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Effect of Drip Fertigation on Dry Matter Production and Nitrogen Use Efficiency of Maize (*Zea mays*)

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ABSTRACT

Maize crop requires number of macro-nutrients and micro-nutrients for its growth and development. Nitrogen is one of the key nutrients needed for crop production; however, it is the most mobile and volatile and mainly exhausted nutrients due to its ability to exist in unusual forms and its easy leach ability. Lack of knowledge among the maize growers about the consequences of irrational use of water and nitrogen is mainly responsible for low water use efficiency and nitrogen use efficiency at field level. A field experiment was conducted during *kharif*, 2018 and *rabi*, 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. The rainfall received during crop growing period of *kharif* 2018 was 303.4 mm and 69.1 mm during *rabi*, 2018-19. The initial soil physical and chemical properties of the experiment site were calculated. The inline drip irrigation system was designed in split pot for the experiment with three irrigation levels (main plots) namely I_1= 0.6 of the crop evapotranspiration, I_2= 0.8 of the crop evapotranspiration and I_3=1.0 of the crop evapotranspiration and four nitrogen levels (sub plots) namely N_1= Drip fertigation with 80% of recommended dose of nitrogen (CF), N_2= Drip fertigation with 100% of recommended dose of nitrogen (CF), N_3= Drip fertigation with 120% of recommended dose of nitrogen (CF) and N_4= No drip fertigation (manual application) with 100% of recommended dose of nitrogen (CF) with three replications. The amount of crop water requirement of maize was estimated with computer software CROPWAT (v 8.0). The dry matter production (DMP) and nitrogen use efficiency (NUF) of maize were estimated for both the seasons. The results shown that during *kharif* 2018 the highest value of DMP was found in I_3 treatment (399.22 kg ha^{-1}) followed by I_2 and I_1 treatments (392.93 and 381.90 kg ha^{-1}). During *rabi* 2018-19, the value of DMP was found in I_3 treatment (574.62 kg ha^{-1}) followed by I_2 and I_1 treatments (565.29 and 446.38 kg ha^{-1}). The highest NUE of 32.88 kg ha^{-1} mm^{-1} was obtained in I_2N_1 treatment during *kharif* 2018. During *rabi* 2018-19, the highest NUE of 32.85 kg ha^{-1} mm^{-1} was in I_2N_2. The lowest NUE of 21.35 and 22.36 kg ha^{-1} mm^{-1} was obtained in I_1N_3 treatment during *kharif* 2018 and *rabi* 2018-19.

Introduction

Maize (*Zea mays*) well known as Queen of grains, also called corn from Graminae family. Maize can be grown on a variety of soils ranging from sandy to clay. But it performs best on well drained, aerated deep-loams and silt loams containing organic matter and nutrients. Maize may be raised on moderately acid soils, but the optimum pH range is from 6.5 to 7.5. Highly saline, acidic, alkaline and water logged soils should be avoided. The crop is cultivated in 9.47 M ha area with 28.72 Million Tonnes of production, 3030 kg per hectare productivity during 2017-18 (Source: Agricultural Statistics at a glance 2018).

Maize crop requires number of macro-nutrients and micro-nutrients for its growth and development. Nitrogen is one of the key nutrients needed for crop production; however, it is the most mobile and volatile and mainly exhausted nutrients due to its ability to exist in unusual forms and its easy leach ability (Palm *et al.*, 1997; Mugendi *et al.*, 2007; Mucheru-Muna *et al.*, 2014). Among several functions, nitrogen plays a key role on maize plants metabolism. Lack of knowledge among the maize growers about the consequences of irrational use of water and nitrogen is mainly responsible for low water use efficiency and nitrogen use efficiency at field level. The excess use and uneven application of irrigation and fertilizer application elevates the cost of cultivation and contributes to dreadful conditions of the water and soil quality. Therefore, there is an urgent need of efficient and judicious application of water resources and nutrients for sustainability of maize production.

Materials and Methods

Field experiments was conducted during *kharif*, 2018 and *rabi*, 2018-19 under maize crop at 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 6m above mean sea level. The rainfall received during crop growing period was 303.4 mm during *kharif*, 2018 and 69.1 mm during *rabi*, 2018-19. Soil samples were collected at every 15 cm layers from land surface till the soil depth of 90 cm using soil augur to characterize the soil. The collected soil samples were analysed in laboratory at Agricultural college, Bapatla for determining the physical properties of the soil such as Textural class, Hydraulic conductivity (cm/h), Bulk density, Field capacity, permanent wilting point and chemical properties like pH, EC, organic carbon and available nitrogen, phosphorous and potassium were shown in Table 1 & 2.

