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Performance of *rabi* maize to fertigation durations and nitrogen levels

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Abstract
A field trial was conducted on clay soils of Advanced Post Graduate Centre, Lam, Guntur to study the effect of different nitrogen fertigation levels at different stages of maize on growth, yield attributes and yield of maize during *rabi* 2019-20. The experiment was laid out in RBD with twelve treatments *i.e.*, 100% recommended dose of nitrogen (RDN) through soil application under surface irrigation (T_1), 100% and 75% RDN through soil application under drip irrigation (T_2 and T_3 respectively), 100%, 75% and 50% RDN through fertigation up to 60 DAS (T_4, T_5 and T_6 respectively), 100%, 75% and 50% RDN through fertigation up to 75 DAS (T_7, T_8 and T_9 respectively) and 100%, 75% and 50% RDN through fertigation up to 90 DAS (T_{10}, T_{11} and T_{12} respectively) and they were replicated thrice. At 90 DAS, among different surface application and nitrogen fertigation levels, the plants that received 100% RDN through fertigation up to 60 DAS (T_4) recorded the highest plant height. Whereas, at harvest, highest dry matter and lower number of days to 50% flowering were observed with 100% RDN through fertigation up to 90 DAS (T_{10}). Maize plants fertigated with 100% RDN up to 90 DAS (T_{10}) recorded higher yield attributes and kernel yield when compared to other treatments.

Keywords: Performance, *rabi*, fertigation, nitrogen

Introduction
Maize is one of the widely grown grain crop which is useful for food and fodder. Maize has highest yield potential compared to other cereal crops under irrigated conditions. In India, maize is grown in an area of 9.6 m ha with a production of 25.89 m t and productivity of 2689 kg ha^{-1}. In AP maize is cultivated in an area of 2.5 lakh ha with a production of 16.5 lakh tonnes and with a productivity of 6612 kg ha^{-1} (www.indiastat.com).

Food security is a growing concern worldwide. Increasing population and consumption increase the demand for food which inevitably increases the use of water. Improving water use efficiency is important to safeguard food security. Because of the huge contribution to increased crop production, fertilizer is being used in every region of the world. However, fertilizer use efficiency is low all over the world. Hence there is a prerequisite for efficient use of water and fertilizer resources to safeguard sustainable food production. Drip irrigation the most efficient methods of watering crops. This practice offers enhanced yields, requires a reduced amount of water, declines the cost of tillage and lessens the quantity of fertilizers applied to the crop. Drip irrigation upsurges water use efficiency, boosts crop yields and quality and improves fertilizer use efficiency.

An appropriately planned drip fertigation system can make best use of crop water and nutrient uptake and minimizes nutrient leaching. The important factors that influence the productivity of maize are water and nutrients. Drip fertigation permits application of nutrients directly at the location of high concentration of active roots. By introducing drip with fertigation, it is possible to increase the yield of crops by three times from the same quantity of water. When fertilizer is applied through drip, it was observed that besides increased yield, about 30 per cent of the fertilizer was saved (Sivanappan and Ranghaswami, 2005) [10].

Drip fertigation, together with split applications of nitrogen fertilizer liquified in drip irrigation water, not only improves nitrogen use efficiency but also decreases the groundwater pollution owing to the high homogeneity of nitrogen application. Compared to conventional practices, split application of fertilizer through drip fertigation also reduces soil compaction.

In general 6th leaf stage to tasseling considered the rapid growth stage involves rapid uptake of nutrients. However, farmers are applying fertilizers even at grain development stage also. In addition, there is no separate fertilizer scheduling for maize under drip irrigation and at present, farmers are following NPK soil application recommendations to fertigation also. Keeping these in view the present project is proposed to standardize the nitrogen fertigation schedules in *rabi* maize of Andhra Pradesh.

Material and Methods

Field investigation was conducted during *rabi* season of 2019-20 at the Advanced Post Graduate Centre, Lam, Guntur. The experimental site was geographically situated at an altitude of 315 m above mean sea level, 16° 36´ N latitude and 80° 43´ E longitude and falls under Krishna Agro-climatic Zone of Andhra Pradesh, India.

