The Pharma Innovation Journal 2023; 12(10): 242-246

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(10): 242-246

www.thepharmajournal.com
Received: 15-08-2023
Accepted: 18-09-2023

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Nutrient uptake in rabi maize as affected by different fertigation 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 NPK uptake 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. Nitrogen uptake in maize kernel and stover were significantly more in the treatment fertigated with 100% RDN up to 90 DAS (T_{10}). The uptake of phosphorous in maize kernel and stover were significantly higher with the treatment receiving 100% RDN through soil application under surface irrigation (T_1) when compared to all other treatments. Potassium uptake in maize kernel was significantly superior with the treatment 100% RDN through fertigation up to 90 DAS (T_{10}) over all other treatments. However, at harvest, application of 100% RDN through soil under surface irrigation (T_1) recorded significantly the highest uptake of potassium in stover over all other treatments.

Keywords: RDN-recommended dose of nitrogen, surface irrigation, drip irrigation, drip fertigation

1. Introduction

Maize is one of the widely grown grain crops 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) [16].

Among major plant nutrients, nitrogen is an important plant nutrient that is usually limited in crop growth because of losses like leaching, volatilization and denitrification; and because of these losses, its utilization efficiency decreases considerably in conventional practices. However, frequent and periodic split applications of fertilizer reduce N losses and improves nitrogen use efficiency. Drip fertigation, together with split applications of nitrogen fertilizer not only improves nitrogen use efficiency *via* application of fertilizer to the active root zone of crops but also decreases the groundwater pollution owing to the high homogeneity of nitrogen application. Studies illustrated the great potential of using fertigation for maize production. However, to what extent the nitrogen application rate can be further decreased by drip fertigation is still a question that needs to be addressed.

2. 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 field 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.

3. Results and Discussion

3.1 Nitrogen uptake (kg ha^{-1}) in maize at different crop growth stages as influenced by different fertigation levels

Nitrogen uptake in kernel was significantly superior in the treatment fertigated with 100% RDN up to 90 DAS (T_{10}) when compared to rest of the treatments; however, it was at par with the treatment fertigated with 100% RDN up to 75 DAS (T_7). N uptake with the treatments 50% RDN up to 60, 75 and 90 DAS (T_6, T_9 & T_{12}) recorded minimum compared with the rest of the treatments. Surface irrigation with 100% RDN soil application (T_1) was found at par with T_7, T_8, T_4 and T_{11}; however, it was found inferior to T_{10} in nitrogen uptake. Similarly drip irrigation with 100 % RDN soil application (T_2) was found at par with the treatments T_4, T_{11}, T_1 and T_8 and found inferior to T_{10} and T_7 in increasing the nitrogen uptake.

At 60 DAS, the highest uptake of nitrogen in stover noticed with the treatment fertigated with 100% RDN up to 60 DAS (T_4) was on a par with the treatment that received 100% RDN up to 75 DAS (T_7). However, there was no significant difference among the treatments T_7, T_5 and T_1. Whereas, lower uptake of nitrogen was observed with the treatments fertigated with 50% RDN up to 90 and 75 DAS (T_{12} and T_9), 75% RDN through soil application under drip irrigation (T_3) and 50% RDN through fertigation up to 60 DAS (T_6).

At 90 DAS, nitrogen uptake was significantly high with the treatments fertigated with 100% RDN up to 90 and 75DAS (T_{10} and T_7) over all other treatments. However, the differences among the treatments T_{10}, T_7 and T_4 were not significant. Whereas, the lower uptake of nitrogen was seen with the treatment fertigated with 50% RDN up to 90 and 75 DAS (T_{12} and T_9), 75% RDN through soil application under drip irrigation (T_3) and 50% RDN through fertigation up to 60 DAS (T_6).

Similarly, at harvest the significantly higher uptake of nitrogen recorded with the treatment 100% RDN through fertigation up to 90 DAS (T_{10}) was on par with the treatment fertigated with 100% RDN up to 75 DAS (T_7). The differences in N uptake among the treatments T_7, T_4, T_8 and T_1 were not significant. Whereas, minimum nitrogen uptake was noticed with the treatments receiving fertigation with 50% RDN up to 60 and 75 DAS (T_6 and T_9), fertigation with 75% and 50% RDN up to 90 DAS (T_{11} and T_{12}).

