Performance of no-till maize under drip-fertigation in a double cropping system in semi arid Telangana state of India

Padmaja Bhimireddy[1,2]*, M Mallareddy[1,2], G Subbaiah[3], K Chandra Sekhar[4], D Vishnu Vardhan Reddy[5], P Ravindra Babu[6]

[1]Regional Agricultural Research Station, PJTSAU, Warangal – 506 007, Telangana State, India
[2]Present Address: Agricultural college, PJTSAU, Polasa, Jagtial, Karimnagar district – 505 329,Telangana State, India
[3]Department of Agronomy, Agricultural College, ANGRAU, Bapatla, Andhra Pradesh, India
[4]Agricultural Research Station, ANGRAU, Jangamaheswarapuram, Guntur district, Andhra Pradesh, India
[5]College of Agriculture, PJTSAU, Rajendranagar, Hyderabad-500 030, India
[6]Department of SSAC, Agricultural College, ANGRAU, Bapatla, Andhra Pradesh, India
*Corresponding author: E-mail: bhimireddymaduri@gmail.com

Abstract

Availability of water for Agriculture is becoming increasingly difficult, besides the cost of power for applying it. Improving the water and nitrogen use efficiency has become imperative in present day's Agriculture. Drip irrigation and fertigation provides the efficient use of limited water with increased water and nutrient use efficiency, respectively. A field experiment was conducted during post rainy season of two consecutive years (2011 and 2012), in sandy loam soils of Warangal, Telangana State, India to study the response of no-till maize (*Zea mays* L) after aerobic rice (*Oryza sativa* L) to drip irrigation and nitrogen fertigation under semi-arid environment. The experiment was laid out in split plot design with four replications. Three irrigation schedules viz. drip irrigation at 75% Pan Evaporation (PE); 100% PE and 125% PE were taken as main plots and three nitrogen levels through fertigation viz. 120, 160, and 200 kg ha^{-1} as sub plots. The growth parameters (plant height, LAI, drymatter accumulation), root volume and dry weight, yield attributes (cobs plant^{-1}, kernels cob^{-1}, kernel weight cob^{-1}) kernel yield, stover yield and nitrogen uptake of no till maize increased with increase in water input from 75% PE to 100% PE irrigation schedule in drip irrigation but could not reach the level of significance at 125% PE. Tasseling and silking was hastened in 125% PE schedule. Increase in the level of N application through fertigation from 120 to 160 kg N ha^{-1} resulted in the increase of all the growth parameters, yield attributes, kernel yield, stover yield and nitrogen uptake. Barrenness and test weight were unaffected by either the irrigation schedules or nitrogen levels. The economic indicators (gross returns, net returns and net benefit: cost ratio) were higher with the irrigation schedule of 125% PE and nitrogen dose of 200 kg N ha^{-1} applied through fertigation. Increased water input from 75 to 125% PE resulted in decreased water use efficiency but enhanced nitrogen use efficiency while the reverse trend was found with respect to N levels under fertigation.

Keywords: drip-fertigation, no-till maize, nitrogen- and water use efficiency, root volume, yield

Introduction

Maize is the third most important crop in the world having the highest genetic yield potential among cereals. It is referred to as the «queen of cereals»; cultivated in almost 178 million ha and contributes to 50% (1,170 Mn M T) in the total grain production of the world (India Maize Summit, FICCI, 2015). It is an important food staple in many countries and is also used in animal feed and many industrial applications. The crop has tremendous genetic variability, which enables it to thrive in tropical, subtropical, and temperate climates. International maize trade is now larger than international rice trade. USA, Brazil, Argentina and India are the major exporters while Japan, South Korea, Mexico are the major importers of maize.

India ranks sixth among maize producing countries (FAO, 2014). It is emerging as third most important crop after rice and wheat with a production of ~17.8 in 2013-14. Its importance lies in the fact that it is not only used for human food and animal feed but at the same time it is also widely used for corn starch industry, corn oil production, baby corns etc. It is predominantly grown as a kharif crop. Of late, rabi maize has emerged as an important crop in the non-traditional season and non-traditional areas.

Maize production in India is dominated by Andhra Pradesh (including Telangana) and Karnataka states producing ~8% of India's maize in 2010-11. In Andhra Pradesh (including Telangana) it is grown in an area of 2.8 lakh ha with a productivity of 5.32 t ha^{-1} (CMIE, 2011), which has the highest productivity due to majority of the area being covered under single cross hybrids followed by Tamil Nadu State.

