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Research Article

Effect of Irrigation and Fertigation Schedules in Rice Fallow Zero Tillage Maize

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Abstract

At the Agricultural Research Station, Garikapadu, Krishna district, ANGRAU, a field experiment was carried during two rabi seasons from 2017–18 to 2018–19 with the aim of determining the most effective irrigation and fertigation schedules for rice fallow zero tillage maize. The experiment was laid out in a split-plot design with nine treatments, each consisting of three combinations of irrigation schedules for the main plot and three combinations of fertigation schedules for the sub-plot treatments, with three replications. Treatments include fertigation schedules for subplot treatments and drip irrigation plans for the main plot (IW/CPE 1.0, 0.75, and 0.5). To illustrate, consider 100%, 75%, and 50% RDF by fertigation. Plant height (in cm) at 30 DAS, 60 DAS, 90 DAS, and at harvest, as well as cob length (in cm) with an IW/CPE ratio of 1.0 and 100% RDF, are growth characteristics. Net returns and the benefit-cost ratio were significantly higher with an IW/CPE ratio of 1.0 with 100% RDF than they were with a ratio of 0.75 with 75% RDF through fertigation. Yield attributes included the number of kernels per cob, the number of kernel rows per cob, the weight (g) and yield (kg/ha) of each 100 kernels, as well as the net returns and benefit-cost ratio. Significantly lower growth and yield characteristics were seen when fertigation was used with an IW/CPE ratio of 0.5 and 50% RDF. Field water efficiency (kg/ha mm) was greatest when 50 % RDF were fertigated with a ratio of 0.5 IW/CPE.

Keywords: Irrigation, fertigation schedule, rice, maize, zero tillage.

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Introduction

The crop that is among the most versatile growing crops is maize (Zea mays L.), which can grow in a variety of agro-climatic settings. As the crop with the highest genetic production potential, maize is referred to as the "queen of grains" internationally. In India, 8.17 million hectares of maize are cultivated, yielding 19.33 million tons of grain and 2414 kg/ha of productivity (5). Andhra Pradesh, Telangana, and Karnataka states produce the majority of the maize in India. Due to the majority of the region being covered by single cross hybrids, Andhra Pradesh, which grows it on a 1 lakh hectare (ha) area, has the greatest output of 6523 kg/ha. Karnataka state is next in line. In Andhra Pradesh it is grown in an area of lakh ha with a productivity of 6523 Kg/ha which has the highest productivity due to majority of the area being covered under single cross hybrids followed by Karnataka state. Maize is cultivated year round in almost most of the states of India and is the third most important crop after rice and wheat. It is said to account for nearly 10% of total food grain production. In conventional method of maize cultivation, the crop is sown behind the plough after 2-3 ploughing, which is highly laborious and high cost. As this crop requires more number of irrigations (500-600 mm) which also became a constraint and the crop is subjected to terminal moisture stress results in low yields. Rice- maize system of cultivation is one of the predominant cropping system where it covers 3.5 million hectares in Asia (2). In present agro climatic conditions, most useful moisture conserving technology for maize is zero tillage maize in rice fallows. Zero tillage is the present trending resource conserving technology that is being adopted in India. Zero tillage means sowing the crops in unprepared soil which has been previously used by another crop. This is also known as no till or direct sowing. This is actually an age old practice followed by farmers since ancient times. The difference in the modern concept is that implanting of the seed mechanically in the untilled soil covered by residues. In Andhra Pradesh *rabi* maize yields in *kharif* rice fallows were affected due to late sowing under traditional practice of sowing after preparatory tillage. The crop was also subjected to terminal moisture stress due to late sowing in command areas particularly in tail end areas. To overcome the above situation zero tillage maize technology was introduced in Andhra Pradesh.

