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Evaluation of Drip Irrigation and Crop Growth Stage Based Fertigation Levels for High-Density Cotton Production

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ABSTRACT

An experiment was conducted at the College farm, College of Agriculture, PJTSAU, Hyderabad, during the 2019 and 2020 *kharif* seasons to examine the effects of various drip irrigation and fertigation levels on the growth and yield of high-density cotton. The experiment was put up in a three-fold Factorial Randomized Block Design (FRBD). Four fertigation levels (application of 100% RDNK in differential dosage as per recommendation [F_1], application of 100% RDNK in differential dosage as per crop coefficient curve [F_2], application of 125% RDNK in differential dosage as per recommendation [F_3] and application of 125% RDNK in differential dosage as per recommendation [F_4]) and three irrigation levels (irrigation scheduled at 0.6 [I_1], 0.8 [I_2] and 1.0 [I_3] Epan throughout the during the years 2020 and 2021, irrigation levels had no substantial impact on cotton growth, yield characteristics, or yield. While the application of 125% RDNK in differential dosage as per the crop coefficient curve (F_4) resulted in significantly greater growth parameters, yield attributes, stalk yield and seed cotton yield than the other three fertigation levels. Furthermore, the growth factors, yield qualities and yield produced by F_3 were comparable to those of F_2.

Keywords Drip irrigation, Fertigation, Growth parameters, High density cotton, Yield attributes.

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INTRODUCTION

With a total area of 13.47 million hectares and production and productivity of 36.06 million bales and 455 kilograms per hectare, respectively, India is the greatest cotton-growing nation in the world (Directorate of Economics and Statistics 2020-21). However, the fact that it is typically produced in rainfed conditions is one of the factors contributing to its poor productivity. In addition, nearly 80% of the cotton farmed in India is grown in low- to medium-fertile soils, necessitating closer planting to maximize variety potential and fit more plants per

square foot. Bt Cotton hybrids considerably increased the output self-sufficiency of India and successfully stopped boll worm infestations. But in recent years, Bt cotton has begun to exhibit resistance to boll worms and has been shown to be inefficient against sucking pests, leading to an increase in the need of pesticides and a higher seed cost compared to non-Bt cotton seeds. In this case, non-Bt cotton cultivars will take the place of Bt cotton hybrids and, if appropriate management practices are employed, will provide superior yields. The most crucial elements in raising cotton output are irrigation and fertilizer management. Modern technology, like the drip irrigation method with high population, is required to get the most out of the resources that are currently available (water and nutrients) and to maximize net returns. This method enables irrigation water and fertilizers to be applied precisely and in a balanced manner to meet the needs of crop plants. In order to maximize output potential, the cotton fertilization schedule needs to be revalidated due to the increased planting density (55.5 to 77.7%) compared to standard planting density (i.e. 18517 and 37037 plants per hectare). The only research-based data on the timing of cotton fertigation based on crop growth phases and nutrient uptake is based on conjecture. Crop coefficient (Kc) measurements, which are based on scientific concepts, are not used to schedule water and nutrients precisely for cotton. Therefore, it is necessary to revalidate the fertigation schedule pattern in accordance with crop growth phases in order to maximize production potential and income. Keeping in view the importance of precise use of two vital inputs like irrigation and nutrients to cotton an experiment was formulated with an objective to study the effect of drip irrigation and fertigation on growth and yield.