Water is the prime natural resource which very often becomes costly and limiting input particularly in semi-arid tropics and needs to be judiciously used

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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 (Mallareddy et al, 2012). Drip irrigation and fertigation are the proved 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.

In the post-green revolution era, resource-conservation issues have assumed greater importance in view of the widespread land and water degradation problems associated with mechanized intensive tillage system, advancement of mechanization in modern conventional agriculture along with increasing demands of food and other products, requires more fossil fuel energy, now has been realized as not very energy efficient and is detrimental to the air, water and soil environment. With aim of conserving resources, improving input-use efficiency and sustain productivity, conservation agricultural system has emerged. Zero or no-tillage is an ecological approach for soil surface management adopted worldwide because of savings in time and economic inputs.

Growing maize under zero tillage after rainy season (kharif) rice has gained importance in south India due to scarcity of water to the second rice crop, rapidly increasing demand for maize for human and livestock consumption and high productivity of maize crop. The rice-maize cropping system occupies around 3.5 M ha in Asia (Timsina et al, 2010). Out of 0.53 M ha of the total area in India, this system is practiced in 0.25 M ha in Andhra Pradesh an Telangana States alone. Keeping this in view, an attempt was made to evaluate the performance of no till maize in rice-maize cropping system under drip irrigation and nitrogen fertigation.

Materials and Methods

Experimental site and weather conditons

A field experiment was conducted during the post rainy season of 2011 and 2012 at Regional Agricultural Research Station, Warangal (18°00'53.2"N;79°36'17.2" E and 275 m above mean sea level), Telangana State, India. Climate of the study site is sub-tropical and semi-arid type with mean annual rainfall of 885 mm and a mean annual evaporation of 1,621 mm. Soil of the experimental field was sandy loam with a pH of 7.9, Electrical conductivity (EC) 0.17 d S m^{-1}, low in organic C (0.40%), available N (227 kg ha^{-1}), available P (11 kg ha^{-1}) and available K (65 kg ha^{-1}). During the growth period of maize, the weekly mean maximum temperature ranged from 27.4 to 34.1°C and 27.0 to 35.3°C during 2011-12 and 2012-13, respectively. The mean minimum temperature for the corresponding period ranged from 14.7 to 24.6°C and 13.4 to 20.4°C during 2011-12 and 2012-13, respectively, while the average maximum and minimum temperatures during the period were 29.4 and 18.6°C in 2011-12 and 30.5 and 17.5°C in 2012-13, respectively. The weekly mean relative humidity ranged from 61.7 to 76.5% during 2011-12 and 64.4 to 77.0% during 2012-13, while the average relative humidity was 69.5 and 71.2% during 2011-12 and 2012-13, respectively. A total rainfall of 3.2 and 23.6 mm was received during 2011-12 and 2012-13 over one and three rainy days, respectively. During the corresponding period, a total of 375.2 and 445.6 mm of evaporation occurred during 2011-12 and 2012-13, respectively. The mean bright sunshine hours ranged from 6.4 to 9.2 and 6.3 to 9.8, during 2011-12 and 2012-13, respectively. Overall, the weather conditions prevailed during the growth period was normal and congenial for optimum performance of maize crop.

Treatments

The treatments consisting of three irrigation schedules viz. drip irrigation at 75% Pan Evaporation (PE), 100% PE and 125% PE in main plots and three nitrogen levels through fertigation (120, 160, and 200 kg ha^{-1}) in sub plots were tested in a split-plot design and replicated four times. The drip system was established keeping 120 cm between two lateral lines. The lateral line of 16 mm diameter lay between two maize rows and another lateral line came after 2 rows of maize. The inline dripper distance was 50 cm with a discharge of 4 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 evaporation (mm) recorded from USWB Class A Open Pan Evaporimeter situated in the Class B Agrometeorological Observatory 200 metres from the experimental site. Drip system was operated on every alternate day. The source of irrigation water was open well fitted with 3 HP electrical motor. Nitrogen was applied through drip system in the form of urea as per the treatments in ten equal splits starting from ten days after sowing with a ventury fixed to the system.

