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Effect of different Levels of Irrigation and Nitrogen on Growth and Yield of Bt Cotton Grown on Alfisols

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ABSTRACT: Marginal soils with shallow depth, low fertility status and low and erratic distribution of rainfall are the important factors affecting cotton growth, development and seed cotton yield and its optimization is important for sustainable production of the cotton. The best irrigation schedule and nitrogen level for Bt cotton in alfisols in Southern Telangana were determined through a field experiment carried out in the kharif of 2015 at the Agricultural Research Institute, Rajendranagar. Rainfed cotton was significantly inferior to irrigation at 0.8 IW/CPE, which resulted in significantly higher plant height (115 cm), dry matter at first picking (241 g plant^{-1}), bolls plant^{-1} (22), seed cotton yield (1965 kg ha^{-1}), lint yield (711 kg ha^{-1}), stalk yield (2554 kg ha^{-1}), and nitrogen uptake (99 kg ha^{-1}). Significantly greater amounts of nitrogen were found in the following parameters: plant height (127 cm), dry matter at first picking (265 g plant^{-1}), days to reach boll development (98 days), number of bolls plant^{-1} (22), boll weight (5.1 g), seed index (9.7 g), and seed cotton content. The notable rise in both yield and yield attributes might potentially be attributed to beneficial effects on growth attributes such as plant height, increased bolls plant^{-1}, accumulation of dry matter plant^{-1}, and its subsequent translocation towards sink, which boosted the yield of seed cotton. It is determined that for Bt cotton cultivated in alfisols, a higher seed cotton yield can be achieved by applying nitrogen at a rate of 150 kg ha^{-1} and scheduling irrigation at 0.4 IW/CPE.

Keywords: Irrigation, Nitrogen, Cotton (*Gossypium hirsutum* L.).

INTRODUCTION

Approximately 25% of the world's total cotton production is produced in India, where cotton is one of the most significant commercial crops. An estimated 6 million cotton growers and 40–50 million people working in allied industries like cotton processing and trading depend heavily on it for their livelihood. The textile industry in India uses a wide variety of fibers, including yams, and the country uses about 60:40 cotton to non-cotton fibers, compared to 30:70 worldwide. Cotton not only provides clothes, which is the second most essential item of food in the world, but it also makes up a significant portion of India's net foreign exchange earnings. Cotton output at farmers' fields is limited by variables such unpredictable monsoons, unsuitable soil, incorrect sowing times, and non-adoption of advised technologies, particularly fertilizer use (Ramasundaram and Hemachandra 2001). Among these, the most significant factors influencing cotton growth, development, and seed cotton output are marginal soils with shallow depth, low fertility status, and low and irregular rainfall distribution. The primary causes of the yield difference in cotton reported in India were delayed sowing in 70% of cotton lands, reliance on the monsoon in 70% of cotton lands, low fertilizer use in 40% of cotton lands, and inappropriate soils in 20% of cotton lands. Improved crop management, such as making the most use of nitrogen and irrigation water, can help close the yield gaps. Typically, cotton is planted in medium-to-deep soil. Water and nitrogen are the key inputs which must be used in most efficient manner to sustain the cotton productivity at higher level. Moisture stress had adverse effect on yield as well as excess irrigation decreases the yield and increases the growing season (Wanjura *et al.*, 2002).

In contrast, high nitrogen availability may tip the balance between vegetative and reproductive growth towards excessive vegetative development, delaying maturity. In cotton, nitrogen deficiency reduces vegetative and reproductive growth and induces premature senescence, potentially reducing yields (Tewiodle and Fernandez 1997). The use of excess N fertilizers causes the problem of N pollution, which is now considered as new threat for environmental sustainability (Kanter *et al*., 2020). Different levels of water and fertilizers have significant combined effects on yield, crop growth, and water productivity (Javed *et al*., 2022). Application of 600 mm of irrigation along with 225 kg N ha^{-1} could be recommended for achieving higher growth and yield, as well as profitability of Bt cotton under hot arid region of Rajasthan and similar agroecologies (Kumar *et al.*, 2022). Since nitrogen and irrigation are both expensive inputs, growing Bt cotton on alfisols in South Telangana Zone regions with low rainfall requires optimal use of both resources in a synergistic combination for maximum yield. A practical solution to the problems with rainfed systems is scientific irrigation scheduling, which enables farmers to administer fertilizer and water according to the needs of their plants at specific growth stages. With the aforementioned considerations in mind, a study was conducted to ascertain the effects of various irrigation schedules and nitrogen levels on cotton growth and output.

