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Research Article

EFFECT OF DEFICIT IRRIGATION THROUGH PRESSURIZED IRRIGATION SYSTEM ON MAIZE (*Zea mays*) GRAIN YIELD AND WATER USE EFFICIENCY

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Abstract: Water is critical resource in India for the development of agriculture, industry, power generation, livestock production and other activities in future. Lack of knowledge among the maize growers about the consequences of irrational use of water is mainly responsible for low water use efficiency at field level. A field experiment was conducted during *kharif*, 2018 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. The rainfall received during crop growing period of *kharif* 2018 was 303.4 mm and 537.5 mm during *kharif*, 2019. The initial soil physical and chemical properties of the experiment site were measured. 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 yield and water use efficiency of maize were estimated for both the seasons. During *kharif*, 2018 the highest grain yield of 6212 kg ha^{-1} was recorded in I_3 which was on par with I_2. The lowest grain yield of 4196 kg ha^{-1} was recorded at I_1. During *kharif*, 2019 the highest grain yield of 6857 kg ha^{-1} was recorded in I_2 which was on par with I_3. The lowest grain yield of 4458 kg ha^{-1} was recorded at I_1 (0.6 of the crop evapotranspiration). The highest WUE of 15.44 and 12.11 kg ha^{-1} mm^{-1} was obtained in I_2N_3 treatment during *kharif*, 2018 and *kharif*, 2019 respectively. The lowest WUE of 10.10and 7.65 kg ha^{-1} mm^{-1} was obtained in I_3N_1 treatment during *kharif*, 2018 and *kharif*, 2019 respectively.

Keywords: *Maize crop, Drip irrigation, Yield, Water use efficiency*

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Introduction

Water is most valuable gift of nature to the mankind and has been recognized as most important resource. It is becoming critical resource in India to the development of agriculture, industry, power generation, livestock production and other activities in future. Water shortage can be observed from the reality that per capita annual water availability has dropped from 5,177 m^3 in 1951 to 1,508 m^3 in 2014 and is prone to decrease further to 1,235 m^3 by 2050. The issue of water shortage may be tackled either by development of additional resources or improving the efficiencies of the available water. Particularly when water using for agriculture, inefficient management of water menaces the surroundings and increases the production cost, thereby reducing profitability and increasing the risk related with crop production. Irrational use of water for growing crops led to decrease the country's water use efficiency. Maize (*Zea mays*) well known as Queen of grains, also called corn from Graminae family. It is the principal one of the cereal crops of the world. Maize is the third ultimate important food grain in India after wheat and rice. The production and consumption of maize have been ascending in India. Maize crop is sensitive to both moisture stress and excessive moisture; hence irrigation regulation is required.

Lack of knowledge among the maize growers about the consequences of irrational use of water is mainly responsible for low water use efficiency at field level.

Materials and Methods

The field experiment was conducted during *kharif*, 2018 and *kharif*, 2019 in 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° N and longitude of 88° E with an altitude of 6 m above mean sea level. The rainfall received during crop growing period was 303.4 mm during *kharif*, 2018 and 537.5 mm during *kharif*, 2019. The initial soil physical and chemical properties of the experimental site were shown in [Table-1] & [Table-2].

A drip irrigation system was designed for the experiment in maize crop. The lateral lines were spaced at 1.2 m interval. Inline drip emitters with 2.0 I_{ph} 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.

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)	pH	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 *Amount of total water applied during crop seasons*

Month	Applied water (mm)			Rainfall during the month (mm)	Effective rainfall (mm)	Total water applied (mm)		
	I_3	I_2	I_1			I_3	I_2	I_1
kharif, 2018								
Jul-18	20.70	16.56	12.42	31.5	8.9	29.6	25.46	21.32
Aug-18	81.88	65.50	49.13	195.7	132.6	214.48	198.1	181.73
Sep-18	139.81	111.85	83.89	64.6	28.8	168.61	140.65	112.69
Oct-18	44.90	35.92	26.94	11.6	0	44.9	35.92	26.94
Total	287.29	229.83	172.38	303.4	170.3	457.58	400.13	342.67
kharif, 2019								
Jul-18	20.37	16.3	12.22	205.6	140.5	160.87	156.8	152.72
Aug-18	120.7	96.56	72.42	147.8	94.2	214.9	190.76	166.62
Sep-18	43.14	34.51	25.88	184.1	123.3	166.44	157.81	149.18
Oct-18	76.02	60.82	45.61	0	0	76.02	60.82	45.61
Total	260.23	208.19	156.13	537.5	358	618.23	566.18	514.14

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.