MATERIALS AND METHODS

College Farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad, Telangana State was the site of the current experiment. The farm is located at an elevation of 542.3 meters above mean sea level in the Southern Telangana agro-climatic zone of Telangana, at 17°19' N latitude and 78°23' E longitude, and is categorized as semi-arid tropics (SAT) by Troll's categorization. Between 26.8 and 34.0°C with an average of 30.4°C in 2019–20 and 25.9 to 33.8°C with an average of 29.9°C in 2020–21, respectively, were the mean weekly maximum temperatures for the cropping period. While the minimum weekly temperature ranged from 14.2 to 20.5°C with an average of 17.4°C in 2019–20 and 14.2 to 23.7°C with an average of 19.0°C in 2020–21. The crop study's total evaporation was 649.9 mm and 611.3 mm. Rainfall totaled 706.1 mm throughout the crop growing period in 2019–20 and 1283.2 mm during 60 rainy days in 2020–21, respectively. The crop was primarily cultivated with moisture from rainfall during both experiment seasons. The soil in the experimental region has a sandy loam texture (75.24 % sand, 10.4% silt, and 14.06% clay), an average bulk density of 1.59 Mg m^3 for 0-60 cm depth and a pH range of 7.4 to 7.5 in response. The experiment used a Factorial Randomized Block Design (FRBD) with twelve treatments that were reproduced three times. In this study, four fertigation levels (100% RDNK in differential dosage as per recommendation [F_1], 100% RDNK in differential dosage as per crop coefficient curve [F_2] and 125% RDNK in differential dosage as per crop coefficient curve [F_4]) and three irrigation levels (irrigation at 0.6 [I_1], 0.8 [I_2] and 1.0 Epan [I_3] throughout the crop growth period) were included as treatments. In the first season, the crop was sowed on July 15, 2019 and in the second season, on June 18, 2020. ADB-542 is the cotton composite variety that was employed in the investigation. The following spacing was 60 x 20 cm. The crop received the recommended fertilizer dose of 90 kg of nitrogen, 48 kg of phosphorus and 48 kg of potassium for one hectare through urea, single super phosphate and sulfate of potash, respectively according to the fertigation levels. Entire phosphorus was applied as basal to all the treatments before sowing. Nitrogen and potassium were applied through fertigation according to the treatments. Fertigation in 17 splits once in 6 days interval in differential dosage as per crop growth was carried out from 10 DAS to 110 DAS. For the treatments F_1 and F_3 fertigation was given in differential dosages as per recommendation in 100% and 125% RDF which was given in detail in Table 1.

For the treatments F_2 and F_4, fertigation was administered in different dosages according to the crop coefficient curve at 100% and 125% RDF, respec-

Table 1. Differential dosage of fertilizer application based on growth stage of cotton crop as per recommendation by PJTSAU.

Crop stage	Nutrient dose (kg ha^{-1} day^{-1}) N	K_2O
After sowing 35 days (10-45 DAS)	0.56	0.29
Squaring 20 days (45-65 DAS)	1.50	0.58
Flowering and boll formation stage 20 days (65-85 DAS)	1.03	0.78
Boll development 30 days (85-115 DAS)	0.75	0.29

tively. The Kc values will be lower in the beginning stages as the crop's ground cover is less, gradually rise with the crop's growth stage as the crop approaches effective full cover, and in the late season, be high if the crop is frequently irrigated until fresh harvest or low if the crop is allowed to dry out in the field before harvest (Table 2). This indicates that the crop evapotranspiration rates will increases as crop growth advances which shows that the water requirement of the crop also increases with the increase in the crop growth. In the same way, the nutrient requirement will also follow the similar trend like water and nutrient requirement increases as the crop growth increases. This principle was used and fertigation pattern based on crop coefficient curve was developed.

It was planned to irrigate every three days. On the basis of pan evaporation replenishment in treatments,

Table 2. Differential dosage of fertilizer application based on growth stage of cotton crop as per crop coefficient curve.

Crop stage	Kc values	Nutrient dose (kg ha^{-1} day^{-1}) N	K_2O
10-25 days	0.45	0.54	0.29
26-31	0.49	0.59	0.31
32-37	0.53	0.64	0.34
38-43	0.57	0.69	0.36
44-49	0.61	0.74	0.39
50-55	0.65	0.79	0.42
56-61	0.69	0.83	0.44
62-67	0.73	0.94	0.47
68-73	0.78	1.00	0.50
74-79	0.83	1.07	0.53
80-85	0.88	1.11	0.57
86-91	0.92	1.17	0.59
92-97	0.97	1.17	0.62
98-103	1.02	1.24	0.66
104-110	1.06	1.28	0.68
Average =	0.74		

irrigation scheduling was made. A water meter was used to measure the amount of water applied to each treatment. On days when it rained, the amount of water used for each treatment was modified according to the actual amount of rain that fell. Each lateral line of 16.mm spaced at 0.6 m on the sub-main and is equipped with build-in emitters of a 2 l h^{-1} discharge rate spaced at 0.2 m on the lateral lines. The application rate in drip irrigated treatments was calculated using following formula.