The experiment was laid out in Randomized Block Design with twelve treatments and replicated thrice. The treatments were: T_1- 100% RDN through soil application under surface irrigation, T_2- 100% RDN through soil application under drip irrigation, T_3- 75% RDN through soil application under drip irrigation, T_4- 100% RDN through fertigation up to 60 DAS, T_5- 75% RDN through fertigation up to 60 DAS, T_6- 50% RDN through fertigation up to 60 DAS, T_7- 100% RDN through fertigation up to 75 DAS, T_8- 75% RDN through fertigation up to 75 DAS, T_9- 50% RDN through fertigation up to 75DAS, T_{10}- 100% RDN through fertigation up to 90 DAS, T_{11}- 75% RDN through fertigation up to 90 DAS, T_{12}- 50% RDN through fertigation up to 90 DAS.

The soil of the experimental site was clay with moderately alkaline (pH 8.4) in reaction, Low in organic carbon (0.48%) and available phosphorus (15 kg P_2O_5 ha^{-1}). Medium in available potassium (184 kg K_2Oha^{-1}) and low in available nitrogen (204 kg N ha^{-1}). The entire phosphorus and half of the potassium were applied as basal before sowing in the form of SSP and MOP respectively. Remaining half of the dose of potassium was applied at the time of flowering. Whereas, the recommended dose of fertilizer nitrogen (240 kg N ha^{-1}) was applied in the form of urea through drip fertigation from nine days after sowing as per the treatments. In soil applied treatments (T_1, T_2 and T_3), urea was applied $^1/_4$ RDN as basal, $^1/_4$ of RDN at 25 DAS, $^1/_4$ of RDN at 45 DAS, $^1/_4$ of RDN at 60 DAS. Irrigations were given based on pan evaporation replenishment at three days interval to the drip irrigated plots. The irrigation water was applied at 100% Epan to the filed on the basis of pan evaporation (PE) data measured from the USWB open pan evaporimeter. Whereas, in surface irrigation (T_1) treatment eight irrigations each with 6 cm depth were applied based on critical stage approach.

Results and Discussion

Higher maize plant height (Table.1) was found when 100% RDN was given as fertigation up to 60 DAS (T_4) when compared to fertigation of 50% RDN up to 90 and 75 DAS (T_{12} and T_9); however, it was found comparable with all the treatments except T_{12}, T_9 and T_3. Due to better availability of nutrients especially nitrogen that increased maize plant biomass which was positively related to plant height. Similar findings were reported by Ganesaraja *et al*., (2009) and Basava *et al*., (2012) [2, 1].

The data (Table.1) showed that drymatter production was significantly higher under the treatment 100% RDN through fertigation up to 90 DAS (T_{10}) recorded (20845 kg ha^{-1}) at harvest over all other treatments. Lowest drymatter production was noticed with the treatment receiving 75% RDN through soil application with drip irrigation (T_3) and it was found non-significant with all the treatments fertigated with 50% RDN. The superiority of treatment having the duration of fertigation up to 90 DAS with higher doses of nitrogen (240 kg N ha^{-1}) might be due to the fact that removal of nitrogen in maize would have continued during the post flowering stages of crop growth up to 90 DAS. Whereas, lower doses of nitrogen (75% and 50% RDN) fertigation might not have supported the crop growth and development. The results were in harmony with the findings of Shruthi and Sheshadri (2017) [7].

The plants that were fertigated with 100% RDN up to 90 DAS (T_{10}) resulted in earlier tasseling and silking (Table.1) and it was comparable with T_{10}, T_4, T_7 and T_5, T_8, T_{11}. The plants grown under 50% RDN in all the treatments delayed their tasseling. Similar results were found with Singh *et al*. (2014) and Jassal *et al*. (2017) [9, 3].

Yield attributes *viz*., cobs $plant^{-1}$, cob length and kernels per cob, test weight and cob weight (Table.2) were superior with 100% RDN through fertigation up to 90 DAS (T_{10}). Whereas, significantly lower yield attributes were recorded with treatments that were fertigated up to 60, 75 and 90 DAS with 50% RDN (T_6, T_9 and T_{12} respectively) compared to the treatment that received 100% RDN (T_1, T_4, T_7 and T_{10}).

