation (CPE) reached the value of 60 mm in I_3 treatment. Nitrogen was applied through drip as per the treatments in 5 equal splits at 20, 30, 45, 60 and 75 days after sowing with a ventury fixed to the system. In I_3 treatment, nitrogen was applied in 3 equal splits by placement method 20, 40 and 60 days after sowing. Phosphorus and potassium @ 60 : 60 kg/ha were applied 15 DAS as pocketing. A total rainfall of 29.3 mm (2 rainy days) during 2007–08; 33.2 mm (1 rainy day) during 2008–09; 40.0 mm (4 rainy days) during 2009–10 and 27.2 mm (3 rainy days) during 2010–11 was recorded during the crop-growth period. A range of mean minimum temperature of 19.0°–24.4°C, 19.0°–22.2°C, 15.0°–21.2°C and 14.0°–22.6°C and mean maximum temperature of 29.8°–31.6°C, 28.0°–34.4°C, 28.0°–30.4°C and 26.0°–28.7°C were recorded during 2007–08, 2008–09, 2009–10 and 2010–11 respectively. The other recommended cultural and pest-management practices were adopted. The crop was harvested on 12, 8, 5 and 22 February during 2008–2011 respectively. 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. Nitrogen-use efficiency (kg kernel/kg nitrogen) was calculated by dividing the kernel yield with the total nitrogen applied to the crop. The uptake and soil status of N after harvest were analysed with standard methods. The production efficiency was calculated by dividing the kernel yield with total number of days of crop period. The economics of various treatments were calculated based on market price.

Application rate of drip system (mm/hr) = Lph (liters per hour) /

Distance between laterals × Distance betweendippers = 4 Lph/1.2 m × 0.5 m = 6.66 mm/hr

Table 1. Month-wise pan evaporation (mm) during the crop-growth period

Month	2007–08	2008–09	2009–10	2010–11
October	128.6	110.5	121.1	-
November	112.3	108.5	113.9	62.3
December	67.4	73.0	79.4	89.6
January	78.2	76.5	60.6	92.4

RESULTS AND DISCUSSION

Dry-matter production

Maize crop exhibited significant response to irrigation regimes in the total dry matter production (DMP). Drip irrigation at 75% PE had produced the highest DMP over the other 2 regimes (Table 2). However, it was on a par with the irrigation regime of 1.0 IW:CPE ratio through furrow irrigation. Both the regimes were superior to 50% PE in dry matter. Dry matter accumulation is an important index for assessment of crop performance (Singh *et al.*, 2012). Increase in dry matter at 75% PE was mainly due to frequent irrigations and more availability of water throughout the crop season and thus no water stress occurred. The maximum dry matter was recorded with the 180 kg N/ha compared to 120 kg/ha, but it was on a par with 150 kg/ha.

Yield attributes

Irrigation regimes showed significant impact on kernels/cob and kernel weight/plant but not on 100-kernel weight (Table 2). Maximum kernels/cob were recorded with 75% PE schedule through drip system and was significantly higher than 50% PE schedule drip system; however it was on a but at par with furrow irrigation at 1.0 IW:CPE ratio. Kernel weight/plant recorded with drip irrigation at 75% PE was significantly higher than the other 2 irrigation schedules. Adequate moisture supply which was sufficient to meet the evapo-transpiration demand of the crop might be the reason for increased yield components under drip irrigation at 75% PE (Ganesaraja *et al.*, 2009). The nitrogen levels in maize manifested significant

Table 2. Effect of irrigation regimes and nitrogen levels on dry matter production, yield attributes and yield of no till *rabi* maize (Pooled data of 4 years)

Treatment	Dry weight at harvest (g/plant)	Kernels/cob	Kernel weight/plant (g)	100-kernel weight (g)	Kernel yield (t/ha)	Stover yield (t/ha)
Irrigation regime						
75% PE (DI)	441	599	170	29.1	7.37	8.98
50% PE (DI)	352	544	142	28.1	5.28	6.91
1.0 1W:CPE (FI)	427	574	154	29.0	6.85	8.52
SEm±	6.4	9.6	3.4	0.34	0.18	0.19
CD (P=0.05)	25.1	37.7	13.3	NS	0.71	0.75
Nitrogen (kg/ha)						
120	384	550	146	28.6	5.64	7.51
150	409	575	155	28.8	6.67	8.21
180	428	592	164	29.1	7.20	8.70
SEm±	8.6	6.8	4.0	0.41	0.24	0.28
CD (P=0.05)	33.8	26.7	15.7	NS	0.94	1.10

DI, Drip irrigation; FI, Furrow irrigation

impact on kernels/cob and kernel weight/plant. Kernels/cob and kernel weight/cob were maximum with 180 kg N/ha, and were significantly higher than 120 kg but statistically on a par with 150 kg N/ha, which was again at par with 120 kg N/ha. Nitrogen levels failed to show any significant effect on the test weight of maize.

