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Influence of Drip Fertigation on Maize Growth Parameters

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ABSTRACT

Field experiment was conducted during *kharif* 2018, *rabi* 2018-19 and *kharif* 2019 at Dr. NTR College of Agricultural Engineering, Bapatla, Andhra Pradesh to study the influence of drip fertigation on maize growth parameters. The experiment was laid out in split plot design consisting of three irrigation levels (0.6 ETc (I_1), 0.8 ETc (I_2) and 1.0 ETc (I_3)) and four nitrogen levels consisting of fertigation levels (80% RDN (N_1), 100% RDN (N_2), 120% RDN (N_3) and Manual application (N_4) on sandy clay loam soil. A drip fertigation system with venturi assembly was designed and fertigation date and quantity of nitrogen in each fertigation were calculated and applied. The results shown that, in all the seasons, the plant height at all the stages of observation, drip fertigation at 120% RDN (N_3) recorded tallest plant height followed by N_2, N_4 and N_1. The lowest days for maturity was observed in I_1 treatment followed by I_2 and I_3 during *kharif* 2018. During *rabi* 2018-19, the lowest days for maturity was observed in I_1 treatment followed by I_2 and I_3. During *kharif* 2019, the lowest days for maturity was observed in I_1 treatment followed by I_2 and I_3.

Keywords Drip fertigation, Days to maturity, Maize crop, Plant height.

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INTRODUCTION

Drip fertigation is particularly important for irrigated agriculture in sandy soils where large quantities of fertilizers should be applied to meet crop requirements and to prevent loss by leaching. It has been proved as one of the superior method for applying water and nutrients through the drip irrigation system.

Maize, scientifically known as *Zea mays*, is a staple food crop that plays a vital role in feeding the world's population. It is not only a major source of human consumption but also serves as livestock feed and a critical raw material for various industries. The height of maize plants and the duration of their growth, as measured by the days to maturity, are pivotal factors in determining crop productivity and overall agricultural efficiency. Drip fertigation offers an efficient and sustainable solution to enhance both these parameters, revolutionizing the way maize is cultivated.

This investigation delves into the profound impact of drip fertigation on maize plant height and days to maturity. By combining the benefits of precise nutrient delivery and efficient water management, this irrigation technique has the potential to optimize the growth process of maize plants, resulting in healthier and more productive crops. In this study, we aim to explore the mechanisms behind these effects, shedding light on the physiological and environmental factors that contribute to the observed improvements in plant height and days to maturity.

Hence, the present study has been planned at Dr NTR College of Agricultural Engineering, Bapatla to study the influence of drip fertigation on maize growth parameters.

MATERIALS AND METHODS

Location of study area

The field experiment was conducted during *kharif* 2018, *rabi* 2018-19 and *kharif* 2019 under maize crop at the field irrigation laboratory, Department of Soil and Water Engineering, Dr. N. T. R. College of Agricultural Engineering, Bapatla, Guntur district of Andhra Pradesh State, India. Geographically the experimental site is located at latitude of 16^0 N and longitude of 88^0 E with an altitude of 6 m above mean sea level.

Design and installation of fertigation system

A drip irrigation system was designed for the experiment under maize crop. The lateral lines were spaced at 1.2 m interval. Inline drip emitters with 2.0 lph rated discharge were placed on the lateral line at a spacing of 30 cm. Each plot has three laterals with a net plot size of 8.0 m × 3.6 m (28.8 m^2). A total of 36 plots were designed for the entire field area of 1350 m^2 (54 × 25 m). A control valve was provided to each plot to regulate the operation of irrigation and fertigation. The installation of surface drip irrigation system in the experimental field was shown in Plate 1.

