



Assessing the Influence of Crop Diversification of Intercrops with Cotton on Growth and Yield Characteristics of Cotton

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ABSTRACT

Background: Intercropping cotton with pulses and millets, forming a multi-tier system, has the potential to shift the cost-intensive cotton production system towards a more profitable and sustainable approach. The study aimed to explore suitable intercrop combinations for multitier cultivation in cotton under rainfed conditions.

Methods: The experiment involved seven multi-tier *Bt* cotton intercropping systems and two sole *Bt* cotton treatments with different spacing tried in a randomized block design with three replications during the *kharif* seasons of 2020-21, 2021-22 and 2022-23.

Result: The study showed significant effects of various multi-tier cropping systems on cotton's growth attributes, yield traits and yield. Seed cotton equivalent yield varied between 864 to 1401 kg/ha in different intercropping systems. In comparison, sole *Bt* cotton yielded 1103 kg/ha and the farmer's practice resulted in 827 kg/ha.

Key words: Cotton, Growth, Intercrops, Yield attributes, Yield.

INTRODUCTION

Cotton (*Gossypium hirsutum*), a crucial cash crop in the textile industry, faces challenges like increased susceptibility to pests, soil nutrient depletion and environmental issues due to monoculture. Due to the slow growth of cotton, much of the space between plants remains unused during the initial stages of crop development. This situation provides ample opportunity for rising intercrops (Kumar *et al.*, 2017). Multitier farming addresses these concerns by integrating complementary crops with cotton, offering synergistic benefits and mitigating the drawbacks of monoculture (Vaghasia and Dobariya, 2021). Redgram (*Cajanus cajan*) and greengram (*Vigna radiata*), as leguminous crops, play a vital role in multitier farming by fixing atmospheric nitrogen and reducing the need for synthetic fertilizers in cotton cultivation. Their deep roots enhance soil structure, promote nutrient cycling and reduce erosion which contributing to overall sustainability (Sravanthi *et al.*, 2022). Foxtail millet (*Setaria italica*), adaptable to various conditions and water-scarce environments, serves as an ideal companion crop and provides an additional income source through millet grain production (Singh *et al.*, 2009).

Multitier farming involving cotton with redgram, greengram and foxtail millet provides numerous advantages that extend well beyond sustainable resource management. The integration of companion crops diversifies the agro-ecosystem, mitigating the risk of pest and disease outbreaks often associated with monoculture (Singh *et al.* 2017 and Ramamurthy *et al.* 2023). Intercropping of legumes is a crucial aspect for biological farming system not only for weed control, but also in

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reducing the pest control, leaching of nutrients and soil erosion (Chaudhari *et al.*, 2017 and Jayakumar and Surendran, 2017).

The primary aim of this study is to delve into the concept of synergistic growth and sustainable development within the context of multitier farming. Specifically, the study focused on the potential for cotton growth and development

achieved by intercropping with redgram, greengram and foxtail millet. Through a thorough examination of the advantages and obstacles associated with this agricultural practice, the study endeavors to offer valuable insights into how such an intercropping system can bolster crop productivity and economic viability.

MATERIALS AND METHODS

Cotton was sown on flatbed under rain-fed conditions in scarce rainfall zone of Andhra Pradesh at Regional Agricultural Research Station in Nandyal, India on 07 July, 11 August and 18 July of 2020, 2021 and 2022 years respectively. The intercropping system are as under: Sole *Bt* cotton (90 cm × 45 cm) (T_1), paired row planting of *Bt* cotton with two rows of greengram (GG) (T_2), paired row planting of *Bt* cotton with two rows of redgram (RG) (T_3), paired row planting of *Bt* cotton with two rows of foxtail millet (FM) (T_4), paired row planting of *Bt* cotton with one row of greengram + one row of redgram (T_5), paired row planting of *Bt* cotton with one row of redgram + one row of foxtail millet (T_6), paired row planting of *Bt* cotton with one row of foxtail millet + one row of greengram (T_7), farmers practice (120 cm × 60 cm) (T_8) and recommended intercropping (1:3 of cotton + greengram) (T_9) (Fig 1). The experiment was laid out in randomized block design with three replications.