Crop variety and agro-practices

Rainy season rice was grown under aerobic condition. It was harvested leaving the stubbles at 5-10 cm height from soil surface. A light irrigation was given and at 5 days after harvest of rice, seed of maize hybrid, 'Pinnacle' developed by Monsanto India Limited was dibbled manually under no till condition by the side of rice stubbles at a depth of 5 cm @ one seed / hill with a spacing of 60 x 20 cm. The plot size was 9.6 x 6.0 m. Tank mixture of atrazine @ 2.5 kg ha^{-1} + glyphosate @ 5 lt ha^{-1} was sprayed immediately after sowing using 500 litres of water per hectare with flood jet nozzle, to control the weeds as well as to prevent ratooning from the harvested rice stubbles. Drip lateral lines were spread as per the layout at one week after sowing. Thinning and gap filling were done at 10 days after sowing. Recommended phosphorus and potassium i.e., 60 and 50 kg ha^{-1}, respectively were applied at 15 DAS as pocketing. No severe incidence of pests or diseases was noticed during the crop period. As a precautionary measure, however, whorl application of three to four carbofuron granules were applied at 15 DAS against stem borer. The crop was harvested at maturity when the cobs dried and the entire plants turned yellow. The cobs harvested from net plot were dried thoroughly under the sun. The stover was dried under the sun separately for recording the weights. Shelling of the cobs was done with a power operated maize sheller.

Sampling and observations

Five plants were tagged in each net plot area for recording observations that did not involve destructive sampling. All such observations were recorded on these plants at 30, 60, 90 DAS, and at maturity. Five plants in the second row from the boarder row in each plot were cut at ground level at each time for recording dry matter accumulation and leaf area index. At 50% tasseling, five plants were uprooted carefully in each plot to retain all the roots and then separated from the stem portion from first node of plants. Roots were thoroughly washed and dipped in a measuring glass cylinder contained known volume of water. The water displaced by roots was considered to be root volume as cm^3 (cc) called as water displacement technique as described by Misra and Ahmed (1987). Other growth parameters, yield attributes and yield were also measured using standard procedures. Harvest index was calculated by dividing the kernel yield with kernel + stover yield multiplied with 100. Based on the pan evaporation data, quantity of water to be given in different treatments was calculated and the drip system was operated for such a time to deliver the said amount of water as per the treatmetns. The quantity of water applied in each irrigation was