Materials and Methods

A field experiment was conducted during two *rabi* seasons during 2017-18 to 2018-19 at Agricultural Research Station, Garikapadu, Krishna district, ANGRAU with an objective to evaluate the suitable irrigation schedule and fertigation schedule under rice fallow zero tillage maize. The experimental site was characterized as red sandy loams with shallow depth (25-30 cm) with water holding capacity 14.5 %, well drained in nature, P^H 6.9, EC 0.14 ds m^{-1}, Organic carbon 0.48%, low in available Nitrogen (149-193kg/ha), medium to high in available phosphorus (16.4-28.3 kg/ha) and potassium (155-349 kg/ha). The experiment was laid out in split plot design with four replications. There are 9 treatment combinations in the study which comprised of irrigation schedules as main plots (3): I_1: 1.0 IW/CPE ratio, I_2 : 0.75 IW/CPE ratio, I_3 : 0.5 IW/CPE ratio and three fertigation schedules as sub plots : F_1 : 100 % RDF through drip, F_2 : 75 % RDF through drip, F_3: 50% RDF through drip. Test variety of rice is BPT-5204 and Maize hybrid is Pioneer (P 1756) respectively. The *kharif* rice was sown with puddling during last week of July and harvested during last week of November. A light irrigation was given four days before harvesting of rice. To facilitate good germination and maize was dibbled manually at a depth of 5 cm @ two seed/hill in the rice fallows on 4th and 7th December with a spacing of 60 × 20 cm during 2017-18 to 2018-19 respectively. Paraquat @ 1.0 lit was sparyed immediately after sowing to arrest the regrowth of rice stubbles, kill the emerged weeds and control the unemerged weeds. Thinning and gap filling was done with utmost care at 10 DAS by keeping one seedling/hill. The monthly actual and normal rainfall at ARS, Garikapadu during the experimentation period is given in **Table 1**.

Table1 Mean monthly rainfall (mm) received from sowing to harvest at ARS, Garikapadu

Month	2017-18		2018-19		Pooled mean	
	Normal (mm)	Actual (mm)	Normal (mm)	Actual (mm)	Normal (mm)	Actual (mm)
December	10.3	0.0	11.7	40.0	11.0	20.0
January	5.2	0.0	8.3	31.0	6.7	15.5
February	7.6	0.0	7.6	0.0	7.6	0.0
March	1.7	0.0	1.0	0.0	1.3	0.0
April	18.8	0.0	22.3	35.0	20.5	17.5
Total	43.6	0.0	50.9	106.0	47.1	53.0

During 2017-18 (December to April) there is no rainfall received during crop growth period. During 2018-19 total rainfall received was 106 mm in 5 rainy days which was surplus by 108.2% against normal rainfall (50.9 mm). Pre-sowing irrigation of 30 mm was given with sprinklers and uniform irrigation of 20 mm through drip was given after emergence of seedling (16 DAS). Irrigation water was measured with water meter fixed to irrigation source taking into consideration each irrigation treatment area and depth of water (10 mm). Scheduling of irrigation was started whenever the cumulative pan evaporation (CPE) reached the value of 10 mm at IW/CPE ratio 1.0, 13.3 mm at 0.75 and 20 mm at 0.5 ratio were maintained from 17 DAS to 66 DAS. From 67 DAS to maturity the volume of water increased so as to increase the pan evaporations from 1.0 to 1.25, 0.75 to 1.0 and 0.5 to 0.75. The cumulative pan evaporation (CPE) was made constant throughout the crop growth in respective treatments. Rainfall data was taken into account while making calculations for scheduling irrigation based on IW/CPE ratio. Fertigation was done through venturi system to each plot. Fertilizer solution was filled in plastic bucket and connected with suction device of venturi. Fertigation was given as per the treatments. The recommended dose of fertilizer (RDF) 240:80:80 N, P_2O_5 and K_2O kg per hectare was applied. Nitrogen, phosphorus and potash were applied in the form of DAP, urea and muriate of potash. DAP, Urea and muriate of potash were applied through irrigation water through fertigation as per the schedule. Fertigation schedule was started on 21 DAS. The drip discharge was 4 lph and emitter spacing was 60 cm. Fertigation treatments were also imposed on same day and the amount of fertilizer was divided into 25% RDF in 4 splits, 50 % RDF in 8 splits and remaining 25 % RDF in 7 splits at IW/CPE ratio 1.0 with 100 %, 75 % and 50% RDF at an interval of every 5 days through drip. At IW/CPE ratio 0.75 the amount of fertilizer was divided into 25% RDF in 3 splits, 50 % RDF in 6 splits and remaining 25 % RDF in 5 splits with 100 %, 75 % and 50% RDF at an interval of every 7 days through drip. The amount fertilizer was divided into 25% RDF in 3 splits, 50 % RDF in 4 splits and remaining 25 % RDF in 3 splits with 100 %, 75 % and 50% RDF at IW/CPE ratio 0.5 at an interval of every 10 days through drip. The depth of irrigation water was given in I_1, I_2 and I_3 treatments was 386 mm, 302 mm and 228 mm, 392 mm, 309 mm and 255 mm respectively including the rainfall during 2017-18 and 2018-19. Healthy crop stand was ensured by adopting need based plant protection and following the recommended package of practices. Five plants were selected at random and tagged. These plants were used for recording plant height at 30 days intervals. Yield attributes viz., rows per cob, kernels per cob, cob length and finally kernel yield were measured. The field water use efficiency (kg/ha mm) of a crop was determined by considering the maize kernel yield (kg/ha) and quantity of water used in each treatment. The cost of cultivation (Rs/ha) incurred by taking into account all the costs involved for different agricultural inputs and operations. Net returns (Rs/ha) were calculated by deducting the cost of cultivation (Rs/ha) from the gross returns (Rs/ha). The results were interpreted on the basis of split plot design and critical difference at 5% was used for calculating the significant difference between the means of two treatments (7).