MATERIAL AND METHODS

At the Agricultural Research Institute, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad, a study was conducted during the 2015 kharif season to ascertain the effects of various irrigation schedules and nitrogen levels on the growth and production of Bt cotton. The experiment was designed as a split plot with four nitrogen levels (N_1- 0 kg ha^{-1}, N_2 - 75 kg ha^{-1}, N_3 - 150 kgha^{-1}, and N_4 - 225 kg ha^{-1}) as sub plot treatments that were duplicated thrice. The major plots of the experiment were I_1- 0.8 IW/CPE, I_2 - 0.4 IW/CPE, and I_3 - Rainfed.

RESULTS AND DISCUSSION

Effect of irrigation

Plant height. The plant height did not differ significantly with irrigation schedules at square initiation and boll development stages. However, irrigation schedules showed significant influence at flowering and final picking stages (Table 1). Significantly higher plant height was recorded with irrigation scheduled at 0.8 IW/CPE (I_1) at flowering (66 cm) and final picking (115 cm) stages over rainfed (I_3) cotton, which recorded 49 cm and 99 cm of plant height at flowering and final picking stages, respectively. This was on par with 0.4 IW/CPE (I_2) which registered 63 cm and 114 cm of plant height at flowering and final picking stages, respectively and was significantly superior over rainfed (I_3) cotton.

Phenology. Days to attain different phenophases did not differ significantly with irrigation schedules.

Drymatter production. Drymatter production differed significantly with irrigation schedules at square initiation and first picking stage. However, it did not differ significantly at flowering, boll development, second and third picking stages. Significantly higher drymatter production (8.6 and 241 g plant^{-1}) was recorded with irrigation scheduled at 0.8 IW/CPE (I_1) and was followed by 0.4 IW/CPE (I_2), which recorded 7.8 and 234 g plant^{-1} of drymatter production at square initiation and first picking stages, respectively and were comparable with each other. These were significantly superior over rainfed (I_3) cotton, which recorded 6.6 and 174 g plant^{-1}.

In addition to producing and retaining more bolls plant-1 at later stages of the crop cycle, increased irrigation frequency may have increased photosynthesis and nutrient and moisture absorption. This could have led to higher drymatter production with irrigation scheduled at 0.8 IW/CPE (I1). On the other hand, in a rainfed environment, a soil moisture shortage may have led to decreased dry matter production through decreased photosynthesis, reduced cell elongation, and decreased carbohydrate synthesis. Dadgale *et al*. (2014) reported similar results.

Number of bolls plant^{-1}. It did not differed significantly by different schedules of irrigation.

Boll weight. The mean boll weight did not differ significantly with irrigation schedules. Optimum soil moisture with 0.8 IW/CPE (I_1) and 0.4 IW/CPE (I_2) might have resulted in greater nutrient uptake, crop growth and drymatter accumulation and positive influence on number of bolls plant^{-1} resulted in higher mean boll weight of cotton (Bhunia, 2007).

Seed cotton yield. Irrigation schedules significantly influenced the seed cotton yield. Significantly higher seed cotton yield (1965 kg ha^{-1}) was recorded with irrigation scheduled at 0.8 IW/CPE (I_1) and was not differed significantly with 0.4 IW/CPE (I_2) with seed cotton yield of 1779 kg ha^{-1}, and were superior over rainfed (I_3) cotton, in turn which recorded significantly lower seed cotton yield (1420 kg ha^{-1}).

The higher seed cotton yields with 0.8 IW/CPE (I_1) might be resulted from greater nutrient uptake in the favorable regime of soil moisture leads to balanced vegetative growth, higher drymatter production, increased number of bolls plant^{-1} which ultimately reflected in seed cotton yield. These observations confirms the Dhadgale *et al*. (2014) who reported that more number of bolls plant^{-1} with increased boll weight and higher seed cotton yield under irrigated conditions as compared to rainfed cotton. The higher advantage in irrigated cotton over rainfed cotton was also reported by Shinde *et al.* (2009); Bandyopadhyay *et al.* (2009).