The treatments that received 100% RDN up to 90 DAS (T_{10}) recorded higher kernel yield (Table.3) over rest of the treatments and followed by 100% RDN up to 75 and 60 DAS (T_7 & T_4 respectively). Significantly maximum kernel yield recorded with treatment T_{10}. Lower kernel yield was produced with 50% RDN up to 75 and 60 DAS (T_9 & T_6). Surface irrigation with 100% RDN soil application (T_1) was found comparable with T_7, T_4 and T_{11}; however, found inferior to T_{10} in kernel yield production. Nitrogen application with more number of splits provides an additional source of nitrogen for a increased rate of photosynthesis and transport of photo-assimilates during grain filling stage. Adequate nutrients that were supplied created more conducive environment for the roots to absorb the nutrients more effectively. These results are in agreement with those obtained by Singh *et al*. (2007), Mehta *et al*. (2011) and Mallareddy *et al*. (2012) [8, 5, 4].

With increase in application of N, stover yield (Table.3) of maize increased; however, application of either 100% or 75% RDN through fertigation does not effect stover yield. From the table it was apparent that the highest stover yield produced in the treatment receiving 100% RDN through fertigation up to 90 DAS (T_{10}) was found comparable with all other treatments, except, for the treatments receiving 75% RDN through soil application under drip irrigation (T_3) and 50% RDN through fertigation up to 75 DAS (T_9). Increased growth attributes at higher rates of nitrogen application might increase stover yield. These results are in accordance with the findings of Tyagi *et al*. (1998) [11] and Padmaja *et al*. (1999).

Harvest index (Table.3) among all the treatments were non-significant with each other. Treatments that received 100% RDN fertigation (T_{10} & T_7) observed higher values of harvest index, whereas the lower values of harvest index were observed with 50% RDN up to 60 DAS (T_6). It can be attributed to balanced increase in kernel and straw yields with proportionate nitrogen fertigations might have resulted in unchanged harvest index.

Table 1: Effect of fertigation duration and nitrogen levels in *rabi* maize on plant height (cm), dry matter accumulation (kg ha^{-1}) and days to 50% flowering

Treatments	Plant height at maturity (cm)	Dry matter production at maturity (kg ha^{-1})	50% tasseling	50% silking
T_1-100%RDN-soilapplication- surface irrigation	286.9	17821	60.3	67.3
T_2- 100% RDN-soil application - drip irrigation	277.8	15027	61.7	68.7
T_3- 75% RDN -soil application - drip irrigation	269.0	13816	62.0	69.3
T_4-100% RDN - fertigation -sowing to 60 DAS	293.5	18428	58.3	65.3
T_5-75% RDN - fertigation -sowing to 60 DAS	290.0	17867	58.7	66.0
T_6- 50% RDN - fertigation -sowing to 60 DAS	274.5	14529	62.3	69.7
T_7-100% RDN - fertigation - sowing to 75 DAS	291.9	17883	59.0	66.0
T_8-75% RDN - fertigation - sowing to 75 DAS	284.3	16302	59.7	66.7
T_9-50% RDN - fertigation - sowing to 75 DAS	262.9	14024	63.7	69.7
T_{10}-100% RDN - fertigation -sowing to 90 DAS	290.5	20845	56.7	63.7
T_{11}-75% RDN - fertigation - sowing to 90 DAS	280.9	16163	57.3	64.3
T_{12}-50% RDN - fertigation - sowing to 90 DAS	261.5	14435	63.7	70.0
S.Em±	7.47	556.41	0.85	0.84
CD (p=0.05)	22.1	1642.4	2.5	2.5
CV %	4.6	5.9	2.4	2.2

Table 2: Effect of fertigation duration and nitrogen levels on yield attributes of *rabi* maize