Results and Discussion

Effect of irrigation levels

Growth attributes

When irrigation was applied at IW/CPE ratio 1.0 (I1), maximum plant height was seen at all observation dates (30 DAS - 90 DAS) for both the years 2017–18 and 2018–19, according to data on growth attributes collected for this study (**Table 2**). For plant height at all crop growth phases, this was followed by irrigation at 0.75 (I2) and irrigation at 0.5 (I3), respectively. This trend in maize growth demonstrated that the crop responded linearly to increasing irrigation schedules from IW/CPE ratios of 0.5 to 1.0, with maize growing from 27.5 cm to 31.5 cm at 30 DAS, 150.5 cm to 163.5 cm at 60 DAS, and 183.5 cm to 202.6 cm at 90 DAS (pooled mean). This also demonstrated that maize requires more water in order to grow more successfully. Increased irrigation level results in better growth characteristics, according to (1), (3), and (4). Maize grown with drip irrigation may have grown more successfully because of improved soil aeration, better moisture availability, and a lack of stress during the crop's growth period. These factors ultimately led to better physiological activity in the plant, which resulted in increased plant height. Similar results were observed in conjunction with (9).

Table 2 Plant height (cm) as influenced by irrigation and fertigation schedules under rice fallow zero tillage maize. (Pooled data of 2017-18 and 2018-19)

Treatments	Plant height (cm)		
	30 DAS	60 DAS	90 DAS
IRRIGATION SCHEDULES (I)			
I_1 at IW/CPE ratio 1.0	31.5	163.5	202.6
I_2 at IW/CPE ratio 0.75	29.0	159.0	195.2
I_3 at IW/CPE ratio 0.5	27.5	150.5	183.5
S.Em ±	0.95	2.72	4.68
C.D at 5%	2.1	4.2	6.9
FERTIGATION SCHEDULES (F)			
F_1 at 100% RDF Through drip	32.5	164.6	196
F_2 at 75% RDF Through drip	29.0	161.0	192
F_3 at 50% RDF Through drip	26.0	158.5	184
S.Em ±	1.24	2.24	7.86
C.D at 5%	2.90	5.6	7.4
Interaction (I x F)			
S.Em ±	1.4	8.30	9.6
C.D at 5%	NS	NS	NS

Yield attributes

Data on yield attributes showed that varied irrigation schedules had a substantial impact on yield attributes such as cob length (17.7 cm), number of rows per cob (15), number of kernels per cob (574), and 100 kernel weight (26.8 g) (**Table 3**). IW/CPE ratio 1.0 (I1) among irrigation schedules recorded noticeably higher values of the yield-attributing characteristics than IW/CPE ratio 0.75 (I2) and was comparable with IW/CPE ratio 0.5 (I3) in both years. This may be the result of water stress under low PE, which led to poor plant growth as a result of restrictions placed on the movement of nutrients, photosynthesis, and metabolic processes in the plant system. With the subsequent reduction in irrigation level, all of the aforementioned yield parameters were also decreased. These findings are in close conformity with those of (4), (10) and (14).

Kernel yield and Stover yield

The schedule of irrigation had a big impact on the production of maize kernels. In comparison to IW/CPE ratio 0.5 (I3) and IW/CPE 0.75 ratio (I2) (8402 kg/ha) (pooled in 2017–19), drip irrigation at IW/CPE ratio 1.0 (I1) observed considerably greater kernel yield of maize (8902 kg/ha) (**Table 4**). Better growth and yield characteristics under

IW/CPE ratio 1.0 (I1) compared to irrigation at lower PE values may be the cause of this. Irrigation at an IW/CPE ratio of 1.0 (I1) produced significantly higher kernel yield, stover yield (14023 kg/ha), and biological yield (22925 kg/ha) than irrigation at an IW/CPE ratio of 0.5 (I3), however it was similar with irrigation at an IW/CPE ratio of 0.75 (I2) (Table 4). Irrigation levels had no impact on the harvesting index, which was numerically higher at IW/CPE ratio 1.0 (I1) (38.8%) than rest of treatments followed by at IW/CPE ratio 0.75 (I_2) (37.6 %) and at IW/CPE ratio 0.5 (I_3) (36.3%), respectively. This indicated little effect on sink-source relation due to fertigation levels.