Lint yield. Irrigation schedules significantly influenced the lint yield. Significantly higher lint yield (711 kg ha^{-1}) was recorded with irrigation scheduled at 0.8 IW/CPE (I_1) over 0.4 IW/CPE (I_2) with lint yield of 644 kg ha^{-1}. However, they were comparable with each other and were superior over rainfed (I_3) cotton, with reduced lint yield (507 kg ha^{-1}).

Stalk yield. Irrigation schedules did not exert any significant influence on stalk yield. Each successive increase in irrigation from rainfed (I_3) cotton to 0.8 IW/CPE (I_1) throughout the crop life cycle increases the stalk yield due to favourable soil moisture supply finally leading to increased vegetative growth. These results were in accordance with the findings of Ahlawat and Gangaih (2010).

Harvest index, Ginning percentage, Lint Index and earliness index. Irrigation schedules did not exert significant influence on harvest index, ginning percentage and lint index, earliness index.

Nitrogen uptake. Nitrogen uptake differed significantly with irrigation schedules at all the stages, significantly higher nitrogen uptake (3.6, 58, 99, 85 and 73 kg ha^{-1}) was recorded with irrigation scheduled at 0.8 IW/CPE (I_1) and was followed by 0.4 IW/CPE (I_2) with nitrogen uptake of 3.3, 55, 94, 81 and 71 kg ha^{-1} at square initiation, boll development, first, second and third picking stages, respectively. However, they were comparable with each other at respective stages and were significantly superior over rainfed (I_3) cotton, with reduced nitrogen uptake (2.7, 41, 65, 60 and 50 kg ha^{-1})

at square initiation, boll development, first, second and third picking stages, respectively.

The higher nitrogen uptake mainly attributed to higher drymatter production at increased irrigation frequencies. The present results were in conformity with the findings of Bandyopadhyay *et al*. (2009).

Table 1: Plant height (cm), phenology and drymatter (g plant^{-1}) production of cotton under varied levels of irrigation schedules and nitrogen levels during 2015.

Treatments	Plant height (cm)				Days to phenology				Drymatter (g plant^{-1}) production					
	SI	Flow	BD	III Pick	Days to SI	Days to Flow	Days to BD	III Pick	SI	Flow	BD	I Pick	II Pick	III Pick
Irrigation (I)														
I_1 - 0.8 IW/CPE	21 a	66 a	83 a	115 a	30 a	46 a	98 a	146	8.6 a	121 a	181 a	241 a	205 a	176 a
I_2 - 0.4 IW/CPE	20 a	63 a	80 a	114 a	30 a	46 a	98 a	146	7.8 a	109 a	177 a	234 a	201 a	178 a
I_3 - Rainfed	19 a	49 b	66 a	99 b	30 a	44 a	97 a	146	6.6 b	94 a	136 a	174 b	160 a	132 a
S. Em±	1.1	3.1	3.9	2.2	0.8	0.49	0.17	-	0.27	8.0	16.5	12.6	17.7	12.4
CD (p=0.05)	NS	11.9	NS	8.6	NS	NS	NS	-	1.10	NS	NS	49.4	NS	NS
Nitrogen (N)														
N_1 - 0 kg ha^{-1}	19 a	51 b	68 b	90 c	30 a	45 a	96 b	146	6.3 c	65 c	112 c	157 c	129 c	107 c
N_2 - 75 kg ha^{-1}	20 a	60 a	76 a	107 b	30 a	45 a	97 b	146	7.0 b	93 b	139 b	202 b	170 b	149 b
N_3 - 150 kg ha^{-1}	21 a	63 a	80 a	110 b	30 a	45 a	98 a	146	8.3 a	131 a	196 a	242 a	217 a	189 a
N_4 - 225 kg ha^{-1}	21 a	65 a	82 a	127 a	31 a	46 a	98 a	146	9.1 a	142 a	212 a	265 a	239 a	202 a
S. Em±	0.89	1.9	2.4	2.88	0.26	0.30	0.28	-	0.30	4.6	5.8	11.1	12.9	11.3
CD (p=0.05)	NS	5.6	7.2	8.55	NS	NS	0.85	-	0.90	13.6	17.0	32.9	38.2	34.0
Interaction (I X N)														
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	-	NS	NS	NS	NS	NS	NS