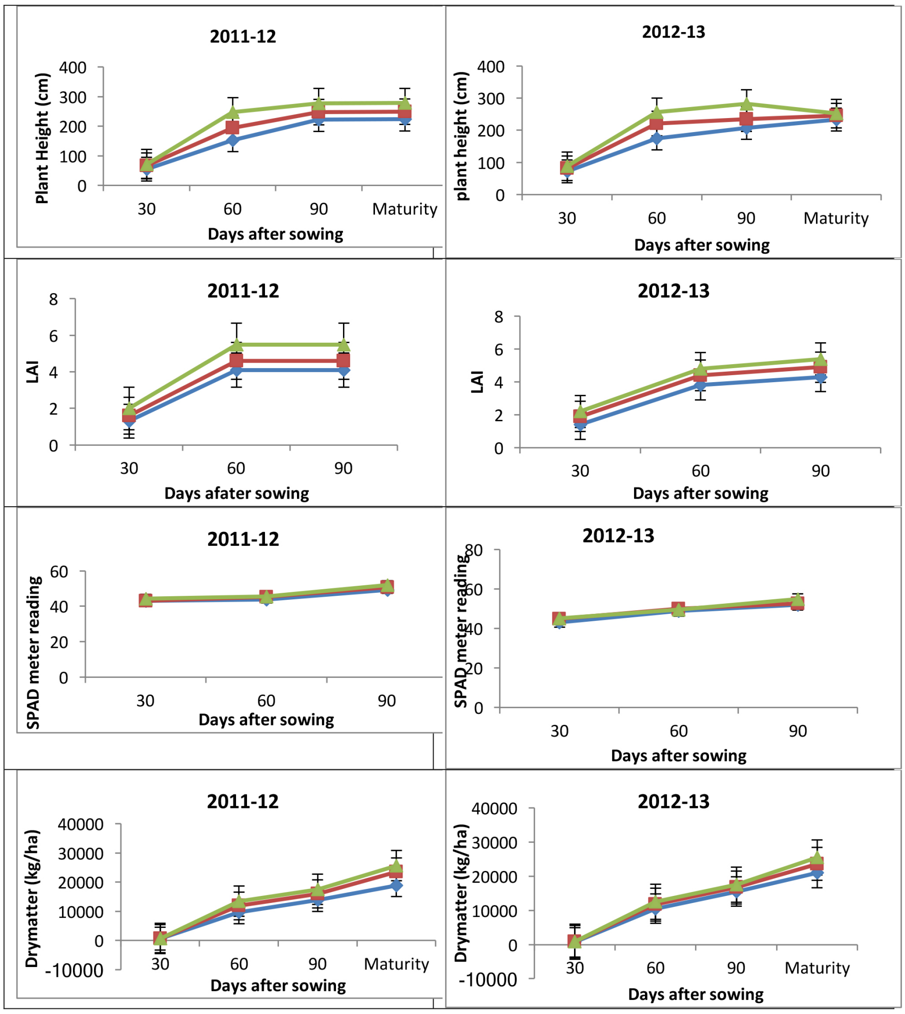

Figure 1 - Growth parameters of no- till maize as influenced by irrigation regimes under drip irrigation. The bars are the SE.

summed up to arrive the total quantity of water applied in the crop season. Water use efficiency (WUE) in kg ha mm^{-1} was calculated by dividing the kernel yield with respective total water use (irrigation + rainfall) for the crop yield. The nitrogen use efficiency (kg kernel kg^{-1} 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 analyzed with standard methods. The economics was estimated in terms of cost of cultivation as per the guidelines of Commission of Cost and Prices and net returns and benefit: cost ratio was calculated on the basis of minimum support price. The Government is promoting micro-irrigation systems by providing subsidy provisions for the benefit of farmers. Hence, the economics of micro-irrigations system was assessed on the basis of 90% subsidy. The net returns ha^{-1} for each treatment is the difference between the gross returns and total cost of cultivation. Net benefit: cost ratio (Net B: C) was calculated by dividing the Net returns (ha^{-1}) by total cost of cultivation (ha^{-1}).

Statistical analysis

The data on growth, yield attributes, kernel, stover yield and N uptake of maize were analyzed statistically applying analysis of variance technique for split-plot design as suggested by Gomez and Gomez (1984). Critical difference for examining treatment means for their significance was calculated at 5% level of probability (P = 0.05).

Results and Discussion

Growth parameters

Drip irrigation schedules and nitrogen doses through fertigation influenced plant height, LAI and above-ground dry matter (Figures 1 and 2). Maize plants grew significantly taller with drip irrigation