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 comprises three laterals with a spacing of 1.2 m distance with a net plot size of 8.0 × 3.6 m (28.8 m^2). A total of 36 plots were designed. A control valve was provided to each plot to regulate the operation of irrigation.

Experiments were conducted with DEKALB DKC 8161 variety of hybrid maize under drip irrigation in split plot design consisting of three irrigation levels (main plots) namely I_1= 0.6 of the crop evapotranspiration, I_2= 0.8 of the crop evapotranspiration and I_3=1.0 of the crop evapotranspiration and four nitrogen levels (sub plots) namely N_1= Drip fertigation with 80% of recommended dose of nitrogen (CF), N_2= Drip fertigation with

100% of recommended dose of nitrogen (CF), N_3= Drip fertigation with 120% of recommended dose of nitrogen (CF) and N_4= No drip fertigation (manual application) with 100% of recommended dose of nitrogen (CF) with three replications.

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 selected treatments was applied through venturi under drip fertigation at every 10 days interval.

The dry matter production and nitrogen use efficiency of maize were estimated for both the seasons. The statistical tool SPSS (v16.0) was used to find out the significance difference between the treatment means. One way ANOVA technique was used to compare the treatment means of dry matter production (DMP) and WUE at 5% level of significance. The Duncan Multiple Range Test (DMRT) was performed to find the significant grouping between means of DMP and NUE.

Results and Discussion

Effect of drip fertigation on dry matter production of maize

The observations recorded on dry matter production of maize at harvest stage are shown in Table 3 and depicting in Fig 1. During *kharif* 2018, the dry matter production of maize was found to be significantly influenced by both irrigation as well as fertigation levels. The results shown that highest value of DMP was found in I_3 treatment (399.22 kg ha^{-1}) followed by I_2 and I_1 treatments (392.93 and 381.90 kg ha^{-1}).

The analysis of variance to compare the means of DMP (Table. 4) for *kharif* 2018 showed that there is a significant difference between irrigation levels (P = 0.000). In case of nitrogen levels, DMP of 399.22 kg ha^{-1} was produced by N_3 treatment followed by N_2, N_4 and N_1. The analysis of variance to compare the means of DMP (Table. 4) showed that there is a significant difference between nitrogen levels (P = 0.000).

The Duncan test (Table 5 & 6) for comparing treatment means for main plots (Irrigation levels) of DMP at harvest stage showed that I_1 treatment has significant difference, whereas I_2 and I_3 have on par effect. Duncan test for comparing treatment means for nitrogen plots of DMP at harvest stage showed that N_1 treatment has significant difference, whereas N_4, N_2 and N_2, N_3 have on par effect. The interaction effect between irrigation and fertigation levels had influenced the DMP (P = 0.041) at harvest stage.

During *rabi* 2018-19, the dry matter production of maize was found to be significantly influenced by both irrigation as well as fertigation levels. The results shown that highest value of DMP was found in I_3 treatment (574.62 kg ha^{-1}) followed by I_2 and I_1 treatments (565.29 and 446.38 kg ha^{-1}). The analysis of variance to compare the means of DMP (Table. 4) for rabi 2018 showed that there is a significant difference between irrigation levels (P = 0.000). In case of nitrogen levels, highest DMP of 574.62 kg ha^{-1} was produced by N_3 treatment followed by N_2, N_4 and N_1. The analysis of variance to compare the means of DMP (Table. 4) showed that there is a significant difference between nitrogen levels (P = 0.000).

The Duncan test (Table 7 & 8) for comparing treatment means for main plots (Irrigation levels) of DMP at harvest stage showed that I_1 treatment has significant difference, whereas

I_2 and I_3 had on par effect. The Duncan test for comparing treatment means for nitrogen plots of DMP at harvest stage showed that N_4, N_1 and N_2, N_3 treatment had on par effect. The interaction effect between irrigation and fertigation levels had not influenced the DMP (P = 0.547) at harvest stage.

As the native soil was low in nitrogen, there was a good response to the excess fertilizer applied, coupled with optimum moisture availability which might have resulted in inducing growth. Rajasekaran (2007) reported higher DMP under 125 per cent RDF followed by 100 per cent in drip irrigated sugar beet. Bar-Yosef *et al.*, (1989) reported that subsurface fertigation hastened dry matter accumulation and affected carbohydrate partitioning between plant organs in a way that contributed to higher ear yield in corn. Vadivel *et al.*, (2001) and Singh and Sharma (1994) reported higher LAI and DMP when N rate was increased in maize.