SI - Square initiation stage; Flow –Flowering stage; BD - Boll Development stage; Days to SI - Days to square initiation stage; Days to Flow - Days to flowering stage; Days to BD - Days to boll development stage; I Pick - 1st picking stage; II Pick - 2nd picking stage; III Pick - 3rd picking stage

Means with the same letter are not significantly different

Table 2: Yield and yield attributes, Ginning percentage, lint index and earliness index and Nitrogen uptake (kg ha^{-1}) of cotton under varied levels of irrigation schedules and nitrogen levels during 2015.

Treatments	No. of bolls plant^{-1}	Boll weight (g)	Seed index (g)	Seed cotton yield (kg ha^{-1})	Lint yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Harvest index	Ginning (%)	Lint index	Earliness Index	Nitrogen uptake (kg ha^{-1})				
											SI	BD	I Pick	II Pick	III Pick
Irrigation (I)															
I_1 - 0.8 IW/CPE	22 a	5.1 a	9.7 a	1965 a	711 a	2554 a	0.44 a	36.2 a	5.5 a	0.77 a	3.6 a	58 a	99 a	85 a	73 a
I_2 - 0.4 IW/CPE	21 a	5.0 a	9.5 a	1779 a	644 a	2507 a	0.41 a	36.1 a	5.4 a	0.78 a	3.3 a	55 a	94 a	81 a	71 a
I_3 - Rainfed	16 a	4.7 a	9.2 a	1420 b	507 b	1698 a	0.45 a	35.7 a	5.2 a	0.81 a	2.7b	41 b	65 b	60 b	50 b
S. Em±	1.43	0.19	0.2	54	23	205	0.02	0.23	0.11	0.02	0.13	3.2	3.8	5.1	4.3
CD (p=0.05)	NS	NS	NS	211	89	NS	NS	NS	NS	NS	0.5	12.6	15.1	19.9	16.8
Nitrogen (N)															
N_1 - 0 kg ha^{-1}	14 c	4.6 a	9.0 a	1100 c	385 c	1547 c	0.42 a	35.1 a	4.9 a	0.82 a	2.8b	33 c	54 c	45 c	37 c
N_2 - 75 kg ha^{-1}	20 b	5.0 a	9.5 a	1814 b	649 b	2109 b	0.47 a	35.8 a	5.3 a	0.78 a	2.8b	42 b	66 b	56 b	48 b
N_3 - 150 kg ha^{-1}	22 a	5.1 a	9.6 a	1979 a	724 a	2601 a	0.44 a	36.5 a	5.6 a	0.77 a	3.5 a	63 a	107 a	96 a	84 a
N_4 - 225 kg ha^{-1}	22 a	5.1 a	9.7 a	1992 a	725 a	2754 a	0.43 a	36.6 a	5.6 a	0.76 a	3.9 a	68 a	117 a	105 a	89 a
S. Em±	0.61	0.15	0.3	50	21	94	0.01	0.75	0.2	0.02	0.12	1.9	3.0	3.3	3.6
CD (p=0.05)	1.8	NS	NS	148	62	278	NS	NS	NS	NS	0.36	5.8	9.2	9.9	10.7
Interaction (I X N)															
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

SI - Square initiation stage; BD - Boll Development stage; I Pick - 1st picking stage; II Pick - 2nd picking stage; III Pick - 3rd picking stage

Means with the same letter are not significantly different

Effect of nitrogen

Plant height. Significantly higher plant height (65, 63 and 60 cm) at flowering and boll development (82, 80 and 76 cm) stage was registered with N_4 (225 kg ha^{-1}), N_3 (150 kg ha^{-1}) and N_2 (75 kg ha^{-1}), respectively over control N_1 (0 kg ha^{-1}) which recorded significantly lower plant height of 51 cm and 68 cm at flowering and boll development stages, respectively. At final picking stage, significantly higher plant height (127 cm) was registered with N_4 (225 kg ha^{-1}) over N_3 (150 kg ha^{-1}), N_2 (75 kg ha^{-1}) and N_1 (0 kg ha^{-1}). Plant height (110 and 107 cm) registered with N_3 (150 kg ha^{-1}) and N_2 (75 kg ha^{-1}), respectively was comparable with each other and significantly superior over N_1 (0 kg ha^{-1}), which recorded the lowest plant height (90 cm). The increase in plant height with increase in nitrogen levels might be due to favorable effect of nitrogen on growth and development of cotton. Similar positive response on plant height with incremental increase in nitrogen was observed by Gundlur *et al.* (2013); Sunitha *et al.* (2010).

