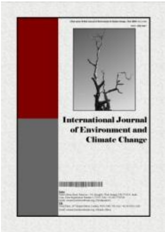

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Influence of Different Drip Irrigation and Fertigation Levels on Yield and Economics of High-density Cotton

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted to study the effect of different drip irrigation and fertigation levels on yield and economics of high-density cotton at College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Hyderabad, during *kharif* 2019 and 2020. The experiment

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consisted of twelve treatments laid out in Factorial randomised block design (FRBD) replicated thrice. Three irrigation levels (irrigation scheduled at 0.6 [I_1], 0.8 [I_2] and 1.0 [I_3] Epan throughout the crop growth period) and 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 crop coefficient curve [F_4],) were included as treatments in this study. Irrigation levels did not show any significant influence on yield and economics during 2020 and 2021. While among the four fertigation levels, application of 125% RDNK in differential dosage as per crop coefficient curve (F_4) recorded significantly higher gross returns, net returns and B:C ratio which were on par with application of 125% RDNK in differential dosage as per recommendation (F_3). Lower gross returns, net returns and B:C ratio were obtained with the application of 100% RDNK in differential dosage as per recommendation (F_1) which were on par with application of 100% RDNK in differential dosage as per crop coefficient curve during both the seasons (F_2). Further the gross returns and net returns produced under F_3 was also on par with F_2.

Keywords: Irrigation; fertigation; gross returnsl; net returns; cotton.

1. INTRODUCTION

Cotton (*Gossypium* sp.) which is known as “King of fibre’’ as well as “White gold” as it possesses more economical value among cultivable crops for a quite long period. It is one of the most important, cash, commercial and fibre crop of our country. India is the largest cotton growing country in the world occupying in an area of 13.47 million ha with production and productivity of 36.06 million bales and 455 kg ha^{-1} respectively [1]. Whereas, in Telangana, cotton is cultivating in an area of 2.45 million ha with production and productivity of 5.03 million bales and 353.73 kg ha^{-1} respectively [2]. About 34.0 % of area in India is growing under irrigation whereas, in Telangana it is only 11.6 % [3]. Cotton is one of the major crop in Telangana. However, it is mostly grown under rainfed conditions being one of the causes for its lower productivity. Apart from this, around 80 % of cotton in Telangana state is cultivated in low to medium fertile soils where closer planting is needed to accommodate more plants per unit area to realise maximum potential of varieties. *Bt* Cotton hybrids played a significant role to attain self-sufficiency in production in India and effectively reduced the attack of boll worms. But in the recent years, *Bt* cotton has started developing resistance against boll worms, proved to be ineffective against sucking pests as a result of which the usage of pesticides has increased and the seed cost is also high as compared to non *Bt* cotton seeds. All the above factors are making the cotton cultivation more risky and non-remunerative [4]. In this scenario, non *Bt* cotton varieties will serve as an alternative to *Bt* cotton hybrids and produce higher yield if proper management practices are followed. In order to achieve higher productivity in cotton, irrigation and fertilizer management are the most important factors. The lower yields of cotton could be attributed to inefficient irrigation and fertilizer management practices [5]. To exploit maximum efficiency from available resources (water and nutrients) and to obtain higher net returns it is necessary to use modern technology such as drip method of irrigation with high density population by which irrigation water and fertilizers can be applied precisely and in balanced manner to cater the need of crop plants. As density is increased 55.5 to 77.7% against normal planting density (*i.e* 18517 and 37037 plants per hectare) there is a need to revalidate fertilizer schedule of cotton to reach maximum yield potential from increased population**.** Available research information on scheduling fertigation to cotton based on crop growth stages, uptake of nutrients are assumptions based only. Precise water as well as nutrients scheduling on scientific basis such as crop coefficient (Kc) values is not available in cotton.Hence, there is need to revalidate the fertigation scheduling pattern as per crop growth stages in order achieve maximum yield potential and profits. 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 yield and economics.

2. MATERIALS AND METHODS

The present experiment was carried out at College Farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural

University, Rajendranagar, Hyderabad, Telangana State. The farm is geographically situated at an altitude of 542.3 m above mean sea level at 17°19' N latitude and 78°23' E longitude in the Southern Telangana agro-climatic zone of Telangana and it is classified under semi-arid tropics (SAT) according to Troll's classification.