Design and layout of experiment

Field experiment was conducted with DEKALB DKC 8161 variety of hybrid maize under drip irrigation in split plot design consisting of three irrigation levels as main treatment and four fertigation levels as sub treatments with three replications during *kharif* 2018 and *rabi* 2018-19 at the field irrigation lab, Dr. NTR College of Agricultural Engineering, Bapatla. Maize seed was sown in a paired row system as plant to plant and row to row spacings were 20 cm and 40 cm, respectively [(80 cm + 40 cm) × 20 cm]. The layout of the each plot in the experiment was shown in Fig.1.

The treatments in the experiment are as follows:

Main plots: Irrigation levels (I)

I_1= 0.6 of the crop evapotranspiration
I_2= 0.8 of the crop evapotranspiration
I_3=1.0 of the crop evapotranspiration

Sub plots: Fertigation levels (N)

N_1= Drip fertigation with 80% of recommended dose of nitrogen (CF)

Plate 1. Installation of drip fertigation system with venturi assembly.

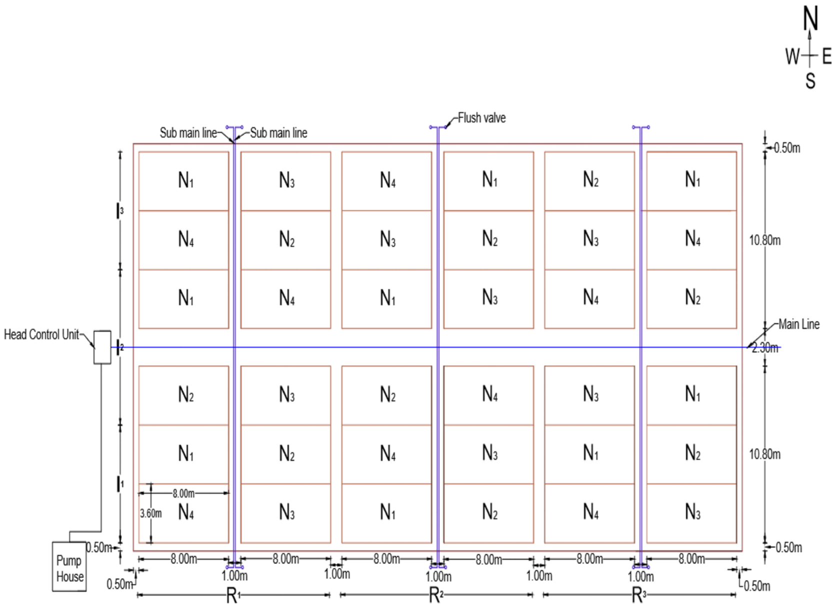

Fig. 1. Layout of the experimental field.

N_2= Drip fertigation with 100% of recommended dose of nitrogen (CF)

N_3= Drip fertigation with 120% of recommended dose of nitrogen (CF)

N_4= No drip fertigation (manual application) with 100% of recommended dose of nitrogen (CF) (CF= Conventional Fertilizers)

Manuring and fertilizer application

Farm yard manure (FYM) was applied to the field at the rate of 24.7 t ha^{-1} in the final ploughing operation. The fertilizers used in the experiment were urea, single super phosphate and muriate of potash. The recommended dose of fertilizers for *kharif* is 180:60:50 kg ha^{-1} NPK and 200:80:80 kg ha^{-1} NPK for *rabi* (Vyavasaya Panchangam, ANGRAU). Treatment wise requirement of N, P and K were estimated. P was applied as basal application manually and the 50% of K was applied in basal at the time of sowing and remaining 50% of K was applied at flowering stage manually. To optimize the fertigation scheduling, the estimated quantity of N for treatments was applied through venturi under drip fertigation at every 10 days interval. Standard cultural practices were adopted during both the crop-growing seasons. The fertigation schedule for maize crop grown seasons during *kharif* and *rabi* are shown in Tables 1 - 2.

Table 1. Fertigation schedule for *kharif* season.