Yield

Irrigation schedules significantly influenced the yield of no-till maize (Table 2). Highest kernel and stover yield was obtained with the drip irrigation at 75% PE which was significantly higher than 50% PE but at par with furrow irrigation at 1.0 IW:CPE ratio. On an average, the increase in the kernel yield owing to the irrigation at 75% PE was in the tune of 39 and 8% over 50% PE through drip irrigation and 1.0 IW:CPE ratio through furrow irrigation respectively. Increase in kernel yield under drip irrigation at 75% PE could be attributed to favourable soil-moisture status in the root zone throughout the crop-growth period owing to higher frequency of irrigation which might have maintained higher plant relative water content and the positive contribution by the yield attributes might have increased the yield (Viswanatha *et al*., 2002). The kernel yield of maize increased with each increment of nitrogen dose. The highest kernel yield was recorded with 180 kg N/ha which was statistically at par with 150 kg and significantly higher than 120 kg/ha. The mean data of four years revealed 8 and 28% increase in kernel yield with 180 kg N/ha over 150 and 120 kg N/ha respectively. The increased kernel yield with 180 kg N/ha was mainly owing to more dry-matter accumulation, kernels/cob and kernel weight/plant. Similar trend was observed with respect of stover yield also. These findings are in line with those obtained by Ramulu *et al.* (2010) and Patil *et al.* (2011), who also reported increased yields of maize at 100% PE and recommended dose of fertilizers through fertigation.

The interaction effect between the irrigation schedules and N levels was not significant for all the parameters recorded.

Quantity of water applied, nitrogen-and water-use efficiency

Irrigation data (mean of 4 years) on different treatments revealed that the total water applied under the furrow irrigation at 1.0 IW:CPE ratio was 409 mm, which was higher than the other 2 schedules through drip system (Fig.1). There was saving of 102 and 206 mm/ha of water by adopting drip irrigation system at 75% and 50% PE compared to furrow irrigation method. Water-use efficiency was also the lowest under 1.0 IW:CPE ratio compared to 75% or 50% PE across all the 4 years of study (Table 3). These results are in accordance with Ko and Piccini (2009) and Reddy *et al.* (2012). This might be due to the fact that drip irrigation provides the efficient use of limited

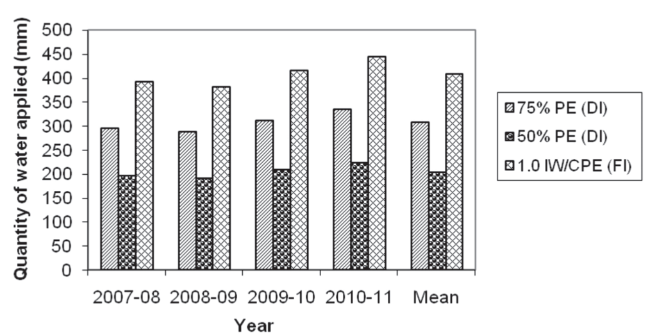

Fig. 1. Quantity of water applied (mm) through irrigation in different irrigation schedules in no till *rabi* maize

water with minimum unavoidable losses and increase the crop productivity (Karam *et al*., 2003). The WUE was the highest with the drip irrigation at 50% PE. Among the nitrogen levels, 180 kg N/ha resulted in increased WUE due to increased kernel yield for unit of water used. Drip irrigation at 75% PE registered the significantly higher nitrogen-use efficiency (NUE) over 50% PE, but at par with the furrow irrigation at 1.0 IW:CPE ratio. Regarding nitrogen, NUE was gradually decreased with increase in N dose from 120 to 180 kg/ha. The lower dose of 120 kg N/ha had significantly higher NUE than the other 2 doses.