The crop water requirement of maize crop was estimated by using past 10 years weather data at experiment site with the help of computer software CROPWAT (v 8.0). The crop evapotranspiration demand was more during *kharif*, 2019 (455.5 mm) than *kharif*, 2018 (443.1 mm). The irrigation water was applied at every alternate day for all the treatments. The yield and water use efficiency of maize were estimated for both the seasons.

The statistical tool SPSS (v16.0) was used to find out the significant difference between the treatment means. One way ANOVA technique was used to compare the treatment means of yield and WUE at 5% level of significance. The Duncan Multiple Range Test (DMRT) was performed to find the significant grouping between means of yield and WUE.

Results and Discussion

The data on irrigation water applied to the maize crop through drip irrigation as per the treatment schedule and effective rainfall received during the crop periods are presented in [Table-3]. The quantity of irrigation water supplied through drip for I_1, I_2 and I_3 treatments was 172.38, 229.83, 287.29 mm during *kharif*, 2018 and 260.23, 208.19, 156.13 mm during *kharif*, 2019 respectively. The effective rainfall received during the cropping period was 170.3 and 358.0 mm during *kharif*, 2018 and *kharif* 2019. The total water used for I_1, I_2 and I_3 treatments was 342.67, 400.13, and 457.58 mm during *kharif*, 2018and 514.14, 566.18, and 618.23 mm during *kharif*, 2019 respectively.

Maize Grain Yield

Grain yield of maize was found to be significantly influenced by drip irrigation and fertigation levels. The results are shown in [Table-4] and depicted in [Fig-1]. Generally, the grain yield was increased when irrigation as well as fertilizer level increased. During *kharif*, 2018 the highest grain yield of 6212 kg ha^{-1} was recorded in I_3 (1.0 of the crop evapotranspiration) which was on par with I_2 (0.8 of the crop evapotranspiration). The lowest grain yield of 4196 kg ha^{-1} was recorded at I_1 (0.6 of the crop evapotranspiration). The analysis of variance to compare the means of grain yield [Table-5] for *kharif*, 2018 showed that there is a significant difference between irrigation levels (P = 0.000). During *kharif*, 2019 the highest grain yield of 6857 kg ha^{-1} was recorded in I_2 (0.8 of the crop evapotranspiration) which was on par with I_3 (1.0of the crop evapotranspiration). The lowest grain yield of 4458 kg ha^{-1} was recorded at I_1 (0.6 of the crop evapotranspiration).

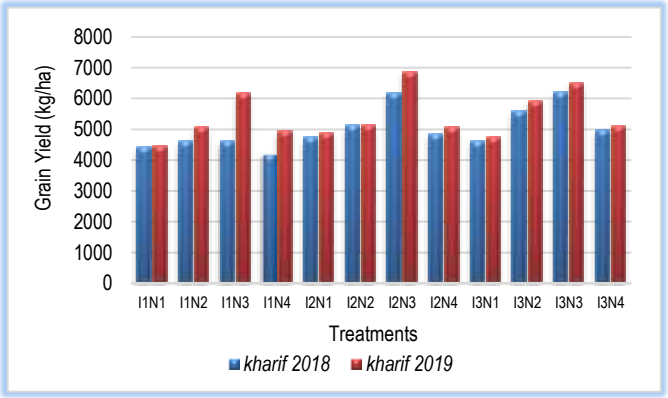

Fig-1 Treatment wise grain yield of the experiment for *kharif* 2018 and 2019

The Duncan test for comparing treatment means for main plots (Irrigation levels) of grain yield for *kharif* 2018 showed that I_1, I_2 and I_3 treatments had significant difference between the irrigation levels [Table-6].

Table-4 *Treatment wise maize grain yield for Kharif 2018 and 2019*

Treatments	Grain yield (kg/ha)							
	Kharif 2018				*Kharif 2019*			
	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
N_1	4408	4734	4621	4588	4458	4889	4732	4693
N_2	4600	5118	5597	5105	5051	5148	5902	5367
N_3	4612	6180	6212	5668	6165	6857	6487	6503
N_4	4196	4846	4960	4667	4943	5058	5084	5028
Mean	4454	5219.5	5347.5		5154	5488	5551	