$$\text{Application rate (mmhr}^{-1}) = \frac{Q}{DL \times DE}$$

Whereas
Q = Dripper discharge (liters h^{-1}), DL = Distance between lateral spacing (m)
DE = Distance between dripper (emitters) spacing (m)
Irrigation time for each treatment was calculated using following formulae.
Epan (mm) × 60 Irrigation time (minutes)=
Application rate (mmhr^{-1})

Observations like plant height, onset of different phenophases, dry matter accumulation, yield attributes were recorded from five representative plants of each treatment. The crop was harvested on 22nd January 2020 (190 days after sowing) and 23rd November 2020 (170 days after sowing) during 1st and 2nd seasons respectively. The cumulative yield of seed cotton from each picking in each treatment from net plot was weighed in g plot^{-1} and converted to kg ha^{-1}. The cotton stalk uprooted from corresponding net plot area of treatment was sun dried for one week and the dry weight was recorded and expressed in kg ha^{-1}. The experimental data recorded on different parameters were analyzed statistically by applying the technique of analysis of variance for FRBD design and significance was tested by F-test (Gomez and Gomez 1984). Critical difference for examining treatments means for their significance was calculated at 5% level of probability.

RESULTS AND DISCUSSION

Growth parameters

Growth parameters like plant height, monopodial,

Table 3. Plant height (cm) of cotton as influenced by drip irrigation and fertigation levels.

Treatments	Days after sowing									
	30		60		90		120		At harvest	
Irrigation levels	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
I_1	14.6	17.7	66.6	72.2	93.0	87.5	102.0	95.7	103.5	98.7
I_2	14.5	17.2	67.1	73.4	93.5	87.8	101.7	97.1	104.5	99.5
I_3	14.5	17.5	67.8	75.0	94.5	89.4	102.0	98.3	107.1	100.7
SEm±	0.4	0.4	1.9	2.0	2.5	2.3	2.5	2.3	2.5	2.6
CD (P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fertigation levels										
F_1	14.3	17.2	64.2	71.2	87.1	83.6	95.2	91.6	98.8	93.4
F_2	14.4	17.3	60.9	68.4	89.4	84.3	99.7	93.3	101.8	95.1
F_3	14.8	17.5	73.4	80.0	97.7	91.6	104.4	100.7	107.9	104.0
F_4	14.7	17.9	70.3	75.6	100.5	93.4	108.4	102.5	111.8	106.0
SEm±	0.5	0.5	2.2	2.3	2.9	2.7	2.9	2.6	2.9	3.1
CD (P=0.05%)	NS	NS	6.4	6.7	8.5	7.8	8.5	7.6	8.5	9.0
Interaction										
SEm±	0.8	0.8	3.8	3.9	5.0	4.6	5.0	4.5	5.00	5.3
CD (P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Factor 1: Irrigation scheduling
I_1: Drip irrigation 0.60 Epan throughout crop growth period
I_2: Drip irrigation 0.80 Epan throughout crop growth period
I_3: Drip irrigation 1.0 Epan throughout crop growth period