The mean weekly maximum temperature during cropping period ranged from 26.8 to 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. Whereas, the weekly mean minimum temperature varied between 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 during 2020-21.The weekly mean morning relative humidity (RH I) fluctuated between 84.0 to 98.2% with an average of 90.1% in 2019-20 and between 83.9 to 98.8% with an average of 91.4% in 2020-21, respectively indicating high percentage of humidity in the atmosphere. The weekly mean afternoon relative humidity (RH II) fluctuated between 41.5 to 79.8% with an average of 60.7% in 2019-20 and between 38.8 to 92.6% with an average of 65.8% in 2020-21, respectively. The total evaporation during the crop study was 649.9 mm in 2019-20 and 611.3 mm during 2020-21. During the crop growth period, rainfall of 706.1 mm was received in 47 rainy days in 2019-20 and 1283.2 mm in 60 rainy days in 2020-21, respectively. During both the seasons of experiment the crop was majorly grown with moisture received through rainfall.

The soil of the experimental area is sandy loam in texture (75.24 sand, 10.4 % silt, and 14.06 % clay) with an average bulk density of 1.59 Mg m^3 for 0-60 cm depth and is slightly alkaline in reaction with pH values ranging from 7.4 to 7.5. Field capacity, wilting point, and available water holding capacity of soil for 60 cm depth were 16.05%, 7% and 83.33 respectively. The available macronutrient values N, P, and K were 182.4, 63.8, and 329.9 kg ha^{-1}. The experiment consisted of twelve treatments laid out in Factorial randomised block design (FRBD) replicated thrice. Three irrigation levels (irrigation at 0.6 [I_1], 0.8 [I_2] and 1.0 Epan [I_3], throughout the crop growth period) and 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],125% RDNK in differential dosage as per recommendation [F_3] and 125% RDNK in differential dosage as per crop coefficient curve) [F_4], were included as treatments in this study The crop was sown on July 15th , 2019 during 1st season and on June 18th, 2020 during 2nd season. Cotton composite variety which was used in the study is ADB-542. The spacing followed was 60x20 cm. The crop was supplied with recommended fertilizer dose of fertilizers with 90 kg N, 48 kg P_2O_5 and 48 kg K_2O ha^{-1} through urea, single super phosphate and sulphate 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.

Whereas, for the treatments F_2 and F_4 fertigation was given in differential dosages as per crop coefficient curve in 100% and 125% RDF respectively which was given in detail in Table 2.

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

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 was scheduled at every 3 days. The irrigation scheduling was done based on pan evaporation replenishment in treatments. The irrigation water was applied on the basis of pan evaporation (PE) data obtained from (USWB open pan evaporation) installed at the Agromet centre, ARI, Rajendranagar, Hyderabad. The quantity of applied water to each treatment was measured with the help of water meter. During rainy days, the volume of water applied to each treatment was adjusted for the effective rainfall received. 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.

$$\text{Application rate (mm hr} - 1) = \frac{Q}{\text{DL X DE}}$$

Whereas

Q = Dripper discharge (liters h^{-1}),D_L = Distance between lateral spacing (m)
D_E = Distance between dripper (emitters) spacing (m)

Irrigation time for each treatment was calculated using following formulae.

$$\text{Irrigation time (minutes)} = \frac{\text{Epan (mm)} \times 60}{\text{Application rate (mm hr} - 1)}$$

The prices of the inputs prevailed in local market during experimentation were considered for working out the cost of cultivation of cotton. The gross returns were calculated using the seed cotton yield of cotton and the market price of the produce at the time of marketing. The net returns per hectare were calculated by deducting the cost of cultivation per hectare from the gross returns per hectare.

Net monetary return = Gross monetary return - Total cost of cultivation

Benefit cost ratio = Gross returns (Rs ha^{-1}) **/** Cost of cultivation (Rs ha^{-1})

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 [6]. Critical difference for examining treatments means for their significance was calculated at 5 percent level of probability.