Nitrogen is an important constituent of all protein within the corn plant and it is needed in high quantities. Maize plant takes most of its nitrogen between sowing and flowering; and then it will be remobilized into sink from all parts of the plant. However, when nitrogen is deficient during this period plant will to continue take nitrogen from soil even during post flowering period also. In the present experiment the higher nitrogen uptake in grain when fertigated during post flowering periods will substantiate this reason. Similar observation was also reported by Aziiba *et al*. (2019) who stated that "maize hybrids with delayed senescence have a greater ability to take up N during the grain-filling period since continued leaf activity stimulates uptake of N. During the grain-filling period, a decline in N supply decreases drymatter partitioning to grain. Maize genotypes with longer stay-green maintain leaf chlorophyll for a greater duration, which can increase grain yield by 10% to 12%".

3.2 Phosphorous uptake (kg ha^{-1}) in maize at different crop growth stages as influenced by different fertigation levels

Data in respect to phosphorous uptake in maize kernels as influenced by application of different rates of nitrogen fertigation levels at different stages of crop growth was given in the Table 1. From the data it was clear that uptake of phosphorous has significant difference with varying fertigation levels at different stages of crop growth.

The uptake of phosphorous in maize kernels was significantly higher with the treatment that received 100% RDN through soil application under surface irrigation (T_1) when compared to all other treatments. The treatment receiving 100% RDN up to 60 DAS (T_4) recorded higher uptake of phosphorous next to T_1; however, it was on par with the treatments T_{10} (100% RDN through fertigation up to 90 DAS), T_2 and T_3 (100% and 75% RDN through soil application under drip irrigation respectively). Whereas, the treatments fertigated with 75% RDN up to 60 DAS (T_5) registered significantly reduced amount of phosphorous uptake in kernel compared to the rest of the treatments.

Data pertaining to uptake of phosphorous in stover as affected by different fertigation levels was presented in Table 3. At 60 DAS, significantly higher uptake of phosphorous was noticed with the treatment received 100% RDN through soil application under surface irrigation (T_1) compared to the rest of the treatments; however, it was found at par with the treatment receiving 75% RDN through fertigation up to 60 DAS (T_5). The differences among the treatments T_5, T_4, T_{11} and T_{10} were comparable with each other; and they were found significantly superior to all the remaining treatments. Whereas, the lower P uptake was found with the treatments that received 50% RDN up to 75, 60 and 90 DAS (T_9, T_6 and T_{12} respectively).

Phosphorous uptake at 90 DAS was significantly higher with the treatment that received 100% RDN through soil application under surface irrigation (T_1) over all other treatments. It was followed by the treatment that received 100% RDN through fertigation up to 60 DAS (T_4) and found at par with the treatment T_2. The lower uptake of phosphorous observed with 75% RDN through fertigation up to 75 DAS (T_8) was comparable with the treatments fertigated with 50% RDN up to 90 and 60 DAS (T_{12} and T_6)

Similarly, at harvest, the highest phosphorous uptake noticed with the treatment 100% RDN through soil application under surface irrigation (T_1) was significantly superior to the rest of the treatments. It was followed by the treatments that received fertigation of 100% RDN up to 90 and 60 DAS (T_{10} and T_4), 100% RDN through soil application with drip irrigation (T_2) and 100% RDN through fertigation up to 75 DAS (T_7). Whereas, the phosphorous uptake was minimum with the treatment receiving 50% RDN through fertigation up to 60 and 75 DAS (T_6 and T_9), 75% RDN through fertigation up to 75 and 90 DAS (T_8 and T_{11}).

In general, maize accumulates phosphorus throughout the growing season until maturity, with maximum uptake between third and sixth week of growth. At maturity, 75% of the total phosphorus of the above ground parts translocate to grain (Sayre, 1948) [14]. Results clearly indicated that higher the quantity of applied nitrogen, more is the effective utilization of soil and applied phosphorus. William Frederick Bennett (1958) [3] concluded in his book that there are three most generally listed as reasons for increased phosphorus uptake in the presence of nitrogen are (a) the increased solubility of phosphorus due to the presence of nitrogen fertilizers (b) an increased ramification of the root system of the plant, thus coming into contact with more soil phosphorus and (c) physiological stimulation of the plant by applied nitrogen, resulting in a greater phosphorus need and subsequent uptake.

Interestingly surface irrigation treatment T_1 with 8 irrigations showed a significant improvement in P uptake in maize kernel and stover as well, which might be due to increased P distribution and mobility in to soil profile due to high rate irrigation. Several studies have examined that proper irrigation management with long-term flood irrigation increased P transfer through soil profiles (Sharpley *et al*., 2001 and Condron *et al*., 2006) [15, 4]. Numerous studies have pointed that a greater P mobility and availability that improved the P conversion in the internal part of plant due to relatively high-water content under frequent irrigations by enhancing root–shoot ratio and root elongation (Bar-Yosef *et al*., 1989 and Hinsinger *et al*., 2003) [2, 3]. Liu *et al*. (2017) [11] reported that the greatest total phosphorus and available phosphorus contents were obtained within the upper soil layers in furrow irrigation compared to surface drip irrigation (SUR) and subsurface drip irrigation (SDI) in 0 to 60 cm soil zone.