Crop stages (Days after sowing, DAS)	Nitrogen quantity (%)	80% RDN (144 kg N.ha^{-1})	100% RDN (180 kg N ha^{-1})	120% RDN (216 kg N ha^{-1})
Vegetative stage (6-30 DAS)	25	36	45	54
Reproductive stage (31-60 DAS)	50	72	90	108
Maturity stage (61-75 DAS)	25	36	45	54
Total	100	144 kg N ha^{-1}	180 kg N ha^{-1}	216 kg N ha^{-1}

Table 2. Fertigation schedule for *rabi* season.

Crop stages (DAS)	Nitrogen quantity (%)	80% RDN (160 kg N ha^{-1})	100% RDN (200 kg N ha^{-1})	120% RDN (240 kg N ha^{-1})
Vegetative stage (6-30 DAS)	25	40	50	60
Reproductive stage (31-60 DAS)	50	80	100	120
Maturity stage (61-75 DAS)	25	40	50	60
Total	100	160kg N ha^{-1}	200kg N ha^{-1}	240kg N ha^{-1}

Plant growth parameters

Plant height

Plant height was measured from the base of the plant to the tip of the top leaf on every 10 days interval from the date of sowing for *kharif* 2018, *rabi* 2018-19 and *kharif* 2019. The height measurement was done for randomly selected three plants in every plot and the average plant height was expressed in cm.

Days to maturity

The number of days taken by 50% of the plants to exert completely the tassel and silk and to attain harvest maturity in maize was recorded for ten plants in each plot following the plant growth system of Schneider and Miller (1981).

RESULTS AND DISCUSSION

The results on the influence of drip irrigation regimes and fertilizer levels on growth parameters like plant height and days to maturity were discussed here under.

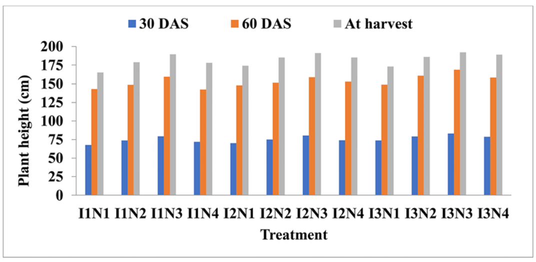

Fig. 2. Plant height at all stages of development during *kharif* 2018.

Plant height

Maize growth in terms of plant height at all stages of development showed significant variation due to different levels of irrigation regimes and nitrogen during three seasons. The data on plant height recorded at 30, 60 days after sowing (DAS) and at harvest stage for *kharif* 2018, *rabi* 2018-19 and *kharif* 2019 are presented in Figs. 2 - 4.

During *kharif* 2018, irrigation regimes as well as fertigation levels significantly influenced the plant height of maize at all stages of crop growth. Drip irrigation at 1.0 ETc (I_3) recorded tallest plant (83,

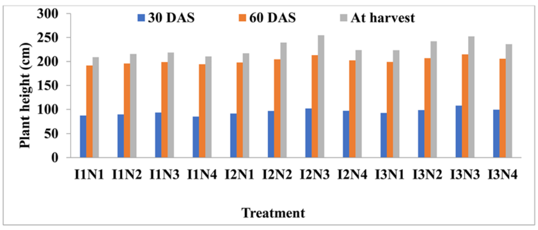

Fig. 3. Plant height at all stages of development during *rabi* 2018-19.

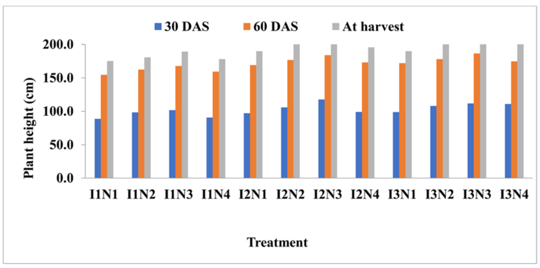

Fig. 4. Plant height at all stages of development during *kharif* 2019.

Table 3. Univariate analysis of variance to compare the means of plant height for *kharif* 2018.