Table-5 *Univariate Analysis of Variance to compare the means of grain yield*

Grain yield, *kharif*, 2018					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
MAIN	5602441.056	2	2801220.528	5.175E3	0
SUB	6638328.083	3	2212776.028	4.088E3	0
MAIN * SUB	2091563.167	6	348593.861	644.053	0
Total	14332332.31	11			
a. R Squared = .999 (Adjusted R Squared = .999)					
Grain yield, *kharif*, 2019					
MAIN	1091941.056	2	545970.528	1.023E3	0
SUB	1.670E7	3	5566993	1.043E4	0
MAIN * SUB	1248410.5	6	208068.417	389.824	0
Total	19040351.56	11			
a. R Squared = 1.000 (Adjusted R Squared = .999)					

The analysis of variance to compare the means of grain yield [Table-5] for *kharif*, 2019 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 grain yield showed that I_1, I_2 and I_3 treatments had significant difference between the irrigation levels [Table-7].

Table-6 *Duncan test for comparing treatment means for main plots (Irrigation levels) of grain yield for kharif 2018*

Main plots	N	Subject for alpha 0.05		
		1	2	3
I_1	12	4454		
I_2	12		5219.42	
I_3	12			5347.5
Sig.		1	1	1
Means for groups in homogeneous subsets are displayed.				
Based on observed means.				
The error term is Mean Square (Error) = 541.250.				

Table-7 *Duncan test for comparing treatment means for main plots (Irrigation levels) of grain yield for kharif 2019*

Main plots	N	Subject for alpha 0.05		
		1	2	3
I_1	12	5154.17		
I_2	12		5487.75	
I_3	12			5551.25
Sig.		1	1	1
Means for groups in homogeneous subsets are displayed.				
Based on observed means.				
The error term is Mean Square (Error) = 533.750.				

Amongst irrigation levels, 1.0 and 0.8 of the crop evapotranspiration (I_3 &I_2) recorded significantly higher values of above referred yield attributing characters over 0.6 of the crop evapotranspiration (I_1). This might be due to the water stress under low ETc which resulted in poor plant growth due to restriction imposed on nutrient translocation, photosynthesis and metabolic activities of plant system. All these above referred yield attributes were decreased with subsequent decrease in the level of irrigation.

These findings are in close conformity with those of Khan *et al*. (1996), Tyagi *et al*. (1998) and Bharti *et al*. (2007). Any stress during reproductive stage of the crop generally limits the partitioning of dry matter into reproductive tissue and will affect the grain yield of the crop. Increase in grain yield drip irrigation with higher level of irrigation schedules could be mainly due to improved soil moisture status in the upper soil layers throughout the crop growth period consequently higher plant relative water content and less negative leaf water potential. Similar findings are also reported by Pandey *et al*. (2000) [1], Viswanatha *et al*. (2002) [2] on, Bozkurt *et al*. (2011) [3] and Padmaja *et al*. (2016) [4] on maize crop.

Water use efficiency of maize crop

The data on water use efficiency of maize under drip irrigation for *kharif*, 2018 and 2019 are furnished in the [Table-8] and depicting in [Fig-2]. WUE varied due to irrigation regimes as well as fertilizer levels. The highest WUE of 15.44 and 12.11 kg ha^{-1} mm^{-1} was obtained in I_2N_3 treatment during *kharif*, 2018 and *kharif*, 2019 respectively. The lowest WUE of 10.10and 7.65 kg ha^{-1} mm^{-1} was obtained in I_3N_1 treatment during *kharif*, 2018and *kharif*, 2019 respectively.

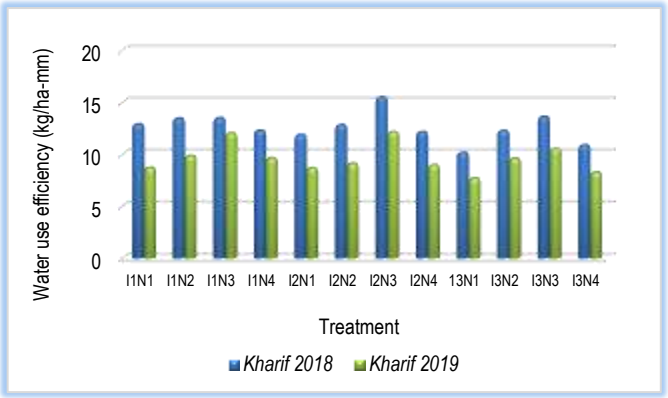

Fig-2 Treatment wise water use efficiency for *kharif* 2018 and 2019

The analysis of variance to compare the means of WUE [Table-9] 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 *kharif*, 2019 respectively. The Duncan test for comparing treatment means for main plots (Irrigation levels) of WUE showed that I_3 treatments had significant difference and I_1 and I_2 treatments had on par between the irrigation levels during *kharif* 2018 [Table-10]. During *kharif* 2019 [Table-11] showed that I_1, I_2 and I_3 treatments had significant difference between the irrigation levels. Similar findings of WUE were observed by Pawar *et al*. (1998) [5] in garlic. Prihar and Tripathi (1989) [6] also reported that increase in soil moisture regime could increase the WUE up to a certain level, but it tends to decline thereafter. The increase in WUE in all drip irrigated treatments was mainly due to considerable saving of irrigation water, greater increase in yield of crops and higher nutrient use efficiency. This was in concordance with Bobade *et al*. (2002) [7].