Production efficiency

There was maximum production efficiency (kg kernel/ha/day) with the drip irrigation at 75% PE which was superior by 7 and 32% to 1.0 IW:CPE ratio and 50% PE, respectively (Table 3). Application of 180 kg N/ha increased the production efficiency over the lower doses.

Nitrogen uptake

The mean uptake of nitrogen by kernel and stover was higher with the irrigation regime of 75% PE than the rest of the treatments due to higher dry matter production which governs the uptake (Table 3). Patil *et al*. (2012) and Reddy *et al.* (2012) made similar observations. Application of 180 kg N/ha significantly increase N uptake of kernel and stover compared to the lower doses. Precise application of fertilizer in right quantity at the right time to match with the crop demand might have resulted in higher nutrient uptake, enhanced bio chemical activities as well as biomass partitioning which in turn led to better growth and yield parameters (Ganesaraja *et al*., 2009).

Economics

The gross returns, net returns and benefit: cost ratio realized with drip irrigation at 75% PE were higher than

Table 3. Effect of irrigation regimes and nitrogen levels on N uptake, water and nitrogen use efficiency and production efficiency of no till *rabi* maize (Pooled data of 4 years)

Treatment	N uptake		WUE	NUE(kg kernel/kg	PE
	Kernel (kg/ha)	Stover (kg/ha)	(kg/ha-mm)	N applied)	(kg/ha/day)
Irrigation regime					
75% PE (DI)	64.8	35.6	24.2	50.3	65.4
50% PE (DI)	37.0	21.5	26.6	36.6	49.5
1.0 1W:CPE (FI)	55.5	31.5	17.0	47.2	60.8
SEm±	1.71	0.77	0.4	1.2	-
CD (P=0.05)	6.72	3.01	1.7	4.7	-
Nitrogen (kg/ha)					
120	45.4	25.8	20.6	50.2	50.0
150	52.7	29.9	22.9	44.4	59.2
180	59.2	32.9	24.4	39.6	57.9
SEm±	2.28	1.10	0.5	1.3	-
CD (P=0.05)	7.03	3.39	1.6	3.9	-

WUE, Water-use efficiency; NUE, Nitrogen-use efficiency; PE, Production efficiency

Table 4. Effect of irrigation regimes and nitrogen levels on economics benefit: cost ratio of no-till *rabi* maize (Pooled data of 4 years)

Treatment	Gross returns ($\times10^3$ ₹/ha)	Cost of cultivation ($\times10^3$ ₹/ha)	Net returns ($\times10^3$ ₹/ha)	Benefit: cost ratio
Irrigation regime				
75% PE (DI)	61.50	24.65	36.86	1.5
50% PE (DI)	44.18	24.45	19.73	0.8
1.0 1W:CPE (FI)	57.28	24.69	32.60	1.3
Nitrogen (kg/ha)				
120	46.96	25.02	21.94	0.9
150	55.80	25.40	30.40	1.2
180	60.21	25.78	34.43	1.4

Cost of drip system with fertigation unit= ₹ 1,20,000/ha; Subsidized cost (90% subsidy under APMIP)= ₹12,000/ha; (Taking drip life as 10 years, annual fixed cost is ₹ 1,200/ha); Cost of depreciation = ₹120/year; Repairs and maintenance of drip system= ₹ 600/year; Total cost of drip system = ₹ 1,200+120+600= ₹ 1,920/year/two crops; Total cost of drip system per one crop = ₹ 960/(included in COC); Price of maize kernel (₹/kg): 7.5 (2007–08), 8.2 (2008–09), 8.6 (2009–10) and 9.0 (2010–11); APMIP, Andhra Pradesh Micro-Irrigation Project that obtained with furrow irrigation at 1.0 IW:CPE ratio or drip irrigation at 50% PE (Table 4). Similarly, more returns and benefit: cost ratio were obtained at N dose of 180 kg/ha over the lower doses applied either as conventional method or fertigation.

Our results revealed that higher yield, production efficiency and net returns can be obtained when winter (*rabi*) maize crop is irrigated at 75% PE through drip system. Application of 150 kg N/ha was found to be optimum to *rabi* maize through drip cum fertigation in sandy-loam soils of Telangana region in Andhra Pradesh.

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