Factor 2: Fertigation scheduling
F_1: 100 % RDNK (differential dosage of N and K as per recommendation)
F_2: 100 % RDNK (differential dosage of N and K as per crop coefficient curve)
F_3: 125 % RDNK (differential dosage of N and K as per recommendation)
F_4: 125 % RDNK (differential dosage of N and K as per crop coefficient curve)

sympodial branches and dry matter production were not significantly influenced by drip irrigation levels at 30, 60, 90, 120 and at harvest during both the years of study (Tables 3-5). This may be the result of the fact that during the two study seasons, the crop was primarily grown and sufficient rainfall was received during the months of July, August, September and October, where the heavy rains coincided with the stages of cotton crop growth known as square formation, flowering, boll formation and bursting. The plant height and dry matter production of cotton was not significantly influenced by the fertigation levels at 30 DAS. But at 60 DAS application of 125% RDNK in differential dosage as per recommendation (F_3) has recorded higher plant height, sympodial branches, dry matter production and was at par with application of 125% RDNK in differential dosage as per crop coefficient curve (F_4) during 2020 and 2021 due to application of fertilizers in higher dosages from 30-60 DAS. While at 90, 120 DAS and at harvest F_4 has recorded higher plant height, sympodial branches, dry matter and was at par with F_3 during 2020 and 2021. While the lowest growth parameters were observed with F_1 and was at par with F_2 during 2020 and 2021. The growth parameters observed under F_2 were also on par with F_3. On the whole, higher growth parameters with 125% RDNK (F_4) might be due to application of nutrients in higher doses than recommended in readily available form through many splits according to crop stages under higher

Table 4. Number of monopodial and sympodial branches per plant of cotton as influenced by drip irrigation and fertigation levels.

Treatments	Monopodial branches		Sympodial branches			
	60 DAS		60		90	
Irrigation levels	2019	2020	2019	2020	2019	2020
I_1	1.1	1.1	7.7	7.9	10.9	9.9
I_2	1.1	1.1	8.1	7.9	10.8	10.1
I_3	1.1	1.2	7.8	8.1	11.2	10.5
SEm±	0.04	0.04	0.2	0.1	0.2	0.3
CD (P=0.05%)	NS	NS	NS	NS	NS	NS
Fertigation levels						
F_1	1.1	1.1	7.6	7.8	10.3	9.5
F_2	1.1	1.1	7.3	7.6	10.6	9.8
F_3	1.2	1.1	8.3	8.3	11.3	10.5
F_4	1.1	1.2	8.2	8.2	11.6	10.8
SEm±	0.04	0.04	0.2	0.1	0.3	0.3
CD (P=0.05%)	NS	NS	0.6	0.4	0.7	0.9
Interaction						
SEm±	0.08	0.07	0.4	0.2	0.4	0.5
CD (P=0.05%)	NS	NS	NS	NS	NS	NS

Table 5. Dry matter production (kg ha^{-1}) of cotton as influenced by drip irrigation and fertigation levels.

Treatments	Days after sowing									
	30		60		90		120		At harvest	
Irrigation levels	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
I_1	243	278	2752	2999	6214	5813	7316	7085	7980	7914
I_2	243	281	2782	3093	6286	5829	7395	7104	8043	7951
I_3	258	276	2832	3044	6297	5873	7476	7171	8079	8001
SEm±	7	6	74	113	153	129	204	235	187	232
CD (P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fertigation levels										
F_1	234	272	2678	2870	5842	5509	6943	6663	7427	7475
F_2	245	277	2592	2689	6043	5662	7093	6755	7740	7566
F_3	253	282	3021	3396	6513	6075	7718	7494	8353	8340
F_4	260	284	2866	3226	6663	6108	7830	7569	8616	8436
SEm±	8	7	85	131	177	149	235	272	216	268
CD (P=0.05%)	NS	NS	249	384	519	437	689	797	634	787
Interaction										
SEm±	14	12	147	227	306	258	407	471	375	465
CD (P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

plant population conditions resulted in more nutrient availability in soil root zone and lead to more nutrient uptake which were efficiently utilized by the plants and resulted in increased plant height of crop. Similar findings were also reported by Mark Gladson *et al*. (2016), Ayyadurai and Manickasundaram (2016), Kakade *et al*. (2017).