Phenology. Days to attain square initiation and flowering stages were comparable with each incremental increase in nitrogen application. However, they differed significantly with number of days taken to attain boll development stage. Significantly more number of days (98) were taken with N_4 (225 kg ha^{-1}) and N_3 (150 kg ha^{-1}) to reach boll development stage over N_2 (150 kg ha^{-1}) and N_1 (0 kg ha^{-1}), in turn which has taken 97 and 96 days, respectively. However, N_2 (150 kg ha^{-1}) and N_1 (0 kg ha^{-1}) were comparable with each other for days to boll development stage. Howard *et al*. (2001) observed similar results and concluded that higher doses of nitrogen lead to more vegetative growth and causes delay in maturity.

D**rymatter production.** Significantly higher drymatter production (9.1, 142, 212, 265, 239 and 202 g plant^{-1}) was registered with N_4 (225 kg ha^{-1}) and was followed by N_3 (150 kg ha^{-1}) at square initiation, flowering, boll development, first, second and third picking stages, (8.3, 131, 196, 242, 217 and 189 g plant^{-1}) respectively in turn these were superior over N_2 (75 kg ha^{-1}) and N_1 (0 kg ha^{-1}). Similarly, significantly higher drymatter production (7.0, 93, 139, 202, 170 and 149 g plant^{-1}) was registered with N_2 (75 kg ha^{-1}) over N_1 (0 kg ha^{-1}), which recorded the lowest drymatter production (6.3, 65, 112, 157, 129 and 107 g plant^{-1}) at square initiation, flowering, boll development, first, second and third picking stages, respectively.

An indicator of a plant's stronger photosynthetic capacity is its higher dry matter output. A sufficient supply of nitrogen that has a positive effect on cell elongation can lead to a relatively higher plant height and leaf area by allowing the plant to absorb more radiant energy, which in turn causes the accumulation of more photosynthates and dry matter in the plant. Increased dry matter production with a sufficient nitrogen supply, as demonstrated by this study, is consistent with the conclusions drawn by Dhadgale *et al.* (2014); Sunitha *et al.* (2010).

Number of bolls plant^{-1}. Increased levels of nitrogen application significantly increased the number of bolls plant^{-1}. Significantly higher bolls plant^{-1} (22) was recorded with N_4 (225 kg ha^{-1}). This was not differed significantly with N_3 (150 kg ha^{-1}) with 22 bolls plant^{-1} and were significantly superior over N_2 (75 kg ha^{-1}) and N_1 (0 kg ha^{-1}). In turn this was followed by significantly higher bolls plant^{-1} (20) with N_2 (75 kg ha^{-1}) over N_1 (0 kg ha^{-1}), which recorded the lowest number of bolls plant^{-1} (14) over higher levels of nitrogen application.

Increased nitrogen application levels may have a positive impact on photosynthate development and translocation towards squares, resulting in increased boll retention and more bolls per plant. On the other hand, compared to when the plant was in an unstressed environment, fewer actively growing bolls resulted in the termination of vegetative growth and boll shedding when the plant was stressed with nitrogen. Therefore, it is reasonable to justify the reaction to applied N by keeping the larger green boll number. Hosamani *et al.* (2013); Gundlur *et al.* (2013) reported similar outcomes.

Seed cotton yield. Perusal of data on seed cotton yield revealed that, incremental increase in levels of nitrogen application significantly increased the seed cotton yield. Significantly higher seed cotton yield (1992 kg ha^{-1}) was recorded with N_4 (225 kg ha^{-1}) and was followed by N_3 (150 kg ha^{-1}) with seed cotton yield of 1979 kg ha^{-1} however these were comparable with each other and significantly superior over N_2 (75 kg ha^{-1}) and N_1 (0 kg ha^{-1}). In turn, significantly higher seed cotton yield (1814 kg ha^{-1}) was registered with N_2 (75 kg ha^{-1}) over N_1 (0 kg ha^{-1}), which showed significantly reduced seed cotton yield (1100 kg ha^{-1}).