Table 3 Yield attributes and yield of zero tillage maize as influenced by irrigation and fertigation schedules in rice fallows. (Pooled data of 2017-18 and 2018-19)

Treatments	Cob length (cm)	No. of kernels/cob	No. of kernel rows/cob	100-Kernel weight (g)	Kernel yield (kg/ha)
IRRIGATION SCHEDULES (I)					
I_1 at IW/CPE ratio 1.0	17.7	574	15.0	26.8	8902
I_2 at IW/CPE ratio 0.75	16.6	548	14.0	24.8	8402
I_3 at IW/CPE ratio 0.5	16.4	512	12.0	23.2	7922
S.E m ±	0.68	8.96	0.37	0.68	168.2
C.D at 5%	1.10	22.4	1.10	1.90	421.5
FERTIGATION SCHEDULES (F)					
F_1 at 100% RDF Through drip	18.3	567	14.0	26.2	8806
F_2 at 75% RDF Through drip	17.8	542	13.0	25.2	8499
F_3 at 50% RDF Through drip	16.5	511	11.0	23.3	7790
S.E m ±	0.98	8.24	0.48	0.59	225.6
C.D at 5%	1.2	20.6	1.1	1.00	305.4
Interaction (I x F)					
S.E m ±	1.12	14.76	0.66	0.72	414.8
C.D at 5%	NS	NS	NS	NS	NS

Table 4 Kernel yield, Stover yield, Biological yield and harvest index as influenced by irrigation and fertigation schedules in rice fallow zero tillage maize.(Pooled data of 2017-18 and 2018-19)

Treatments	Kernel yield (kg/ha)	Stover yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
IRRIGATION SCHEDULES (I)				
I_1 at IW/CPE ratio 1.0	8902	14023	22925	38.83
I_2 at IW/CPE ratio 0.75	8402	13906	22308	37.66
I_3 at IW/CPE ratio 0.5	7922	13898	21820	36.30
S.Em ±	168.2	345.9	245.8	-
C.D at 5%	421.5	115.4	614.6	-
FERTIGATION SCHEDULES (F)				
F_1 at 100% RDF Through drip	8806	14021	22827	38.57
F_2 at 75% RDF Through drip	8499	13926	22425	37.89
F_3 at 50% RDF Through drip	7790	13335	21125	36.87
S.Em ±	225.6	362.9	159.4	-
C.D at 5%	305.4	92.5	398.6	-
Interaction (I x F)				
S.Em ±	414.8	182.4	594.2	-
C.D at 5%	NS	NS	NS	-

Effect of fertigation levels

Growth attributes

Data on growth characteristics for all observations showed that, when combined in 2017–19, 100% RDF through drip (F1) demonstrated highest plant height at 30 DAS, 60 DAS, and 90 DAS compared to the other fertigation levels, namely 75% RDF through drip (F2) and 50% RDF through drip (F3). This may be due to improved nutrient availability under water soluble fertilizer application, which led to higher or comparable growth characteristics with low fertigation levels, i.e. 50% RDF and 75% RDF through drip over 100% RDF through soil. Similar outcomes were discovered for (I1) and (I3).

Yield attributes

Yield attributing characters of maize viz., cob length (18.3 cm), number of kernels rows per cob (14), number of kernels per cob (567), 100 kernel weight (26.2 g) were differed statistically due to various fertigation levels (Table 3). 100% RDF through drip (F_1) recorded significantly higher values of all above referred yield attributes over 50% RDF through fertigation (F_3). However, the treatment 100% RDF through fertigation (F_1) was at par with 75% RDF through fertigation (F_2) for all yield attributes. The lowest values of yield attributes were observed with 50% RDF through drip (F_3) (pooled in 2017-19). This may be due to increased availability of water and nutrients in the soil and their uptake by crop, thus resulted in better yield attributes. Similar results were recorded with of (12) in maize.

Kernel yield and Stover yield

Significantly higher kernel yield (8806 kg/ha), stover yield (14021 kg/ha) and biological yield (22827 kg/ha) was observed with 100% RDF through drip (F_1) 50% RDF through drip (F_3), however, it was found comparable with 75% RDF through drip (F_2) (pooled in 2017-19). (Table 4). This may be attributed to the reason that plants have efficiently utilized the higher concentration of nutrients present in the root zone. Higher nutrient uptake has resulted in more biomass accumulation and more translocation of photosynthates towards the sink i.e. grains. (8) Also reported that maize crop irrigated with sub surface drip and surface drip methods have shown statistically similar yield but it was significantly higher as compared to surface furrow irrigation method; which was attributed to uniform distribution of irrigation water and lesser evapotranspiration. Harvest index revealed no difference in fertigation levels; 100% RDF through drip (F1) had a numerical advantage over other treatments (38.5%), followed by 75% RDF through drip (F2) and 50% RDF through drip (F3), respectively (Table 4). This indicated that fertigation levels showed little impact on the sink-source relation.