3. RESULTS AND DISUSSION

3.1 Seed Cotton Yield (kg ha^{-1})

A perusal of data (Table 3) on seed cotton yield revealed that the seed cotton yield was not significantly influenced by the different drip irrigation levels during both the years of study and in means. However, seed cotton yield ranged from 2237 to 2252 kg ha^{-1} during 2019, 2046 to 2090 kg ha^{-1} during 2020 and 2141 to 2171 kg ha^{-1} in means. This was mainly due to the fact that throughout the crop growth period during the 1st season of study i.e from 15th July 2019 to 23rd January 2020 there was an amount of rainfall of 706.1 mm. Most of the rainfall was distributed during the months of august, September and October where it coincided with the moisture sensitive stages of the cotton crop i.e square formation, flowering and boll formation stages. Due to heavy rains during these crop growth stages irrigation was not scheduled and the treatment effect got nullified. While, during the second season of study i.e 18th June 2020 to 28th November 2020, the total amount of rainfall 1283.2 mm was received which was distributed during the months of July, August, September and October, which resulted into continuous rains throughout the crop growth stages. As a result, crop did not suffered from moisture stress during moisture sensitive periods and there was uniform distribution of soil moisture in the root zone. In this way during both the years of study crop grown with sufficient amount of moisture received through rainfall. This might be the reason that there was no significant effect of irrigation regimes on seed cotton yield.

While, among four fertigation levels, application of 125 % RDNK in differential dosage as per crop coefficient curve (F_4) produced significantly higher seed cotton yield (2446, 2178 and 2312 kg ha^{-1}) over application of 100 % RDNK in differential dosage as per recommendation (F_1) (2040, 1953 and 1997 kg ha^{-1}) and application of 100 % RDNK in differential dosage as per crop coefficient curve (F_2) (2113, 2000 and 2057 kg ha^{-1}) which was statistically at par with with the seed cotton yield obtained with the application of 125 % RDNK in differential dosage as per recommendation (F_3) (2384, 2129 and 2256 kg ha^{-1}) during 2019, 2020 and in means. While application of 100 % RDNK in differential dosage as per recommendation (F_1) resulted in lower seed cotton yield which was on par with F_2 during both the years and in means. Further seed cotton yield obtained through F_3 was also comparable with F_2.

The higher yield recorded with the application of 125 % RDNK in differential dosage as per crop coefficient curve (F_4) might be due to applying lower rates of fertiliser during initial stages and higher rates at flowering and boll formation stages met the crop nutrient requirement which made the crop to uptake more nutrients thereby resulting in producing more yield attributes finally resulting in higher seed cotton yield when compared to other fertigation levels (F_3, F_2 and F_1). On the other hand, F_3 and F_2 were also at par with each other which shows that applying the nutrients according to the crop growth needs in a more scientific way (Kc curve based) can also save the amount of fertilisers (25%) used. Further, the higher seed cotton yield under the treatments (F_3 and F_4) over (F_2 and F_1) might be due to the fact that increased nutrient availability and absorption by the crop at the optimum moisture supply coupled with frequent and higher nutrient supply by fertigation and consequent better formation and translocation of assimilates from source to sink. Increase in the seed cotton yield with the increase in N and K levels were also earlier reported by Kakade et al*.* [7], Bhaskar [8], Jayakumar et al*.* [9], Aladakatti et al*.* [10] and Hadole et al*.* [11].

There was no significant interaction effect between different drip irrigation and fertigation levels during both the years on seed cotton yield.

3.2 Stalk Yield (kg ha^{-1})

An overview of data (Table 3) indicated that the irrigation levels did not showed any significant influence on stalk yield of cotton crop during both the years and in means. However, it ranged from 5897 to 5935 kg ha^{-1} during 2019, 5788 to 5857 kg ha^{-1} during 2020 and 5843 to 5896 kg ha^{-1} in means. Among the fertigation levels, application of 125 % RDNK in differential dosage as per crop coefficient curve (F_4) produced significantly higher stalk yield (6287, 6210 and 6248 kg ha^{-1}) which was at par with the application of 125 % RDNK in differential dosage as per recommendation (F_3) (6241, 6007 and 6124 kg ha^{-1}). While application of 100 % RDNK in differential dosage as per recommendation (F_1) resulted in lower stalk yield (5551, 5419 and 5485 kg ha^{-1}) which was comparable with the application of 100 % RDNK in differential dosage as per crop coefficient curve (F_2) (5586, 5666 and 5626 kg ha^{-1}) during 2019. Higher stalk 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 and ultimately produced more biological yield. These results are in accordance with the findings of Magare et al*.* [12]. Fertigation in differential dosage as per crop