Source	Type III sum of squares	df	Mean square	F	Sig
		Plant height at 30 DAS			
MAIN	184.722	2	92.361	6.192	.009
SUB	496.083	3	165.361	11.086	.000
MAIN * SUB	8.167	6	1.361	.091	.996
Total	688.972	11			
a. R squared = .752 (Adjusted R squared = .518)					
		Plant height at 60 DAS			
MAIN	734.000	2	367.000	18.461	.000
SUB	1200.972	3	400.324	20.137	.000
MAIN * SUB	176.444	6	29.407	1.479	.241
Total	2111.416	11			
a. R squared = .865 (Adjusted R Squared = .737)					
		Plant height at harvest			
MAIN	343.056	2	171.528	6.384	.008
SUB	1866.083	3	622.028	23.149	.000
MAIN * SUB	78.500	6	13.083	.487	.810
Total	2287.639	11			
a. R squared = .838 (Adjusted R squared = .685)					

169, 192 cm) at 30 DAS, 60 DAS and at harvest stage followed by drip irrigation at 0.8 ETc (80, 161, and 191 cm). The lowest plant height was recorded at 0.6 ETc (68, 142, 165 cm) respectively. The analysis of Variance to compare the means of plant height (Table 3) for *kharif* 2018 showed that there is a significant difference between irrigation levels at 30 DAS, 60 DAS and at harvest (P = 0.009, 0.000 and 0.008). The Duncan test for comparing treatment means for main plots (Irrigation levels) of plant height at 30 DAS showed that I_3 treatment has significant difference, whereas I_1 and I_2 has on par effect. At 60 DAS I_1, I_2 and I_3 treatments have significant difference on plant height. At harvest I_1 treatment has significant difference, whereas I_2 and I_3 have on par effect.

The height of maize crop at all the stages showed a marked difference among different levels of nitrogen. At all the stages of observation, drip fertigation at 120% RDN (N_3) recorded tallest plant height followed by N_2, N_4 and N_1. Analysis of variance to compare the means of plant height (Table 3) for *kharif* 2018 showed that there is a significant difference between nitrogen levels at 30 DAS, 60 DAS and at harvest (P = 0.000, 0.00 and 0.00). The Duncan test for comparing treatment means for sub plots (nitrogen levels) of plant height at 30 DAS, 60 DAS and at harvest showed that N_1 and N_4 treatments showed significant difference, whereas N_2 and N_3 has on par effect.

The interaction effect between irrigation and fertigation levels did not influence the plant height significantly (P = 0.996. 0.241 and 0.810) at all the growth stages of maize during *kharif* 2018.

During *rabi* 2018-19, irrigation regimes as well as fertigation levels significantly influenced the plant height of maize at all stages of crop growth (Fig. 3). Drip irrigation at 1.0 ETc (I_3) recorded tallest plant height (108 and 215 cm) at 30 DAS and 60 DAS. At harvest stage it was highest in I_2 treatment (255 cm) followed by drip irrigation at 0.8 ETc (102, 213, and 252 cm). The lowest plant height was recorded at 0.6 ETc (87, 191 and 209 cm) respectively. The analysis of variance to compare the means of plant height (Table 4) for *rabi* 2018-19 showed that there

Table 4. Univariate analysis of variance to compare the means of plant height for *rabi* 2018-19.

Source	Type III Sum of squares	df	Mean square	F	Sig
		Plant height at 30 DAS			
MAIN	748.500	2	374.250	9.260	.002
SUB	531.194	3	177.065	4.381	.018
MAIN * SUB	103.056	6	17.176	.425	.853
Total	1382.75	11			
a. R Squared = .681 (Adjusted R squared = .379)					
		Plant height at 60 DAS			
MAIN	910.167	2	455.083	39.351	.000
SUB	753.639	3	251.213	21.722	.000
MAIN * SUB	72.944	6	12.157	1.051	.426
Total	1736.75	11			
a. R squared = .900 (Adjusted R squared = .805)					
		Plant height at harvest			
MAIN	4230.500	2	2115.250	72.408	.000
SUB	3293.889	3	1097.963	37.585	.000
MAIN * SUB	763.278	6	127.213	4.355	.007
Total	8287.667	11			
a. R squared = .942 (Adjusted R squared = .887)					