Better growth of maize under drip might be attributed to better moisture availability, soil aeration and also crop did not experience stress during the crop growth period at 1.0 PE irrigation schedule.

This ultimately reflected better physiological activity in plant and there by increased plant height, and dry matter production per plant. Similarly findings were reported by Patel *et al.*, (2006), Bindhani *et al.*, (2008), Ganesaraja *et al.*, (2009), Muthukrishnan *et al.*, (2011), Mallareddy *et al.*, (2012) and Bibe *et al.*, (2017).

Table.1 Physical properties of the experimental soil

Soil depth from surface (cm)	Mineral content % mass			Textural class	Hydraulic conductivity (cm h^{-1})	Bulk density (g/cm^3)	Field capacity (% vol)	Permanent wilting point (% vol)
	Clay	Silt	Sand					
0-15	35	10	55	Sandy clay loam	0.94	1.37	21.48	6.73
15-30	35	10	55	Sandy clay loam	0.50	1.57	27.17	9.12
30-45	40	10	60	Sandy clay	0.46	1.53	28.24	10.56
45-60	35	5	60	Sandy clay loam	0.96	1.63	27.69	10.92
60-75	35	5	60	Sandy clay loam	0.96	1.63	27.73	11.61
75-90	30	5	65	Sandy clay loam	0.95	1.67	26.62	10.75

Table.2 Chemical properties of the experimental soil

Soil depth from surface (cm)	P^H	EC (ds m^{-1})	Organic carbon (%)	Available		
				N (Kg ha^{-1})	P (Kg ha^{-1})	K(Kg ha^{-1})
0-15	5.62	0.10	0.27	141.12	28.21	141.12
15-30	6.86	0.16	0.12	147.39	34.88	87.36
30-45	7.05	0.20	0.10	119.16	21.03	87.36
45-60	5.34	0.11	0.09	56.44	13.33	53.76
60-75	5.14	0.05	0.075	40.76	12.82	53.76
75-90	5.42	0.03	0.06	25.08	11.28	47.07

Table.3 Effect of drip fertigation on dry matter production (kg ha^{-1})

Treatment	Dry matter production (kg ha^{-1})	
	Kharif 2018	Rabi 2018
I1N1	344.37	404.55
I1N2	375.97	440.02
I1N3	381.90	446.38
I1N4	370.10	379.86
I2N1	382.77	528.58
I2N2	392.93	555.57
I2N3	392.21	569.86
I2N4	388.85	536.92
I3N1	381.76	536.03
I3N2	397.66	565.29
I3N3	399.22	574.62
I3N4	389.73	538.17

Table.4 Univariate Analysis of Variance to compare the means of dry matter production

Kharif 2018					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
MAIN	4121.002	2	2060.501	47.845	.000
SUB	2508.090	3	836.030	19.413	.000
MAIN * SUB	726.421	6	121.070	2.811	.041
Total	7355.513	11			
a. R Squared = .910 (Adjusted R Squared = .824)					
Rabi 2018-19					
MAIN	141560.198	2	70780.099	206.788	.000
SUB	13503.058	3	4501.019	13.150	.000
MAIN * SUB	1751.711	6	291.952	.853	.547
Total	156814.97	11			
a. R Squared = .963 (Adjusted R Squared = .928)					

Table.5 Duncan test for comparing treatment means for main plots (Irrigation levels) of Dry matter production for kharif 2018

Main plots	N	Subject for alpha 0.05	
		1	2
I_1	12	3.6809E2	
I_2	12		3.8919E2
I_3	12		3.9209E2
Sig.		1.000	0.293
Means for groups in homogeneous subsets are displayed. Based on observed means. The error term is Mean Square(Error) = 43.066.			

Table.6 Duncan test for comparing treatment means for sub plots ((Nitrogen levels) of Dry matter production for kharif 2018

Sub plots	N	Subject for alpha 0.05		
		1	2	3
N_1	9	3.6963E2		
N_4	9		3.8290E2	
N_2	9		3.8885E2	3.8885E2
N_3	9			3.9111E2
Sig.		1.000	.070	0.476

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 43.066.

Table.7 Duncan test for comparing treatment means for main plots (Irrigation levels) of Dry matter production for Rabi 2018

Main plots	N	Subject for alpha 0.05	
		1	2
I_1	12	4.1770E2	
I_2	12		5.4773E2
I_3	12		5.5353E2
Sig.		1.000	0.453

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 342.283.