Conclusion

Drip irrigation led to higher maize grain yield with I_2 treatment (0.8 of the crop evapotranspiration) when compared to I_1 treatment (0.6 of the crop evapotranspiration) and on par with I_3 treatment (1.0 of the crop evapotranspiration).

Table-8 *Effect of drip fertigation on water use efficiency during crop seasons*

Treatment	*Kharif 2018*			*Kharif 2019*		
	Yield (kg/ha)	Applied water (mm)	Water Use Efficiency (kg/ha-mm)	Yield (kg/ha)	Applied water (mm)	Water Use Efficiency (kg/ha-mm)
I_1N_1	4408	342.67	12.86	4458	514.14	8.67
I_1N_2	4600	342.67	13.42	5051	514.14	9.82
I_1N_3	4612	342.67	13.46	6165	514.14	11.99
I_1N_4	4196	342.67	12.25	4943	514.14	9.61
I_2N_1	4734	400.13	11.83	4889	566.18	8.64
I_2N_2	5118	400.13	12.79	5148	566.18	9.09
I_2N_3	6180	400.13	15.44	6857	566.18	12.11
I_2N_4	4846	400.13	12.11	5058	566.18	8.93
I_2N_1	4621	457.59	10.10	4732	618.23	7.65
I_2N_2	5597	457.59	12.23	5902	618.23	9.55
I_2N_3	6212	457.59	13.58	6487	618.23	10.49
I_2N_4	4960	457.59	10.84	5084	618.23	8.22

Table-9 *Univariate Analysis of Variance to compare the means of water use efficiency*

kharif, 2018					
Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
MAIN	14.235	2	7.118	2.396E3	0
SUB	38.169	3	12.723	4.283E3	0
MAIN * SUB	10.658	6	1.776	598.02	0
Total	63.062	11			
a. R Squared = .999 (Adjusted R Squared = .999)					
kharif, 2019					
MAIN	6.853	2	3.426	2.031E3	0
SUB	52.489	3	17.496	1.037E4	0
MAIN * SUB	3.752	6	0.625	370.7	0
Total	63.094	11			
a. R Squared = 1.000 (Adjusted R Squared = .999)					

Table-10 *Duncan test for comparing treatment means for main plots (Irrigation levels) of WUE for kharif 2018*

Main plots	N	Subject for alpha 0.05	
		1	2
3	12	11.6875	
1	12		12.9975
2	12		13.0442
Sig.		1	0.05
Means for groups in homogeneous subsets are displayed.			
Based on observed means, The error term is Mean Square(Error) = .003.			

Table-11 *Duncan test for comparing treatment means for main plots (Irrigation levels) of WUE for kharif 2019*

Main plots	N	Subject for alpha 0.05		
		1	2	3
3	12	8.9792		
2	12		9.6925	
1	12			10.025
Sig.		1	1	1
Means for groups in homogeneous subsets are displayed.				
Based on observed means, The error term is Mean Square(Error) = .002.				

The higher WUE was obtained at I_2 treatment at coastal Andhra Pradesh. This shows that the drip irrigation makes effective utilization of resources and increases area under cultivation there by farmers can be empowered economically and socially.

Application of research: This article has been prepared with the objective of giving information to the maize growers on yield and water use efficiency in coastal region of Andhra Pradesh. The investigations of the research used for the purpose of proper planning of irrigation schedule to achieve high water use efficiency.

Research category: Irrigation Engineering.

Abbreviations: CF-Conventional Fertilizer, CROPWAT-Crop water requirement, SPSS - Statistical Package for the Social Sciences, ANOVA - Analysis of Variance, DMRT - Duncan Multiple Range Test, WUE-Water Use Efficiency.

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Research project name or number: PhD Thesis

Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Dr NTR College of Agricultural Engineering, Bapatla, 522 101,

Cultivar / Variety / Breed name: Maize (*Zea mays*)

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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