3.3 Potassium uptake (kg ha^{-1}) in maize at different crop growth stages as influenced by different fertigation levels

From the data presented in the table, it showed that phosphorous uptake in maize kernel was significantly superior with the treatment 100% RDN through fertigation up to 90 DAS (T_{10}) over all other treatments. It was followed by the treatment fertigated with 100% RDN through fertigation up to 75DAS (T_7) which was at par with the treatments fertigated with 100% RDN up to 60 DAS (T_4) and 100% RDN through soil application under surface irrigation (T_1). Whereas, the uptake of phosphorous was minimum with the treatments fertigated with 50% RDN up to 60 and 90 DAS (T_6 and T_{12}) and 75% RDN through soil application under drip irrigation (T_3).

The uptake of potassium at 60 DAS was also significantly higher with treatment receiving 100% RDN through soil application under surface irrigation (T_1) compared with the rest of the treatments. It was followed by the treatments that received 100% RDN through fertigation up to 90 DAS (T_{10}) and 50% RDN through fertigation up to 75 DAS (T_9) and these two treatments were found with higher K uptake in stover compare to the remaining treatments. Whereas, the lowest uptake of potassium by stover was seen with the treatment receiving 50% RDN through fertigation up to 90 DAS (T_{12}) which showed comparable results with the treatments T_5, T_3, T_8, T_6 and T_7.

At 90 DAS, the uptake of potassium recorded with the treatment that received 100% RDN through soil application under surface irrigation (T_1) was on a par with the treatment received 100% RDN through fertigation up to 90 DAS (T_{10}). The differences observed in K uptake between T_{10} and T_7 were also not significant. Whereas, the lower uptake of potassium was observed with the treatment fertigated with 50% RDN up to 90 DAS (T_{12}), 75% RDN through soil application with drip irrigation (T_3) and 50% RDN through fertigation up to 75 DAS (T_9).

At harvest, application of 100% RDN through soil under surface irrigation (T_1) showed significantly higher uptake of potassium over all other treatments; and it was followed by the treatment fertigated with 75% RDN up to 75 DAS (T_8). However, there were no significant differences in the uptake of potassium among the treatments T_8, T_{11}, T_{10}, T_2, T_3 and T_4. Whereas, the lower K uptake noticed with the treatment received 75% RDN through fertigation up to 60 DAS (T_5) was on a par with the treatment fertigated with 50% RDN up to 90 DAS (T_{12})

Based on the results of the previous studies, the increase of N, P, and K % in maize plants may be attributed to increasing of soil moisture. As soil moisture content increased solubility and mobility of N, P and K are increased (Othman-Sanaa *et al*., 2005; Ibrahim and Kandil 2007; Eissa and Ahmed 2016; Eissa *et al*., 2016) [12,, 9, 5, 6]. Deficit irrigation had a negative effect on the uptake of N, P, and K by maize plants (Pascale *et al*., 2001; Karandish and Shahnazari 2016) [13, 10].

Table 1: N, P, K (kg ha^{-1}) uptake in maize kernels at harvest as influenced by different fertigation levels

Treatments	N uptake	P uptake	K uptake
T_1- 100% RDN - soil application - surface irrigation	92.2	32.6	63.4
T_2- 100% RDN - soil application - drip irrigation	84.2	20.6	56.5
T_3- 75% RDN - soil application - drip irrigation	75.7	20.1	43.6
T_4-100% RDN - fertigation -sowing to 60 DAS	95.2	22.9	65.0
T_5-75% RDN - fertigation -sowing to 60 DAS	74.5	10.5	46.2
T_6- 50% RDN - fertigation -sowing to 60 DAS	56.6	14.8	35.1
T_7-100% RDN - fertigation - sowing to 75 DAS	104.4	19.1	72.6
T_8-75 % RDN - fertigation - sowing to 75 DAS	99.6	16.6	61.7
T_9-50% RDN - fertigation - sowing to 75 DAS	63.3	15.2	45.2
T_{10}-100% RDN - fertigation -sowing to 90 DAS	116.8	22.5	82.7
T_{11}-75% RDN - fertigation - sowing to 90 DAS	93.5	15.5	61.2
T_{12}-50% RDN - fertigation - sowing to 90 DAS	64.7	18.2	43.4
SEm±	4.54	1.16	3.40
CD (p=0.05)	13.4	3.4	10.0
CV %	9.2	10.5	10.4