is a significant difference between irrigation levels at 30 DAS, 60 DAS and at harvest (P = 0.002, 0.000 and 0.000). The Duncan test for comparing treatment means for main plots (Irrigation levels) of plant height at 30 DAS and 60 DAS showed that I_1 treatment has significant difference, whereas I_2 and I_3 had on par effect. At harvest, I_1, I_2 and I_3 treatments had significant difference. This is similar to Santosh *et al.* (2017).

The height of maize crop at all the stages showed a marked difference among different levels of nitrogen. At all the stages of crop growth, drip fertigation at 120% RDN (N_3) recorded tallest plant height followed by N_2, N_4 and N_1. Analysis of variance to compare the means of plant height (Table 4) for *rabi* 2018-19 showed that there is a significant difference between nitrogen levels at 30 DAS, 60 DAS and at harvest (P = 0.018, 0.000 and 0.000). The Duncan test for comparing treatment means for sub plots (nitrogen levels) of plant height at 30 DAS showed that N_1, N_4 and N_2 had on par effect and also N_2 and N_3 had on par effect. At 60 DAS, N_1 and N_3 had significant difference whereas N_4 and N_2 had on par effect and at harvest stage, N_1, N_4, N_2 and N_3 treatments showed significant difference between the treatments.

The interaction effect between irrigation and fertigation levels did not influence the plant height significantly (P = 0.853 and 0.426) at 30 DAS and 60 DAS. At harvest stage, it showed significant difference (P=0.007).

During *kharif* 2019, irrigation regimes as well as fertigation levels significantly influenced the plant height of maize at all stages of crop growth. Drip irrigation at 1.0 ETc (I_3) recorded tallest plant height (186.3 and 214 cm) at 60 DAS and at harvest. At 30 DAS it was highest in I_2 treatment (117.7 cm) and on par with I_3 followed by drip irrigation at 0.8 ETc. The lowest plant height was recorded at 0.6 ETc (88.7, 154.7 and 175.0 cm) at different stages of crop growth. The analysis of variance to compare the means of plant height (Table 5) for *kharif* 2019 showed that there is a significant difference between irrigation levels at 30 DAS, 60 DAS and at harvest (P = 0.000, 0.000 and 0.000). The Duncan test for comparing treatment means for main plots (Irrigation levels) of plant height at 30 DAS, 60 DAS and at

Table 5. Univariate analysis of variance to compare the means of plant height for *kharif* 2019.

Source	Type III sum of squares	df	Mean square	F	Sig
		Plant height at 30 DAS			
MAIN	1050.000	2	525.000	12.913	.000
SUB	1154.889	3	384.963	9.468	.001
MAIN * SUB	293.778	6	48.963	1.204	.349
Total	2498.667	11			
a. R squared = .832 (Adjusted R squared = .674)					
		Plant height at 60 DAS			
MAIN	1991.722	2	995.861	22.557	.000
SUB	953.778	3	317.926	7.201	.002
MAIN * SUB	12.056	6	2.009	.046	.999
Total	2957.556	11			
a. R squared = .845 (Adjusted R squared = .698)					
		Plant height at harvest			
MAIN	3364.056	2	1682.028	51.696	.000
SUB	1863.667	3	621.222	19.093	.000
MAIN * SUB	120.167	6	20.028	.616	.715
Total	5347.89	11			
a. R squared = .928 (Adjusted R squared = .861)					

harvest stage showed that I_1 treatment has significant difference, whereas I_2 and I_3 had on par effect (Ghiyal and Bhatia 2017).