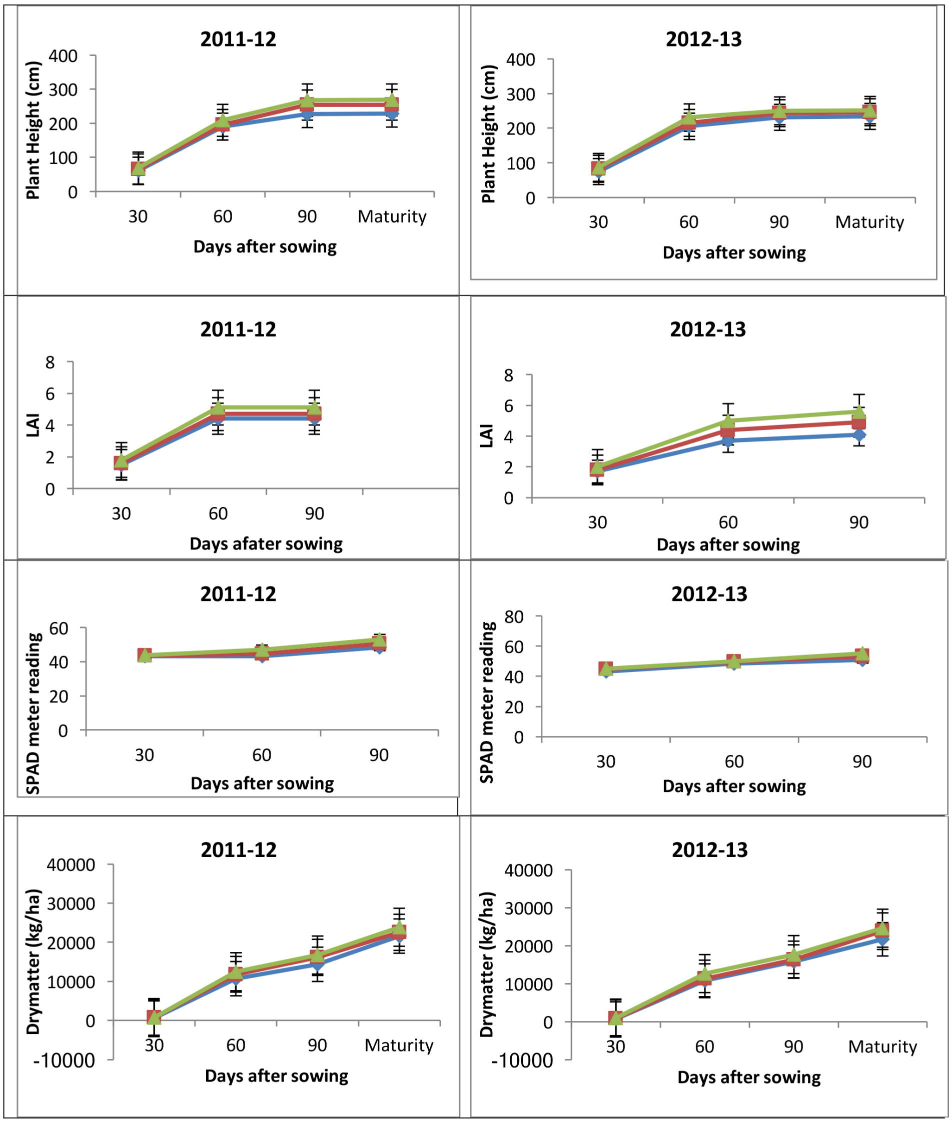

Figure 2 - Growth parameters of no-till maize as influenced by N levels under fertigation. The bars are the SE.

Table 1 - Root volume, root dry weight, days to 50% tasseling and silking in no till maize as influenced by irrigation regimes and N levels through fertigation.

Treatment	Root volume ($cc\ hill^{-1}$)		Root dry weight ($g\ hill^{-1}$)		Days to 50% tasseling		Days to 50% silking	
	2011	2012	2011	2012	2011	2012	2011	2012
Irrigation regime								
75% PE	31.8	46.0	11.6	13.3	70.1	68.9	77.3	76.6
100% PE	39.0	54.8	14.3	15.3	68.5	68.0	76.2	75.8
125% PE	43.3	61.9	16.9	17.6	67.7	67.2	75.2	74.4
SEm±	0.87	1.60	0.12	0.45	0.15	0.24	0.23	0.47
LSD (P = 0.05)	3.0	5.5	0.40	1.5	0.5	0.8	0.8	1.6
N level ($kg\ ha^{-1}$)								
120	26.4	43.2	13.0	13.4	69.3	68.3	76.5	75.7
160	38.3	53.0	13.9	14.7	68.8	68.1	76.3	76.2
200	49.3	66.6	15.9	18.0	68.1	67.7	75.8	74.9
SEm±	1.28	0.94	0.36	0.32	0.37	0.43	0.38	0.45
LSD (P = 0.05)	3.8	2.8	1.1	1.0	NS	NS	NS	NS
Interaction								
SEm±	3.14	2.77	0.21	0.78	0.26	0.42	0.41	
LSD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS

scheduled at 125% PE than at 75% PE but was at par with that of 100% PE at 30 DAS during 2011, but at the later stages during 2011 and all the stages during 2012, the irrigation schedule of 125% PE maintained its superiority over the other two schedules of irrigation (Figure 1). A significant increase in LAI was recorded with increase in the quantity of water applied between 75% and 125% PE at 30, 60, and 90 DAS during both the years of study. The aboveground drymatter was significantly higher when no-till maize crop was irrigated at 125% PE compared to 100% and 75% PE at all the stages except at 30 DAS during 2012 wherein 125% PE and 100% PE were at par with each other.

The tallest plants were recorded with 200 kg N ha^{-1} which was superior to 120 kg N ha^{-1} but at par with 160 kg N ha^{-1} except at 30 DAS during first year and at 60 DAS during second year of experimentation (Figure 2). At 30 DAS, LAI measured with the application of 200 kg N ha^{-1} was significantly higher than that with 120 kg N ha^{-1} but was at par with that of 160 kg N ha^{-1} during both the years of study. At 60 and 90 DAS, 200 kg N ha^{-1} was also superior to 160 kg N ha^{-1} apart from 120 kg N ha^{-1}. The latter two doses were at par with each other with respect to LAI during 2011 but differed during 2012. Leaf expansion is closely linked to nitrogen uptake and plant N status during the vegetative growth stage (Sinclair and Muchow, 1995). In the absence of N stress, 60-80% of the above-ground N is partitioned to the leaf blades during vegetative stage in grain crops (Lemaire et al, 2007). Similarly, increased N application at 200 kg ha^{-1} resulted in significant increase in drymatter accumulation over 120 kg N ha^{-1} at all the stages of observation during both the years of study, but it was found to be at par with that of 160 kg N ha^{-1} at 60 and 90 DAS during 2011 and 30 DAS and maturity during 2012. Increased supply of nitrogen might have helped the maize plants to increase their growth which in turn put forth more photosynthetic surface, thus contributed to more drymatter accumulation. Tasseling and silking in maize plants was hastened by scheduling the irrigation water at 125% compared to other schedules but not influenced by nitrogen levels (Table 1). Fertigation distributes nutrients and water through the drippers directly into the root zone of the plant, entering the soil through the combined forces of gravity and capillarity. This reduces the nutrients losses through volatilization and leaching (Hebbar et al, 2004; Anitta Fanish et al, 2011).