Irrigation and fertigation levels during 2020, 2021 and in mean time did not statistically affected the monopodial branches, number of days required to reach phenological events of cotton crop like initiation of monopodial branches, sympodial branches, square initiation, 50% flowering, boll formation and boll bursting stage (Table 4 - 6).

Yield attributes

Yield attributes like number of sympodial branches per plant, number of bolls per plant, boll weight and test weight were not significantly differed among irrigation levels during 2020 and 2021 (Table 7). While higher number of sympodial branches per plant, number of bolls per plant and boll weight

Table 6. Onset of different phenophases (no. of days) in cotton as influenced by drip irrigation and fertigation levels.

Treatments	Days after sowing									
	Sympodial branches		Square initiation		50% flowering		Boll formation		Boll bursting	
Irrigation levels	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
I_1	39.7	38.6	47.1	43.4	47.1	43.4	86.2	83.1	47.1	43.4
I_2	39.6	38.2	46.7	42.9	46.7	42.9	86.1	82.6	46.7	42.9
I_3	39.3	38.0	46.1	43.3	46.1	43.3	85.1	82.9	46.1	43.3
SEm±	0.6	0.8	0.7	0.5	0.7	0.5	1.6	1.2	0.7	0.5
CD (P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fertigation levels										
F_1	40.3	39.0	46.9	43.8	68.7	65.0	86.3	83.7	105.6	106.9
F_2	40.0	38.8	46.8	43.8	68.8	64.9	86.0	83.3	105.2	106.2
F_3	39.1	37.8	46.6	42.7	67.3	64.1	85.9	82.4	104.9	106.0
F_4	38.7	37.4	46.2	42.6	67.7	63.8	85.7	82.0	104.2	104.9
SEm±	0.7	0.9	0.8	0.6	1.2	1.2	1.6	1.4	1.9	2.0
CD (P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction										
SEm±	1.2	1.5	1.4	1.0	2.1	2.0	2.8	2.4	3.2	3.5
CD (P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 7. Yield attributes of cotton as influenced by drip irrigation and fertigation levels.

Treatments	No. of sympodial branches plant^{-1}		No. of bolls plant^{-1}		Boll weight (g)		Test weight/seed index (g)	
Irrigation levels	2019	2020	2019	2020	2019	2020	2019	2020
I_1	12.8	11.6	20.4	19.2	3.1	3.1	9.0	9.1
I_2	13.1	11.8	20.7	19.6	3.3	3.1	9.2	9.1
I_3	12.7	11.5	20.7	19.8	3.2	3.2	9.2	9.2
SEm±	0.3	0.3	0.4	0.4	0.10	0.09	0.2	0.2
CD (P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS
Fertigation levels								
F_1	11.9	10.7	19.3	18.2	2.9	2.9	9.1	9.1
F_2	12.4	11.3	20.0	19.0	3.0	3.0	9.0	9.1
F_3	13.4	12.1	21.3	20.2	3.3	3.2	9.0	9.2
F_4	13.7	12.4	21.8	20.7	3.6	3.3	9.2	9.2
SEm±	0.4	0.3	0.5	0.5	0.11	0.10	0.2	0.2
CD (P=0.05%)	1.1	1.0	1.5	1.4	0.33	0.30	NS	NS
Interaction								
SEm±	0.6	0.6	0.9	0.7	0.20	0.18	0.4	0.4
CD (P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS

were recorded with application of 125% RDNK in differential dosage as per crop coefficient curve (F_4) over application of 100% RDNK in differential dosage as per recommendation (F_1) and application of 100% RDNK in differential dosage as per crop coefficient curve (F_2) and was on par with 125% RDNK in differential dosage as per recommendation (F_3) during 2020 and 2021. While F_3 was again on par with F_2. Fertigation levels had no effect on test weight. Increased nutrient availability and uptake may have contributed to improved photosynthesis, the production of more leaves and the transport of nutrients to reproductive organs, which improved square formation and boll retention under greater degrees of fertigation (F_3 and F_4). The findings of Kakade *et al*. (2017), Shekhar *et al*. (2016), Mark Gladston *et al*. (2016) and Jayakumar *et al*. (2016) were all in agreement with these results.