Interaction effect

Interaction effect due to different irrigation and fertigation levels were non-significant for all growth attributes, yield attributes, grain yield, fodder yield and biological yield

Table 5.Influence of irrigation and fertigation schedules on Field water use efficiency in rice fallow zero tillage maize. (Pooled data of 2017-18 and 2018-19)

Treatments	**Kernel yield (kg/ha)**	**Depth of irrigation (mm)**	**Field water use efficiency (kg/ha mm)**
IRRIGATION SCHEDULES (I)			
I_1 at IW/CPE ratio 1.0	8902	386	23.0
I_2 at IW/CPE ratio 0.75	8402	305	27.5
I_3 at IW/CPE ratio 0.5	7922	228	34.7
S.Em ±	-	-	-
C.D at 5%	-	-	-
FERTIGATION SCHEDULES (F)			
F_1 at 100% RDF Through drip	8806	386	22.8
F_2 at 75% RDF Through drip	8499	305	27.8
F_3 at 50% RDF Through drip	7790	228	34.1
S.Em ±	-	-	-
C.D at 5%	-	-	-

Field water use efficiency

Field water use efficiency (FWUE) was estimated for the years 2017-18 and 2018-19 and pooled mean and the results were presented in **Table 5** (pooled in 2017-19). The highest field water use efficiency (23 kg/ha mm) was noticed with an IW/CPE ratio 0.5 (I_3) and fertigation 100% RDF through drip (F_1) (38.6 kg/ha mm).Irrigating at 1.0 IW/CPE ratio and fertigation 50% RDF through drip (F_3) recorded low field water use efficiency. These results confirm the findings of FAO (1995) which reported that an irrigation regime that provides soil moisture for maximum crop growth and yield per unit area would be unlikely to produce maximum output per unit of water i.e. field water use efficiency. Although, irrigation water amounts of 1.0 IW/CPE ratio produced the highest kernel yield during both the years, it couldn't translate this yield into higher field water use efficiency as the relative difference in the kernel yield was compensated for by the relative difference in the seasonal amount of irrigation water applied to this IW/CPE ratio.

Economics

The higher net returns (Rs 65248/ha) and benefit cost ratio (1.8) obtained with irrigation at IW/CPE ratio 1.0 (I_1) were higher during the both the years compared to other two irrigation schedules (**Table 6**). Similarly with more net returns (Rs 67655/ha) and benefit cost ratio (1.9) were realized when fertigation at 100% RDF through drip (F_1) than the other fertigation schedules i.e 75% RDF through drip (F_2) and 50% RDF through drip (F_3) (pooled in 2017-19).

Table 6 Yield and Economics of zero tillage maize under rice fallows as influenced by irrigation and fertigation schedules (Pooled data of 2017-18 and 2018-19)

Treatments	Kernel yield (kg/ha)	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C Ratio
IRRIGATION SCHEDULES (I)					
I_1 at IW/CPE ratio 1.0	8902	78964	144212	65248	1.8
I_2 at IW/CPE ratio 0.75	8402	76660	136112	59452	1.7
I_3 at IW/CPE ratio 0.5	7922	72411	128336	55925	1.7
FERTIGATION SCHEDULES (F)					
F_1 at 100% RDF Through drip	8806	75002	142657	67655	1.9
F_2 at 75% RDF Through drip	8499	73449	137683	64234	1.8
F_3 at 50% RDF Through drip	7790	69913	126198	56285	1.8

Conclusion

From this study effect of irrigation and fertigation schedules on rice fallow zero tillage maize, it can be concluded that yield enhancement of zero tillage maize is possible through the use of drip irrigation and fertigation. Scheduling of irrigation water at 1.0 IW/CPE ratio and fertigation 100% RDF through drip was found to be beneficial in in terms of getting higher kernel yield, net returns, benefit cost ratio. Field water use efficiency was higher at IW/CPE ratio of 0.5-0.75 with all fertigation schedules. When seasonal irrigation water is limited, irrigating to maize crop at 0.5 E Pan upto 60 DAS and 0.75 IW/CPE ratio from 61 DAS to maturity was found better in terms of water saving and leading to higher field water use efficiency. With this irrigation schedule, 100% RDF was found optimum in red sandy loam soils of Krishna district of Andhra Pradesh

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