The height of maize crop at all the stages showed a marked difference among different levels of nitrogen. At all the stages of crop growth, drip fertigation at 120% RDN (N_3) recorded tallest plant height followed by N_2, N_4 and N_1. Analysis of variance to compare the means of plant height (Table 5) for *kharif* 2019 showed that there is a significant difference between nitrogen levels at 30 DAS, 60 DAS and at harvest (P = 0.001, 0.002 and 0.000). The Duncan test for comparing treatment means for sub plots (nitrogen levels) of plant height at 30 DAS and 60 DAS showed that N_3 had significant effect whereas N_1, N_4 and N_4, N_2 have on par effect. At harvest stage, N_1 and N_3 treatments showed significant difference between the treatments and N_2 and N_4 had shown on par effect.

The interaction effect between irrigation and fertigation levels did not influence the plant height significantly (P = 0.349, 0.999 and 0.715) at 30 DAS, 60 DAS and at harvest stage.

The availability of moisture under optimum level might have contributed to effective absorption and utilization of nutrients and better proliferation of roots resulting in better canopy growth. Better soil moisture condition may positively contribute for higher solubility and conductivity of nutrients which ultimately results into increased mass flow transport of nutrients. The frequent application of irrigation through drip at optimum level maintained most of the root zone with well aerated condition and at adequate soil moisture content that did not fluctuate between wet and dry extremes Selvakumar (2006) reported higher plant height of hybrid chilli under drip irrigation at 100% WRc compared to other drip irrigation levels. Crops irrigated with 75% WRc performed equally better to 100% irrigation regime for all the growth parameters. This indicates that the crops need was satisfied at 75% WRc itself. Better growth attributes with increased irrigation level also reported by Niveditha and Nagavani (2016) and Bibe *et al.* (2017).

Effect of fertigation levels on plant height at all

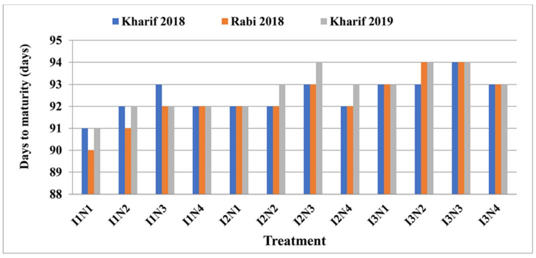

Fig. 5. Effect of drip fertigation on days to maturity of maize crop for three seasons.

observations indicated that 120 % RDF through drip showed maximum plant height than rest of the fertigation levels. This might be due to accelerated cell division and cell elongation as promoted by nitrogen. Similar results were reported by Sampathkumar and Pandian (2010), Muthukrishnan and Fanish (2011), Basava *et al.* (2012), Dai *et al.* (2019) and Ning *et al.* (2019).

Days to maturity

Significant advancement in the phenological stages was observed due to the influence of irrigation and fertigation levels. Days to maturity of maize was shown in Fig. 5.

During *kharif* 2018, the days to maturity of maize was found to be significantly influenced by both irrigation as well as fertigation levels. The results shown that lowest days for maturity was observed in I_1 treatment (91 days) followed by I_2 and I_3 (92 and 94 days). The analysis of variance to compare the means of days to maturity (Table 6) showed that there is a significant difference between irrigation levels (P = 0.000). The Duncan test for comparing treatment means for main plots (Irrigation levels) of days to maturity showed that I_3 treatment has significant difference, whereas I_1 and I_2 had on par effect.

In case of nitrogen levels, the lowest days to maturity for N_1 (91) followed by N_2 and N_3. The analysis of variance to compare the means of days to maturity (Table 6) showed that there is no significant difference between nitrogen levels (P = 0.001). The Duncan test for comparing treatment means for nitrogen plots of days to maturity showed that $N_1$and N_2, N_2 and N_4, N_4 and N_3 treatment has on par effect. The

Table 6. Univariate analysis of variance to compare the means of days to maturity for three seasons.