The cultivar sown were '*Bt* hybrid Sadananda' (cotton) with 155 days maturity, 'PRG 176 (Redgram)' with 130 days maturity, 'Sia 3222' (Foxtail millet) and 'IPM-2-214' (greengram) with 60 days maturity. Recommended nutrients were applied to cotton (*i.e.*, 150:60:60 N:P:K kg/ha). Entire quantity of phosphorus was applied basally. Nitrogen and potassium were applied in three splits at 30, 60 and at 90 DAS. While, the intercrops received fifty per cent of the recommended nutrients of their sole cropping, *i.e.* redgram (6.25:12.5:6.25 NPK kg/ha), Foxtail millet (20:15:0 NPK kg/ha) and greengram (6.25:12.5:6.25 NPK kg/ha). All the intercropping treatments have 100 per cent population of cotton along with pulses and millet as an intercrop in paired row planting method. Cotton and intercrops were hand dibbled simultaneously. Plot dimension was 8.4 m × 3.6 m. Recommended cultural practices and plant protection measures were followed throughout the crop growing season as per the guidelines of ANGRAU University.

During the harvest phase, the data on different observations were recorded, including growth (Plant height and No. of monopodia), yield attributes (No. of sympodia, No. of bolls/m² and boll wt.) and yield. A concept of cotton equivalent yield was devised to standardize the comparison of different crops' yields. This method facilitates a consistent assessment across various crops by converting their yields into a comparable value based on cotton prices as the standard benchmark.

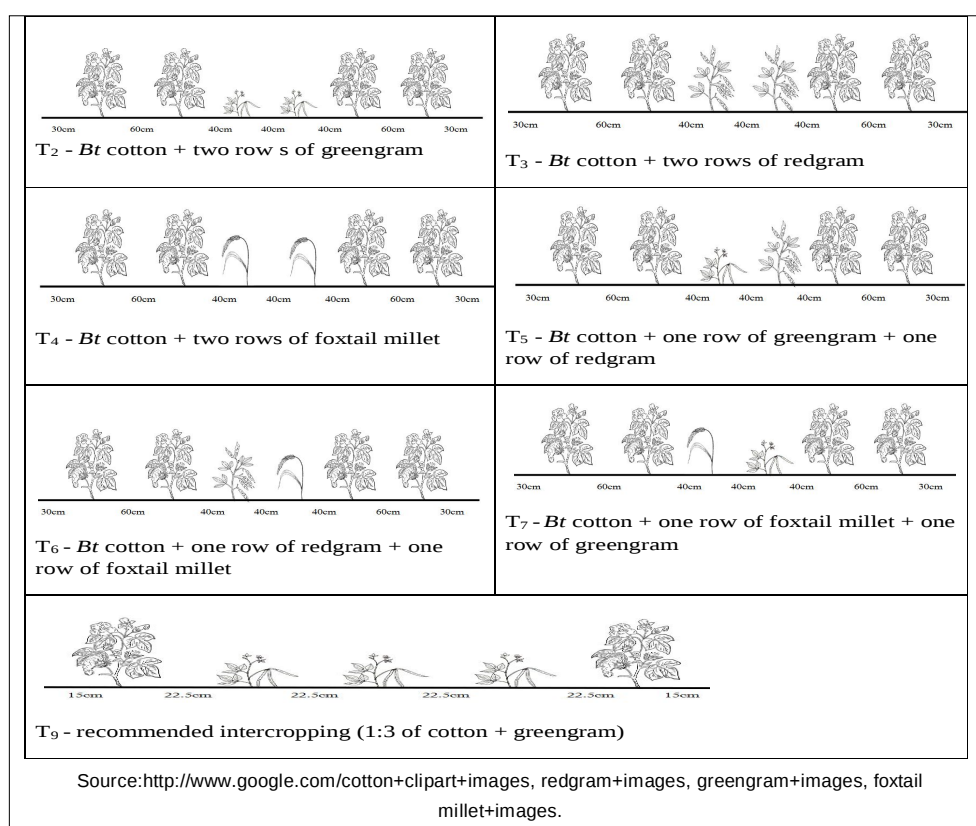


Fig 1: Layout of multitier cropping system in cotton.