Table 3. Seed cotton and stalk yield (kg ha^{-1}) of cotton as influenced by different drip irrigation and fertigation levels

Treatments	Seed cotton yield (kg ha^{-1})			Stalk yield (kg ha^{-1})		
	2019	2020	Means	2019	2020	Means
Irrigation levels (I)						
I_1: Drip irrigation 0.60 Epan throughout crop growth period	2237	2046	2141	5897	5788	5843
I_2: Drip irrigation 0.80 Epan throughout crop growth period	2248	2060	2154	5917	5831	5874
I_3: Drip irrigation 1.0 Epan throughout crop growth period	2252	2090	2171	5935	5857	5896
SEm±	81	50	-	166	187	-
CD (P=0.05%)	NS	NS	-	NS	NS	-
Fertigation levels (F)						
F_1:100 % RDNK (differential dosage of N & K as per recommendation)	2040	1953	1997	5551	5419	5485
F_2:100 % RDNK (differential dosage of N & K as per crop coefficient curve)	2113	2000	2057	5666	5586	5626
F_3: 125 % RDNK (differential dosage of N & K as per recommendation)	2384	2129	2256	6241	6007	6124
F_4:125% RDNK (differential dosage of N & K as per crop coefficient curve)	2446	2178	2312	6287	6210	6248
SEm±	94	58	-	192	216	-
CD (P=0.05%)	275	170	-	562	634	-
Interaction (IXF)						
SEm±	163	100	-	332	374	-
CD (P=0.05%)	NS	NS	-	NS	NS	-

Table 4a. Economics of cotton as influenced by different drip irrigation and fertigation levels

Treatments	Cost of cultivation (≠ ha^{-1})			Gross returns (≠ ha^{-1})		
	2019	2020	Means	2019	2020	Means
Irrigation levels (I)						
I_1: Drip irrigation 0.60 Epan throughout crop growth period	53565	57835	55700	116888	113637	115262
I_2: Drip irrigation 0.80 Epan throughout crop growth period	53883	58457	56170	117476	114415	115945
I_3: Drip irrigation 1.0 Epan throughout crop growth period	54331	58984	56657	117655	116104	116879
SEm±	-	-	-	4087	2784	-
CD (P=0.05%)	-	-	NS	NS	NS	-
Fertigation levels (F)						
F_1:100 % RDNK (differential dosage of N & K as per recommendation)	52361	56836	54599	106595	108510	107552

Treatments	Cost of cultivation (≠ ha^{-1})			Gross returns (≠ ha^{-1})		
	2019	2020	Means	2019	2020	Means
F_2:100 % RDNK (differential dosage of N & K as per crop coefficient curve)	52361	56836	54599	110423	111088	110755
F_3: 125 % RDNK (differential dosage of N & K as per recommendation)	55492	60014	57753	124556	118265	121410
F_4:125% RDNK (differential dosage of N & K as per crop coefficient curve)	55492	60014	57753	127785	121013	124399
SEm±	-	-	-	4719	3215	-
CD (P=0.05%)	-	-	-	13842	9429	-
Interaction (IXF)						
SEm±	-	-	-	8174	5568	-
CD (P=0.05%)	-	-	-	NS	NS	-

Table 4b. Economics of cotton as influenced by different drip irrigation and fertigation levels

Treatments	Net returns (≠ ha^{-1})			Benefit cost ratio		
	2019	2020	Means	2019	2020	Means
Irrigation levels (I)						
I_1: Drip irrigation 0.60 Epan throughout crop growth period	63323	55802	59562	2.2	2.0	2.1
I_2: Drip irrigation 0.80 Epan throughout crop growth period	63592	55958	59775	2.2	2.0	2.1
I_3: Drip irrigation 1.0 Epan throughout crop growth period	63324	57120	60222	2.2	2.0	2.1
SEm±	2904	1391	-	0.08	0.05	-
CD (P=0.05%)	NS	NS	-	NS	NS	-
Fertigation levels (F)						
F_1:100 % RDNK (differential dosage of N & K as per recommendation)	54234	51674	52954	2.0	1.9	2.0
F_2:100 % RDNK (differential dosage of N & K as per crop coefficient curve)	58062	54251	56156	2.1	2.0	2.0
F_3: 125 % RDNK (differential dosage of N & K as per recommendation)	69064	58250	63657	2.2	2.0	2.1
F_4:125% RDNK (differential dosage of N & K as per crop coefficient curve)	72292	60998	66645	2.3	2.0	2.2
SEm±	3354	1606	-	0.09	0.05	-
CD (P=0.05%)	9837	4711	-	NS	NS	-
Interaction (IXF)						
SEm±	5809	2782	-	0.15	0.09	-
CD (P=0.05%)	NS	NS	-	NS	NS	-