Yield

Seed cotton, stalk yield and lint yield were not significantly influenced by the drip irrigation levels during 2020, 2021 and in mean (Table 8). Due to continuous rains during the months of July, august, September and October, there was equal distribution of soil moisture in the root zone and the crop did not experienced moisture stress during moisture-sensitive periods. Crop was grown during both of the years of study with an adequate amount of moisture from rainfall. This could be the cause of the lack of a discernible impact of irrigation regimes on seed cotton output.

While application of 125% RDNK in differential dosage as per crop coefficient curve (F_4) has recorded higher seed cotton, stalk yield and lint yield and was at par with application of 125% RDNK in differential dosage as per recommendation (F_3) during 2020 and 2021. While the lowest seed cotton, stalk yield and lint yield was observed with application of 100% RDNK in differential dosage as per recommendation (F_1) and was at par with application of 100% RDNK in differential dosage as per crop coefficient curve (F_1) during 2020, 2021 and in mean. The seed cotton yield, stalk yield and lint yield produced under F_3 was also comparable with F_2 during both the years of study. Higher yield with the application of 125% RDNK over 100% RDNK in both the fertigation patterns was due to higher availability of both the two major nutrients (N and k) in the soil solution which led to higher uptake and better crop growth which also gave maximum plant height, LAI, biological yield, yield attributes and ultimately producing higher yield. These results are in accordance with the findings of Magare *et al*. (2018), Kakade *et al*. (2017), Bhaskar (2014), Jayakumar *et al*. (2014), Aladakatti *et al*. (2012) and Hadole *et al*. (2012). Fertigation in differential dosage as per crop coefficient curve (F_2, F_4) has met the crop growth needs without much loss, when compared to other fertigation in differential dosage as per recom-

Table 8. Yield of cotton as influenced by drip irrigation and fertigation levels.

Treatments	Seed cotton yield (kg ha^{-1})		Stalk yield (kg ha^{-1})		Lint yield (kg ha^{-1})		Harvest index (%)	
Irrigation levels	2019	2020	2019	2020	2019	2020	2019	2020
I_1	2237	2046	5897	5788	745	679	27.9	25.6
I_2	2248	2060	5917	5831	749	684	27.8	25.8
I_3	2252	2090	5935	5857	750	694	27.8	25.9
SEm±	81	50	166	187	27	16	0.8	0.5
CD (P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS
Fertigation levels								
F_1	2040	1953	5551	5419	679	650	27.4	26.2
F_2	2113	2000	5666	5586	704	665	27.1	26.2
F_3	2384	2129	6241	6007	794	706	28.4	25.1
F_4	2446	2178	6287	6210	814	721	28.4	25.6
SEm±	94	58	192	216	32	19	1.0	0.6
CD (P=0.05%)	275	170	562	634	93	56	NS	NS
Interaction								
SEm±	163	100	332	374	55	33	1.7	1.0
CD (P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS

mendation (F_1, F_3) which produced higher dry matter production thus resulting in higher yield.

The harvest index was not significantly influenced by the drip irrigation and fertigation levels.

Interaction effect of irrigation and fertigation levels on growth parameters, yield attributes and yield was found non-significant during 2019 and 2020.

CONCLUSION

Different irrigation levels (0.6, 0.8 and 1.0 Epan throughout the crop growth period) did not significantly influenced the growth, yield attributes and yield in high density cotton due to heavy rainfall during crop growth period. While, among fertigation levels, application of 125% RDNK in differential dosage as per crop coefficient curve and application of 125% RDNK in differential dosage as per recommendation curve recorded higher growth and yield in high density cotton. Further, growth and yield obtained with application of 100% RDNK in differential dosage as per crop coefficient curve was comparable with application of 125% RDNK in differential dosage as per recommendation. Where in 25% of the nutrients can be saved when fertigation is given as per crop coefficient curve.

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