Cotton equivalent yield (kg/ha) = Yield of component crop * (Price of cotton/Price of component crop).

A Two-Way ANOVA was employed to statistically assess the impact of the multitier cropping system in cotton with different intercrops. Variations among the means were examined using the Bartlett test for homogeneity of variances, and significance was considered at a p-value below 0.05. The ANOVA analysis and correlation analysis were conducted using the Grapes software provided by KAU Gopinath *et al.* (2020).

RESULTS AND DISCUSSION

Intercropping of pulses and millet with cotton had significant effect on plant height (Table 1). In the three years pooled data, Intercropping of cotton+greengram (1:3) did not reduce the plant height (92.2 cm) and was comparable with sole *Bt* cotton (100.2 cm). The increased plant height in these cases can be attributed to improved light penetration and enhanced air circulation among the plants. Similarly, cotton+greengram, cotton+foxtail millet, cotton + greengram + redgram, cotton+redgram+foxtail millet and cotton+foxtail millet+greengram did not affect plant height statistically with each other but differed significantly with that from rest of the intercropping systems (S). Conversely, the shortest plant height of 75.1 cm was recorded with cotton+redgram. This reduction in height may be attributed to the competitive nature of redgram, which hindered the growth of the companion cotton crop. Sankaranarayanan

et al. (2012) also reported reduction in plant height in different intercropping systems as compared to sole cotton plots. Whereas, intercropping with pulses and millet in cotton did not have a notable effect on the development of monopodial branches.

Intercropping of pulses and millet in cotton had significant effect on number of sympodia and number of bolls/m² (Table 2). Cotton + redgram recorded significantly lowest number of bolls/m² (8.0) as compared to sole *Bt* cotton (11.8), followed by cotton + foxtail millet (10.8). Number of bolls/m² was highest with sole *Bt* cotton (25.2) which was on par with cotton + foxtail millet (22.8), but the lowest number of bolls/m² was with the cotton + greengram in 1:3 ratio (16.0). These findings align with the research conducted by Pandagale *et al.* (2019) and can be attributed to intense competition among component crops in various intercropping systems for essential growth factors such as water, nitrogen, and light, crucial for boll setting. Similar results were reported by Sangameshwari (2023), while studying the compatibility of intercropping of oilseeds in rainfed cotton.

The data on boll weight and seed cotton yield are presented in Table 3 and cotton equivalent yield in Fig 2. Pooled data of three years indicated that boll weight and seed cotton yield was adversely affected by intercropping with different pulses and millet. In the pooled analysis, the highest boll weight (Table 3) was observed in sole *Bt* cotton (4.4 g), followed closely by the farmers' practice (3.9 g).

Table 1: Effect of multitier cropping system on plant height and no.of monopodia at harvest stage during the study period of 2020-2022.

Treatments	Plant height (cm)				No. of monopodia			
	2020	2021	2022	Pooled	2020	2021	2022	Pooled
Sole <i>Bt</i> cotton (90 cm × 45 cm)	116.6 ^a	83.1 ^a	100.8 ^a	100.2 ^a	0.73	0.80	0.73	0.76
Paired planting of <i>Bt</i> cotton + two rows of GG	100.0 ^{bcd}	65.8 ^{bc}	92.4 ^{ab}	86.1 ^{bcd}	0.80	0.87	0.87	0.84
Paired planting of <i>Bt</i> cotton + two rows of RG	90.9 ^d	63.6 ^c	70.7 ^c	75.1 ^e	0.67	0.87	0.80	0.78
Paired planting of <i>Bt</i> cotton + two rows of FM	107.9 ^{abc}	74.7 ^{ab}	78.8 ^{bc}	87.1 ^{bcd}	0.67	0.60	0.60	0.62
Paired planting of <i>Bt</i> cotton + one row of GG + one row of RG	97.9 ^{bcd}	70.7 ^{bc}	80.3 ^{bc}	82.2 ^{cde}	0.53	0.87	0.87	0.76
Paired planting of <i>Bt</i> cotton + one row of RG + one row of FM	98.16 ^{bcd}	68.4 ^{bc}	78.7 ^{bc}	79.9 ^{de}	0.87	0.73	0.73	0.78
Paired planting of <i>Bt</i> cotton + one row of FM +one row of GG	95.5 ^{cd}	68.5b ^c	71.8 ^c	79.4 ^{de}	0.73	0.93	0.73	0.80
Farmers practice (120 cm × 60 cm)	112.3 ^{ab}	72.3 ^{bc}	83.2 ^{bc}	89.3 ^{bc}	0.80	0.80	0.80	0.80
Recommended intercropping (1:3 ratio of cotton + GG)	110.3 ^{abc}	75.2 ^{ab}	91.2 ^{ab}	92.2 ^{ab}	0.87	0.93	0.87	0.89
SEd	7.3	4.8	7.3	3.7	0.10	0.10	0.08	0.09
SEm±	5.2	3.4	5.2	2.6	0.07	0.07	0.06	0.07
CD (5%)	15.6	10.2	15.7	8.1	NS	NS	NS	NS
CV%	8.8	8.3	11	10	17	15	12	14