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

Interaction effect of irrigation and fertigation levels on stalk yield was found non-significant during 2019, 2020 and in means.

3.3 Cost of Cultivation

Cost of cultivation varied from □. 52361 to 55492 ha^{-1} and □.56836 to 60014 ha^{-1} (Table 4.4a) in different treatments of cotton crop. Main variation in cost of cultivation was due to fertigation levels of N & K_2O, cost of water, fertilizers and man power required for irrigation, fertigation and other operations among treatments.

3.4 Gross Returns (≠. ha^{-1})

The data related to gross returns of cotton crop was presented in Table 4.4a.

Gross returns were not affected statistically because of varied irrigation levels during both the years of study. Whereas, Gross returns from drip irrigated cotton varied among different fertigation levels. Higher gross returns (□.127785, 121013 and 124399 ha^{-1}) were recorded with the application of 125 % RDNK as per crop coefficient curve (F_4) when compared to application of 100 % RDNK as per crop coefficient curve (F_2) (□.110423, 111088 and 110755 ha^{-1}) and application of 100 % RDNK as per recommendation (F_1) (□. 106595, 108510 and 107552 ha^{-1}) and was on par with application of 125% RDNK as per recommendation (F_3) (□.124556, 118265 and 121410 ha^{-1}) during 2019, 2020 and in means. While, F_1 and F_2 were at par with other. The higher gross returns among F_3, F_4 was due to higher seed cotton yield obtained over other fertigation levels F_1, F_2. Further the gross returns obtained with F_3 was also on par with F_2. Similar results were reported by Magare et al*.* [12], Mark Gladson [13], Bharath Raj et al*.* [14] and Jagvir et al*.* [15].

The interaction effect was found non significant during 2019 and 2020.

3.5 Net Returns (Rs. ha^{-1})

Net returns obtained from cotton during 2019 and 2020 were not influenced significantly by different irrigation regimes.

Data revealed (Table 4.4b) that the fertigation levels influenced the net returns obtained from cotton crop. Net returns were higher (□.72292, 60998 and 66645 ha^{-1}) with the application of 125 % RDNK as per crop coefficient curve (F_4) when compared to application of 100 % RDNK as per crop coefficient curve (F_2) (□.58062, 54251 and 56156 ha^{-1}) and application of 100 % RDNK as per recommendation (F_1) (□.54234, 51674 and 52954 ha^{-1}) and was on par with application of 125% RDNK as per recommendation (F_3) (□.69064, 58250 and 63657 ha^{-1}) during 2019 and 2020. The higher net returns among F_3, F_4 was due to higher seed cotton yield obtained over other fertigation levels F_1, F_2. Further the net returns obtained with F_3 was also on par with F_2. The results observed with present investigation are in support with the results reported by Magare et al*.* [12], Mark Gladson. [13], Bharath Raj et al*.* [14] and Jagvir et al*.* [15].

There was no significant interaction effect due to irrigation regimes and fertigation levels on net returns in this present investigation.

3.6 Benefit: Cost Ratio

B:C ratio were not significantly influenced by different irrigation, fertigation levels and their interaction during both the seasons of investigation.

4. CONCLUSIONS

Based on the results obtained in the present investigation, it is concluded that the high-density cotton crop grown with fertigation at 125 % RDN and K in differential dosage as per crop coefficient curve and as per recommendation during *kharif* under Hyderabad semi-arid conditions realized better seed cotton yield and returns. Fertigation given through scientific basis i.e according to crop coefficient curve can save the 25% of fertilizers such that cost of cultivation can also be reduced.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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