Differential chlorophyll levels (SPAD units)

The chlorophyll concentration is a very important indicator of photosynthetic potential. The difference in the chlorophyll levels, as measured by the SPAD meter, was not significant due to irrigation schedules. However, the SPAD units increased significantly with increasing N from 120 to 160 kg ha^{-1} but not beyond it. Nitrogen has direct role in synthesis of chlorophyll and due to this reason; higher N levels resulted in better chlorophyll concentration and more SPAD value.

Root parameters at 50% tasseling

Root volume (cc $plant^{-1}$) and dry weight (g $plant^{-1}$) of zero till maize at 50 per cent tasseling was influenced by irrigation schedules and nitrogen levels under fertigation (Table 1). There was a significant increase in root volume and root dry weight with the water input from 75% PE to 100% PE and in turn to 125% PE during both the years. Crop roots take up nutrients and water from upper layers of the soil under the condition of low water-stress or non-stress (Rhodes and Bennet, 1990). Frequently watered plants produce a shallow root system whereas, occasionally watered plants produce deep root system (Kirtok, 1998).

Irrigation schedules and nitrogen levels interacted

Table 2 - Yield attributes of no till maize as influenced by irrigation regimes and N levels through fertigation.

Treatment	Barrenness (%)		No. cobs plant^{-1}		Cob length (cm)		No. of kernels cob^{-1}		Test weight (g)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Irrigation regime										
100% PE	5.68	5.18	1.3	1.4	17.4	19.8	506	488	29.1	29.9
150% PE	4.71	4.73	1.5	1.5	18.0	20.9	532	559	28.8	29.7
200% PE	4.84	4.33	1.6	1.5	18.3	22.1	553	611	29.7	30.1
SEm±	0.38	0.26	0.03	0.03	0.31	0.30	8.3	17.5	0.47	0.64
LSD (P = 0.05)	NS	NS	NS	NS	NS	1.0	29	60.0	NS	NS
N level (kg ha^{-1})										
90	5.07	4.80	1.5	1.5	17.1	20.1	510	503	29.3	30.3
120	5.18	4.94	1.4	1.4	18.1	20.8	528	561	28.8	29.6
150	4.98	4.50	1.5	1.5	18.4	21.9	552	593	29.4	29.8
SEm±	0.37	0.31	0.07	0.06	0.23	0.43	10.4	18.2	0.47	0.53
LSD (P = 0.05)	NS	NS	NS	NS	0.7	1.3	31.0	54.0	NS	NS
Interaction										
SEm±	0.67	0.45	0.05	0.05	0.54	0.52	14.3	30.2	0.81	1.10
LSD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

for root volume during 2012 (Supplemetary Table 1). It significantly increased with the increased level of N at each irrigation schedule. Similarly, with the increased water input from 75% PE to 125% PE, root volume increased at 160 and 200 kg N ha^{-1} but the difference between 75% PE and 125% PE was only significant at lower dose i.e., 120 kg N ha^{-1}. Root dry weight recorded with 200 kg N ha^{-1} was superior to that of the two lower doses (Table 1). Root volume and dry weight increase under drip fertigation practice with water soluble fertilizers, while rooting depth is enhanced in surface irrigation (Anitta Fanish et al, 2013).