Treatments	Number of cobs $plant^{-1}$	Cob length (cm)	100 kernel weight (g)	No. of kernels cob^{-1}	Cob weight (g)
T_1- 100% RDN - soil application - surface irrigation	1.2	13.4	28.3	477.1	213.3
T_2- 100% RDN - soil application -drip irrigation	1.2	12.9	27.5	431.9	200.0
T_3- 75% RDN - soil application - drip irrigation	1.1	12.1	27.0	429.7	193.3
T_4-100% RDN - fertigation -sowing to 60 DAS	1.1	13.7	28.4	517.2	220.0
T_5-75% RDN - fertigation -sowing to 60 DAS	1.1	12.0	27.9	429.6	203.3
T_6- 50% RDN - fertigation -sowing to 60 DAS	1.0	11.8	26.4	385.6	173.3
T_7-100% RDN - fertigation - sowing to 75 DAS	1.3	13.8	28.8	517.4	223.3
T_8-75% RDN - fertigation - sowing to 75 DAS	1.1	12.3	27.8	469.3	201.3
T_9-50% RDN - fertigation - sowing to 75 DAS	1.1	11.6	25.9	384.0	173.3
T_{10}-100% RDN - fertigation -sowing to 90 DAS	1.5	14.1	30.9	522.9	243.3
T_{11}-75% RDN - fertigation - sowing to 90 DAS	1.3	13.3	27.6	508.5	220.0
T_{12}-50% RDN - fertigation - sowing to 90 DAS	1.0	11.3	26.6	389.1	176.7
S.Em±	0.09	0.61	0.87	31.22	14.33
CD (p=0.05)	0.3	1.8	2.6	92.2	42.3
CV %	13.0	8.3	5.4	11.9	12.2

Table 3: Effect of fertigation duration and nitrogen levels on kernel yield, stover yield and harvest index of *rabi* maize

Treatments	Kernel yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)
T_1- 100% RDN - soil application - surface irrigation	6806	8663	44.2
T_2- 100% RDN - soil application –drip irrigation	6271	8256	43.0
T_3- 75% RDN - soil application - drip irrigation	5947	7870	43.0
T_4-100% RDN - fertigation -sowing to 60 DAS	6975	8976	43.7
T_5-75% RDN - fertigation -sowing to 60 DAS	6034	8539	41.4
T_6- 50% RDN - fertigation -sowing to 60 DAS	5108	7948	39.1
T_7-100% RDN - fertigation - sowing to 75 DAS	7361	8693	45.9
T_8-75% RDN - fertigation - sowing to 75 DAS	6739	8513	44.2
T_9-50% RDN - fertigation - sowing to 75 DAS	5098	6867	42.7
T_{10}-100% RDN - fertigation -sowing to 90 DAS	7814	9105	46.2
T_{11}-75% RDN - fertigation - sowing to 90 DAS	6914	8374	45.2
T_{12}-50% RDN - fertigation - sowing to 90 DAS	5633	7937	41.5
S.Em±	296.82	399.43	1.79
CD (p=0.05)	876	1179	NS
CV %	8	8	7.1

Conclusions

The study revealed that at 90 DAS, plant height was significantly higher with T_4, that fertigated 100% N up to 60 DAS over other treatments; however, it was found comparable with that of fertigation up to 75 and 90 DAS. The highest drymatter production at harvest and earlier flowering was noted with the treatment fertigated with 100% RDN up to 90 DAS (T_{10}) which was higher over all other treatments. Significantly higher kernel yield and yield parameters were noticed with the treatments, that received 100% RDN through fertigation up to 90 DAS (T_{10}) followed by 75 DAS and 60 DAS (T_7 & T_4) over that of 50% RDN (T_9, T_6 & T_{12}) and 75% RDN with fertigation and soil application (T_5 & T_3 respectively). Higher yield and yield attributes in when 100% N fertigated up to 90 DAS shows that maize might be utilizing N even during post flowering periods also. However, there was no significant differences among the treatments fertigated 100% RDN up to 60, 75 and 90 DAS. Hence, it can be concluded that maize takes most of its nitrogen up to flowering periods, and whenever, nitrogen is deficient during this period, maize might take nitrogen even after flowering and grain formation phase.

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