Source	Type III sum of squares	df	Mean square	F	Sig
		Kharif 2018			
MAIN	12.667	2	6.333	19.543	.000
SUB	8.222	3	2.741	8.457	.001
MAIN * SUB	2.444	6	.407	1.257	.325
Total	23.33	11			
a. R square = .806 (Adjusted R square = .622)					
		Rabi 2018-19			
MAIN	20.667	2	10.333	25.364	.000
SUB	5.556	3	1.852	4.545	.015
MAIN * SUB	5.111	6	.852	2.091	.105
Total	31.33	11			
a. R square = .817 (Adjusted R square = .644)					
		Kharif 2019			
MAIN	14.389	2	7.194	11.597	.001
SUB	5.639	3	1.880	3.030	.056
MAIN * SUB	0.944	6	.157	.254	.951
Total	20.97	11			
a. R square = .718 (Adjusted R square = .452)					

interaction effect between irrigation and fertigation levels have not influenced the days to maturity (P = 0.325) at harvest stage.

During *rabi* 2018-19, the days to maturity of maize was found to be significantly influenced by both irrigation as well as fertigation levels. The results shown that lowest days for maturity was observed in I_1 treatment (90 days) followed by I_2 and I_3 (92 and 94 days). The analysis of variance to compare the means of days to maturity (Table 6) showed that there is a significant difference between irrigation levels (P = 0.000). The Duncan test for comparing treatment means for main plots (Irrigation levels) of days to maturity showed that I_1, I_2 and I_3 treatment has significant difference on days to maturity.

In case of nitrogen levels, the lowest days to maturity for N_1 (90) followed by N_2 and N_3. The analysis of variance to compare the means of days to maturity (Table 6) showed that there is a significant difference between nitrogen levels (P = 0.015). The Duncan test for comparing treatment means for nitrogen plots of days to maturity showed that N_1, N_2, N_4 and N_2, N_4, N_3 treatment has on par effect. The interaction effect between irrigation and fertigation levels have not influenced the days to maturity (P = 0.105) at harvest stage.

During *kharif* 2019, the days to maturity of maize was found to be significantly influenced by both irrigation as well as fertigation levels. The results shown that lowest days for maturity was observed in I_1 treatment (91 days) followed by I_2 and I_3 (92 and 94 days). The analysis of variance to compare the means of days to maturity showed that there is a significant difference between irrigation levels (P = 0.001). The Duncan test for comparing treatment means for main plots (Irrigation levels) of days to maturity showed that I_1 treatment has significant difference, whereas I_2 and I_3 had on par effect. This is similar to the results of Fahad *et al.* (2014).

In case of nitrogen levels, the lowest days to maturity for N_1 (9_1) followed by N_2 and N_3. The analysis of variance to compare the means of days to maturity showed that there is no significant difference between nitrogen levels (P = 0.056). The Duncan test for comparing treatment means for nitrogen plots of days to maturity showed that N_1, N_2, N_4 and N_2,N_4, N_3 treatment has on par effect. The interaction effect between irrigation and fertigation levels have not influenced the days to maturity (P = 0.951) at harvest stage.

The phenological events were advanced when the irrigation regime and fertigation levels were decreased. Irrigation at 0.8 ETc and 100% fertigation stimulated the phonological events earlier than other treatments. Applying excess irrigation and fertilizers delayed the process of flowering, maturity. This shows negative relationship between crop growth with yield. Probably the yield becomes source limited in the early flowering treatments. Because of the insufficiency of source and transformation of reproductive phase, these treatments would not supply sufficient photosynthates for the developing sinks. In the treatments, where the source was not limiting, the availability of photosynthates would have been sufficient to put forth more number of flowers as to meet the demand of flowers produced thereby the yield would have been better. The obtained results are also in agreement with the findings of Basava *et al.* (2012), Singh *et al.* (2014) and Padmaja *et al.* (2016).

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