Yield attributes

Yield attributes of no-till maize were also influenced by irrigation schedules and nitrogen levels under drip fertigation. Significantly higher number of cobs plant^{-1} and kernels cob^{-1} were recorded with 100% PE compared to 75% PE but comparable at 125% schedule during both the years of experimentation (Table 2). Cob length during second year and kernel weight cob^{-1} during both years were increased at 125% PE compared to the other two schedules. Similarly, longer cobs with more number of kernels cob^{-1} and kernel weight cob^{-1} were registered with increase in N level from 120 to 160 kg N ha^{-1} but not beyond it. Adequate soil water availability lead to both a better uptake and use of nutrients in the cell metabolic processes, increasing crop biomass, sink size and partitioning of the assimilates (Paolo and Rinaldi, 2008). N also plays an important and direct role in kernel development by regulating the enzymatic activities involved in the translocation of sucrose from stem to the developing ovaries (Below et al, 2000). It increases the potential sink capacity and sink growth rate (Melchiori and Caviglia, 2008). Maize yield is mainly related to kernel number per unit area (Andrade et al, 1999). Nitrogen levels did not influence the cobs plant^{-1} during both the years. Barrenness and test weight were also not influenced by either the irrigation schedules or nitrogen levels (Table 2).

Kernel, stover yield and harvest index

Irrigation schedules and nitrogen doses in fertigation significantly influenced the kernel yield of maize under no till condition (Table 3). The kernel yield was significantly increased with increase in the quantity of water applied from the irrigation schedule 75% PE to 100% PE during both the years of study. However, 100% PE and 125% PE were at par with each other. Increase in kernel yield under drip irrigation at higher levels of irrigation could be attributed mainly due to improved soil moisture status throughout the crop growth period consequently higher plant relative water content and less negative leaf water potential (Viswanatha et al, 2002). Plant water deficit in 75% PE treatment might have affected the final yield through its influence on various physiological processes. The magnitude of the adverse effect of plant water deficit on final yield depends on stage of the growth at which the moisture stress occurs (Salter and Goode, 1967). The research findings of several workers support the same (Soltan et al, 2001; Oktem et al, 2003; Choudhary et al, 2006; El-Hendawy et al, 2008; Basava et al, 2012). Among the three nitrogen levels studied, higher kernel yield was recorded at 200 kg N ha^{-1} which was superior to that of two lower doses during first year and 120 kg N ha^{-1} only during second year (Table 3). Application of 160 kg was again superior to 120 kg N ha^{-1} during both the years. Nitrogen fertigation with more readily available form at more frequent intervals might have resulted in higher availability of nitrogen in the soil solution which led to higher growth, uptake and better translocation of assimilates from source to sink thus in turn increased the yield (Anitta Fanish and Muthukrishnan, 2011). These results are in line with those obtained by Tank

Table 3 - Yield, harvest index and N uptake of no till maize as influenced by irrigation regimes and N levels through fertigation.

Treatment	Kernel yield ($kg\ ha^{-1}$)		Stover yield ($kg\ ha^{-1}$)		Harvest Index		N uptake by kernel ($kg\ ha^{-1}$)		N uptake by stover ($kg\ ha^{-1}$)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Irrigation regimes										
100% PE	8039	9331	9861	11499	45.0	44.7	67.0	77.9	48.3	55.9
150% PE	10045	10649	12217	12793	45.2	45.5	85.9	93.0	57.2	58.5
200% PE	11345	11716	12933	13566	46.7	46.4	100.9	106.6	75.3	79.0
SEm±	455.1	332.6	617.0	354.9	0.34	0.80	3.76	3.39	2.66	3.07
LSD (P = 0.05)	1571.0	1148.0	2130.0	1225	1.20	NS	13.0	11.7	9.2	10.6
N level ($kg\ ha^{-1}$)										
90	9168	9536	11304	11965	44.8	44.3	72.7	74.9	54.4	56.8
120	9801	10849	11565	12812	45.9	45.8	84.8	96.1	56.8	63.1
150	10461	11311	12141	13081	46.2	46.5	96.4	106.6	69.5	73.6
SEm±	171.1	318.2	256.6	543.2	0.43	0.58	1.52	4.06	3.82	3.38
LSD (P = 0.05)	508.0	946.0	NS	NS	NS	NS	4.50	12.10	11.40	10.00
Interaction										
SEm±	788.3	576.1	1068.7	614.6	0.59	1.38	6.52	5.86	4.61	5.32
LSD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

et al (2006), Kumar et al (2009), Mehta et al (2011), Mallareddy et al (2012), and Rathore et al (2014). Interaction between irrigation schedules and nitrogen levels was not significant.