Table 2: Nitrogen uptake (kg ha^{-1}) in maize at different stages of crop growth as influenced by different fertigation levels

Treatments	60 DAS	90 DAS	At harvest
T_1- 100% RDN - soil application - surface irrigation	176.7	183.0	83.4
T_2- 100% RDN - soil application -drip irrigation	152.4	172.3	80.0
T_3- 75% RDN - soil application - drip irrigation	131.7	154.5	68.6
T_4-100% RDN - fertigation -sowing to 60 DAS	215.5	223.0	91.2
T_5-75% RDN - fertigation -sowing to 60 DAS	180.7	192.2	75.1
T_6- 50% RDN - fertigation -sowing to 60 DAS	140.4	162.0	51.5
T_7-100% RDN - fertigation - sowing to 75 DAS	208.5	231.6	96.8
T_8-75 % RDN - fertigation - sowing to 75 DAS	168.5	195.5	91.1
T_9-50% RDN - fertigation - sowing to 75 DAS	124.9	152.5	58.8
T_{10}-100% RDN - fertigation -sowing to 90 DAS	175.0	235.9	106.9
T_{11}-75% RDN - fertigation - sowing to 90 DAS	155.6	192.2	58.8
T_{12}-50% RDN - fertigation - sowing to 90 DAS	114.9	147.6	59.2
SEm±	11.29	10.20	5.06
CD (p=0.05)	33.3	30.1	14.9
CV %	12.1	9.5	11.4

Table 3: Phosphorous uptake (kg ha^{-1}) in maize at different crop growth stages as influenced by different fertigation levels

Treatments	60 DAS	90 DAS	At harvest
T_1- 100% RDN - soil application - surface irrigation	28.3	44.5	34.7
T_2- 100% RDN - soil application - drip irrigation	17.0	26.2	22.4
T_3- 75% RDN - soil application - drip irrigation	19.0	17.9	16.1
T_4-100% RDN - fertigation -sowing to 60 DAS	24.1	30.1	23.2
T_5-75% RDN - fertigation -sowing to 60 DAS	25.4	25.3	18.2
T_6- 50% RDN - fertigation -sowing to 60 DAS	14.5	17.4	12.1
T_7-100% RDN - fertigation - sowing to 75 DAS	18.7	19.1	20.3
T_8-75 % RDN - fertigation - sowing to 75 DAS	18.8	15.5	15.3
T_9-50% RDN - fertigation - sowing to 75 DAS	13.8	20.6	13.9
T_{10}-100% RDN - fertigation -sowing to 90 DAS	23.3	22.2	24.3
T_{11}-75% RDN - fertigation - sowing to 90 DAS	23.7	23.2	15.9
T_{12}-50% RDN - fertigation - sowing to 90 DAS	14.5	15.6	19.4
SEm±	1.14	1.31	1.38
CD (p=0.05)	3.4	3.9	4.1
CV %	9.8	9.8	12.1

Table 4: Potassium uptake (kg ha^{-1}) in stover of maize at different stages of crop growth as influenced by different fertigation levels

Treatments	60 DAS	90 DAS	At harvest
T_1- 100% RDN - soil application - surface irrigation	124.2	187.8	248.6
T_2- 100% RDN - soil application - drip irrigation	79.9	111.4	173.8
T_3- 75% RDN - soil application - drip irrigation	64.4	87.2	169.2
T_4-100% RDN - fertigation -sowing to 60 DAS	81.3	137.1	163.9
T_5-75% RDN - fertigation -sowing to 60 DAS	60.8	106.8	122.8
T_6- 50% RDN - fertigation -sowing to 60 DAS	65.0	124.5	158.2
T_7-100% RDN - fertigation - sowing to 75 DAS	71.0	158.1	104.9
T_8-75 % RDN - fertigation - sowing to 75 DAS	64.6	136.6	194.9
T_9-50% RDN - fertigation - sowing to 75 DAS	100.9	104.4	162.5

T_{10}-100% RDN - fertigation -sowing to 90 DAS	104.4	163.9	177.8
T_{11}-75% RDN - fertigation - sowing to 90 DAS	80.9	137.1	192.5
T_{12}-50% RDN - fertigation - sowing to 90 DAS	54.4	80.6	142.8
SEm±	6.31	8.85	10.93
CD (p=0.05)	18.6	26.1	32.3
CV %	13.8	12.0	11.3

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