The lowest value was recorded in the recommended intercropping method (1:3 ratio of cotton to greengram) at 3.2 g. Similar result was reported by Ramamurthy *et al.* (2023). Significantly lower SCY was recorded when cotton + greengram in 1:3 row proportions (757 kg/ha), where as sole Bt cotton yielded the highest (1103 kg/ha), comparable to cotton + foxtail millet (974 kg/ha) and cotton + foxtail millet + greengram (962 kg/ha). In comparison to sole cotton, all other intercropping methods, including cotton + greengram, cotton + redgram, cotton + greengram + redgram, and cotton + redgram + foxtail millet, resulted in a reduction of 22.3%, 21.9%, 23.11% and 23.7% in seed cotton yield, respectively. Similar reductions in seed cotton yield in intercropping system compared to sole cotton were

reported by Sunil *et al.* (2022). The reduction in plant height and number of sympodia per plant in cotton due to pulses and millet intercrops might have reduced the number of bolls per plant and ultimately the seed cotton yield (Sangameshwari, 2023).

Pooled data of three years on cotton equivalent yield indicated that cotton + redgram (2:1) recorded significantly highest cotton equivalent yield (1401 kg/ha) followed by cotton + greengram + redgram (1204 kg/ha) and cotton + redgram + foxtail millet (1152 kg/ha) as compared to the other intercropping systems and sole cotton treatment of farmers practice (827 kg/ha). Similar results were reported by Prasannasreenithi *et al.* (2023) and Shaukat *et al.* (2021). Though suppression effect of redgram on cotton