Stover yield ($kg\ ha^{-1}$) of no till maize was influenced by irrigation schedules but not by the nitrogen levels (Table 3). During both the years of study, stover yield significantly increased from 75% PE to 100% PE drip schedule. The increase in stover yield at 125% PE was not significant compared to 100% PE. The harvest index of maize was influenced by irrigation schedules during the first year of study only (Table 3). It was significantly increased with 125% PE compared to the other two schedules i.e., 75% and 100% PE both of which were found to be at par with each other. Nitrogen levels as well as interaction between irrigation and nitrogen did not influence the harvest index. Nitrogen uptake by kernels and stover was higher at 125% PE than that of other two schedules (Table 3). It was increased from 120 to 160 kg N ha^{-1} but not beyond it.

Water-use efficiency and nitrogen-use efficiency

Water requirement enhanced in the order of 125% PE, 100% PE and 75% PE during both the years. However, water use efficiency decreased gradually from 75% PE to 125% PE schedule during both the years (Table 4). It declined by 6.0, 13.6 and 14.9, 23.3% in 100% and 125% PE schedules during first and second years, respectively compared to 75% PE drip schedule. The increase in water productivity in water deficit treatment (75% PE) over sufficiently watered treatments in drip system was probably due to larger decline in plant transpiration because of reduced green leaf area as a consequence of water stress, which probably might have reduced evaporation from dry soil (Amit et al, 2013). These results corroborate with those of Karam et al (2003), Jihua et al (2006) and Lan-Sheng and Cheng-Lin (2007). Nitrogen levels also influenced water productivity. With the increase in N level from 120 to 200 kg ha^{-1}, water productivity gradually increased to the tune of 6.5, 14.2 and 3.0, 19.0 per cent with 160 and 200 kg over 120 kg N ha^{-1}, during 2011 and 2012, respectively.

In contrast to water productivity, nitrogen use efficiency (kg kernel kg^{-1} N applied) enhanced with the increase in water input but declined with the increase in N level (Table 4). Among the three, highest nitrogen use efficiency was recorded at 125% PE irrigation schedule and the lowest with the 75% PE. With the increase in nitrogen levels, nitrogen use efficiency was reduced. It was lesser by 19.8 and 14.7 % at 160 kg; 31.5 and 28.8 % at 200 kg N ha^{-1} over 120 kg N ha^{-1}, during first and second year, respectively. Studies conducted by Paolo and Rinaldi (2008) and Wang et al (2011) also showed that NUE increase linearly with soil water availability and decreased with applied N in corn.

Post-harvest status of available N, P, and K

A perusal of the data on soil available N, P, and K status after harvest of maize crop (Supplementary Table 2) reflects that the soil N status increased at higher N level of application from 120 to 200 kg N ha^{-1} at all the irrigation schedules studied. Among the irrigation schedules, it declined from 75% PE to 125% PE across all the three nitrogen levels. The status of available P and K did not differ with the irrigation schedules and nitrogen levels after harvest of maize crop during both the years of experimentation. Zhao et al (2006) and Kumar (2009) also reported similar observations.

Economics

The data presented in Supplementary Table 3 indicated that gross returns, net returns and net benefit: cost ratio gradually increased with the increase in water input from irrigation schedule of 75% PE to 125% PE and from 120 to 200 kg N ha^{-1} in drip ferti-

Table 4 - Water- and nitrogen use efficiency of no till maize as influenced by irrigation regimes and N levels through fertigation.

Treatment	WUE ($kg\ ha\ mm^{-1}$)		NUE (kg grain kg^{-1} N applied)	
	2011	2012	2011	2012
Irrigation regime				
100% PE	28.4	26.6	51.7	59.8
150% PE	26.7	23.0	65.2	68.7
200% PE	24.1	20.4	73.0	75.4
N level ($kg\ ha^{-1}$)				
90	24.7	21.0	76.4	79.5
120	26.3	24.0	61.3	67.8
150	28.2	25.0	52.3	56.6

gation during both the years of study. It was evident that scheduling of irrigation at 125% PE alongwith the application of 200 kg N ha^{-1} in fertigation resulted in realization of higher gross returns, net returns and returns per rupee of investment closely followed by 160 kg N ha^{-1} in the same irrigation schedule during both the years.

Conclusion

From this study it is evident that yield enhancement of no-till maize is possible through the use of drip irrigation and fertigation. Scheduling irrigation water at 100% pan evaporation and application of 160 kg N ha^{-1} was found to be beneficial with improved water- and nitrogen use efficiency.

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