Table.8 Duncan test for comparing treatment means for sub plots (Nitrogen levels) of Dry matter production for Rabi 2018

Sub plots	N	Subject for alpha 0.05	
		1	2
N_4	9	4.8498E2	
N_1	9	4.8972E2	
N_2	9		5.2029E2
N_3	9		5.3028E2
Sig.		.594	0.267

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 342.283.

Table.9 Effect of drip fertigation on nutrient use efficiency during crop seasons

Treatment	Kharif 2018			Rabi 2018-19		
	Yield(kg/ha)	Amount of nitrogen applied(kg/ha)	Nitrogen Use Efficiency	Yield(kg/ha)	Amount of nitrogen applied(kg/ha)	Nitrogen Use Efficiency
I1N1	4408	144	**30.61**	4870	160	**30.44**
I1N2	4600	180	**25.56**	5219	200	**26.10**
I1N3	4612	216	**21.35**	5367	240	**22.36**
I1N4	4196	180	**23.31**	4986	200	**24.93**
I2N1	4734	144	**32.88**	5143	160	**32.14**
I2N2	5118	180	**28.43**	6569	200	**32.85**
I2N3	6180	216	**28.61**	7720	240	**32.17**
I2N4	4846	180	**26.92**	6170	200	**30.85**
13N1	4621	144	**32.09**	5209	160	**32.56**
I3N2	5597	180	**31.09**	6394	200	**31.97**
I3N3	6212	216	**28.76**	7447	240	**31.03**
I3N4	4960	180	**27.56**	5903	200	**29.52**

Table.10 Univariate Analysis of Variance to compare the means of nitrogen use efficiency

Kharif 2018					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
MAIN	152.991	2	76.496	5.077E3	.000
SUB	201.181	3	67.060	4.451E3	.000
MAIN * SUB	39.973	6	6.662	442.151	.000
Total	394.145	11			
a. R Squared = .999 (Adjusted R Squared = .999)					
Rabi 2018					
MAIN	180.762	2	90.381	3.252E4	.000
SUB	47.498	3	15.833	5.696E3	.000
MAIN * SUB	86.778	6	14.463	5.203E3	.000
Total	315.038	11			
a. R Squared = 1.000 (Adjusted R Squared = .999)					

Table.11 Duncan test for comparing treatment means for main plots (Irrigation levels) of NUE for kharif 2018

Main plots	N	Subject for alpha 0.05		
		1	2	3
1	12	25.2075		
2	12		29.2100	
3	12			29.8750
Sig.		1.000	1.000	1.000
Means for groups in homogeneous subsets are displayed. Based on observed means. The error term is Mean Square(Error) = .015.				

Table.12 Duncan test for comparing treatment means for sub plots (Nitrogen levels) of NUE kharif 2018

Sub plots	N	Subject for alpha 0.05			
		1	2	3	4
4	9	25.9300			
3	9		26.2411		
2	9			28.3611	
1	9				31.8578
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = .015.

Table.13 Duncan test for comparing treatment means for main plots (Irrigation levels) of NUE for RABI 2018

Main plots	N	Subject for alpha 0.05		
		1	2	3
1	12	26.9233		
3	12		31.2675	
2	12			32.0008
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = .003.

Table.14 Duncan test for comparing treatment means for sub plots (Nitrogen levels) of NUE RABI 2018

Sub plots	N	Subject for alpha 0.05			
		1	2	3	4
3	9	28.5189			
4	9		29.7222		
2	9			30.3022	
1	9				31.7122
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = .003.