The significant increase in seed cotton yield that resulted from applying higher nitrogen levels may have been caused by nitrogen's beneficial effects on growth characteristics, such as plant height, an increase in the number of bolls plant-1, the accumulation of dry matter plant^{-1}, and the plant's subsequent translocation towards the sink. These findings align with the findings of Dhadgale *et al.* (2014). Meena *et al.* (2007); Basavanneppa (2005) both noted a similar favorable impact of nitrogen on seed cotton output.

Lint yield. Significantly higher lint yield (725 kg ha^{-1}) was recorded with N_4 (225 kg ha^{-1}) and was followed by N_3 (150 kg ha^{-1}) with lint yield of 724 kg ha^{-1} however these were comparable with each other and significantly superior over N_2 (75 kg ha^{-1}) and N_1 (0 kg ha^{-1}). Further, significantly higher lint yield (649 kg ha^{-1}) with N_2 (75 kg ha^{-1}) over N_1 (0 kg ha^{-1}), which recorded significantly the lowest lint yield (385 kg ha^{-1}).

The increased lint yield might be due to availability of adequate nitrogen at increased levels of nitrogen application which resulted in more mature fibers which led to higher lint yield. These results were in accordance with the findings of Modhvadia *et al.* (2012).

Stalk yield. Graded levels of nitrogen significantly influenced the stalk yield. Significantly higher stalk yield (2754 kg ha^{-1}) was recorded with N_4 (225 kg ha^{-1}) and was followed by N_3 (150 kg ha^{-1}) with stalk yield of 2601 kg ha^{-1}, however these were comparable with each other and were significantly superior over N_2 (75 kg ha^{-1}) and N_1 (0 kg ha^{-1}). Further, significantly higher stalk yield (2109 kg ha^{-1}) was obtained with N_2 (75 kg ha^{-1}) over N_1 (0 kg ha^{-1}), with significantly lesser stalk yield (1547 kg ha^{-1}).

Harvest index, Ginning percentage, Lint Index, earliness index. Incremental increase in nitrogen application from N_1 (0 kg ha^{-1}) to N_4 (225 kg ha^{-1}) did not exert significant influence on harvest index, ginning percentage and lint index, earliness index.

Nitrogen uptake. The difference in nitrogen uptake was conspicuous with graded levels of nitrogen application. At square initiation stage significantly higher nitrogen uptake (3.9 and 3.5 kg ha^{-1}) was registered with N_4 (225 kg ha^{-1}) and N_3 (150 kg ha^{-1}) and were comparable with each other. These were significantly superior over N_2 (75 kg ha^{-1}) and N_1 (0 kg ha^{-1}), with nitrogen uptake of 2.8 kg ha^{-1}. At boll development, first, second and third picking stages significantly higher nitrogen uptake (68, 117, 105 and 89 kg ha^{-1}) was registered with N_4 (225 kg ha^{-1}) and was comparable with N_3 (150 kg ha^{-1}) with 63, 107, 96 and 84 kg ha^{-1} of nitrogen uptake, in turn these were significantly superior over N_2 (75 kg ha^{-1}) and N_1 (0 kg ha^{-1}). Further, significantly higher nitrogen uptake (42, 66, 56 and 48 kg ha^{-1}) was registered with N_2 (75 kg ha^{-1}) over N_1 (0 kg ha^{-1}), which recorded significantly the lowest nitrogen uptake (33, 54, 45 and 37 kg ha^{-1}) at boll development, first, second and third picking stages, respectively.

Higher levels of application improve plant height, boll number, boll weight, and dry matter output. This could be the result of favorable soil moisture and nutrient nitrogen availability in the soil. These results closely matched those reported by Modhvadia *et al.* (2012).

CONCLUSIONS

The experiment's results indicate that higher kapas yields of Bt cotton in the alfisols of the Southern Telangana Zone were achieved by applying nitrogen at a rate of 150 kg ha^{-1} and scheduling irrigation at 0.4 IW/CPE.

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