Fig.1 Effect of drip fertigation on dry matter production (kg ha^{-1}) of maize

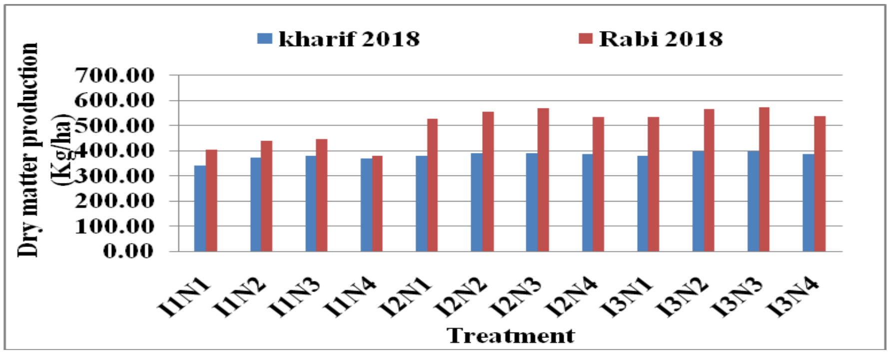
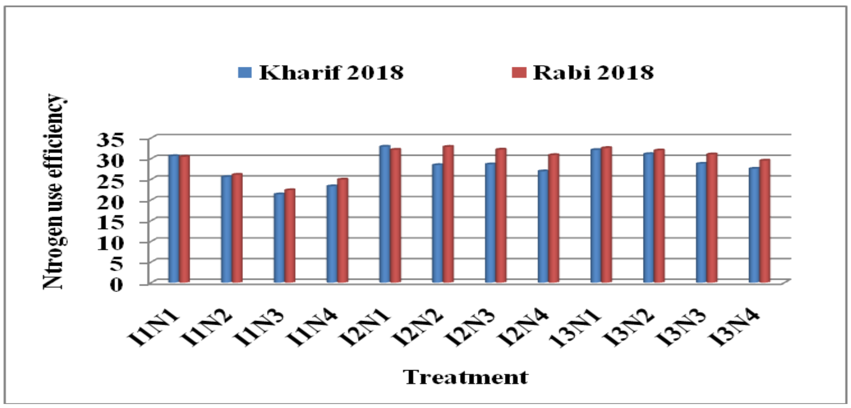


Fig.2 Treatment wise nitrogen use efficiency for crop seasons



Nitrogen use efficiency of maize crop

The data on nitrogen use efficiency of maize under drip irrigation for two seasons are furnished in the Table 9 and depicted in Fig 2. NUE varied due to irrigation regimes as well as fertilizer levels. The highest NUE of 32.88 kg ha^{-1} mm^{-1} was obtained in, I_2N_1 treatment during $_{kharif}$ 2018. During $_{rabi}$ 2018-19 the highest NUE of 32.85 kg ha^{-1} mm^{-1} was in I_2N_2. The lowest NUE of 21.35 and 22.36 kg ha^{-1} mm^{-1} was obtained in I_1N_3 treatment during *kharif* 2018 and *rabi* 2018-19.The analysis of variance to compare the means of NUE (Table 10) for main, sub and main Vs sub treatments showed that there is a significant difference between irrigation levels (P = 0.000) for *kharif* 2018 and *rabi* 2018-19 respectively.

The Duncan test for comparing treatment means of NUE showed that all the treatments for main plots (Irrigation levels) (Table 11&13) and sub plots (Nitrogen levels) (Table 12&14) have significant difference during *kharif* 2018 and *rab*i 2018-19 respectively.

Nutrients may be used very effectively when applied continuously through the irrigation system at rates not exceeding the requirements of the plants, which is in agreement with the results obtained earlier by Bar-Yosef and Sagiv, 1982; Miller *et al.*, 1981; Phene *et al.*, 1979 and Stark *et al.*, 1983.

Availability of adequate and optimum moisture under 0.8 ETc resulted in higher nutrient use efficiency and even with 1.0 Etc also. This proves the efficiency of drip fertigation system. Lower fertilizer dose (80 per cent RDN) through drip fertigation with greater nutrient use efficiencies was in line with the findings of Raman (1995); Singh *et al.*, (1989); Dangler and Locascio, (1990); Goyal *et al.*, (1985). Nitrogen uptake increased with N rate, but it is obvious that NUE decreased with increasing the N rate (Thompson and Doerge, 1996b; Stark *et al.*, 1983; Iqbal *et al.*, 2003).

In conclusion the drip fertigation led to a higher dry matter production with I_3N_3 treatment in both *kharif* 2018 and *rabi* 2018-19 seasons and higher NUE was obtained at I_2N_1 treatment during *kharif* 2018 season and I_2N_2 treatment in rabi 2018-19 season at coastal Andhra Pradesh. This results shows that the drip fertigation makes effective utilization of nitrogen under drip fertigated maize crop.

Application of research

This article has been prepared with the objective of giving information to the maize growers on dry matter production and nitrogen use efficiency in coastal region of Andhra Pradesh. The investigations of the research used for the purpose of proper planning of irrigation and fertigation schedule to achieve high nutrient use efficiency.

Abbreviations

mm – Millimeter, CF – Conventional Fertilizer, DMP – dry matter production, CROPWAT – Crop water requirement, SPSS - Statistical Package for the Social Sciences, ANOVA - Analysis Of Variance, DMRT - Duncan Multiple Range Test, NUE – Nutrient Use Efficiency.

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