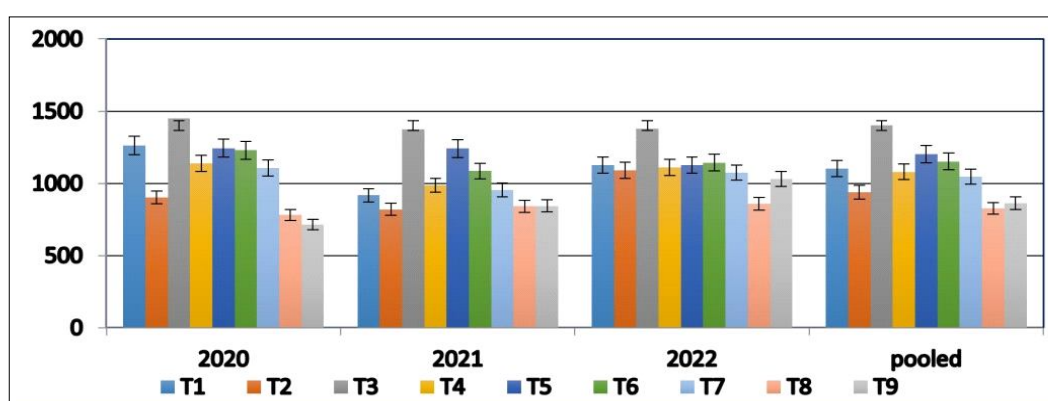


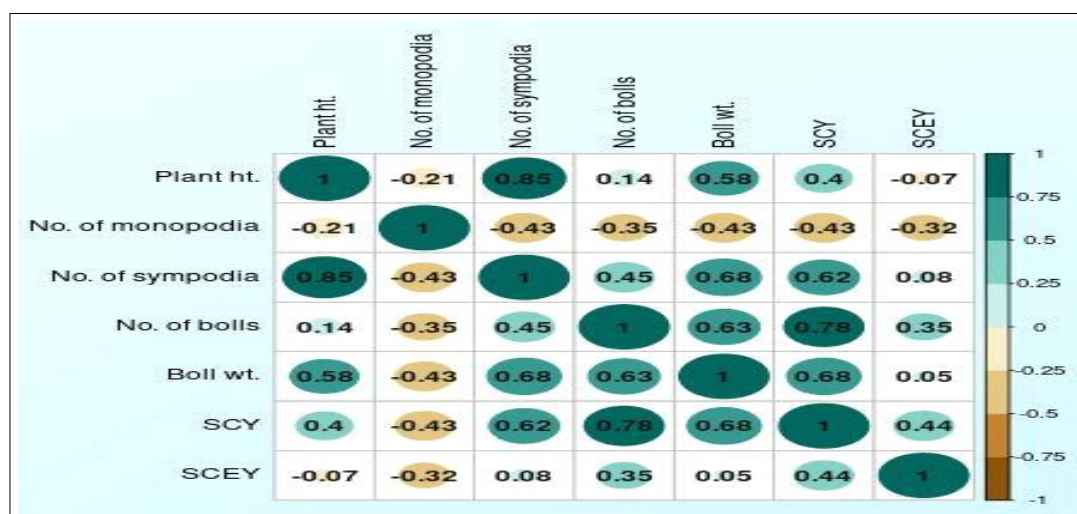
Fig 2: Effect of multitier cropping system on seed cotton equivalent yield during the study period of 2020-2022.

Table 2: Effect of multitier cropping system on no. of sympodia and no. of bolls/m² at harvest stage during the study period of 2020-2022.

Treatments	No. of sympodia				No. of bolls/m ²			
	2020	2021	2022	pooled	2020	2021	2022	pooled
Sole Bt cotton (90 cm × 45 cm)	14.5 ^a	9.5 ^a	11.5 ^a	11.8 ^a	24.7 ^a	23.5 ^a	26.9 ^a	25.2 ^a
Paired planting of Bt cotton + two rows of GG	11.3 ^{bc}	7.5 ^{bc}	8.4 ^{cd}	9.0 ^{def}	17.3 ^d	16.9 ^c	21.5 ^{bc}	18.6 ^{de}
Paired planting of Bt cotton + two rows of RG	10.7 ^{cd}	6.4 ^c	7.0 ^d	8.0 ^f	23.5 ^{ab}	18.5 ^{bc}	19.7 ^{bc}	20.6 ^{bcd}
Paired planting of Bt cotton + two rows of FM	13.0 ^{ab}	8.9 ^{ab}	10.4 ^{ab}	10.8 ^{ab}	23.0 ^{ab}	22.1 ^{ab}	23.3 ^{ab}	22.8 ^{ab}
Paired planting of Bt cotton + one row of GG + one row of RG	11.8 ^{bc}	8.4 ^{ab}	9.5 ^{bc}	9.9 ^{bcd}	18.3 ^{cd}	20.1 ^{abc}	22.6 ^{ab}	20.3 ^{bcd}
Paired planting of Bt cotton + one row of RG + one row of FM	11.8 ^{bc}	7.6 ^{bc}	8.8 ^{bc}	9.4 ^{cde}	19.8 ^{bcd}	17.5 ^c	20.2 ^{bc}	19.2 ^{cde}
Paired planting of Bt cotton + one row of FM + one row of GG	12.9 ^{ab}	8.4 ^{ab}	9.3 ^{bc}	10.2 ^{bc}	23.0 ^{ab}	21.5 ^{ab}	22.7 ^{ab}	22.3 ^{abc}
Farmers practice (120 cm × 60 cm)	13.1 ^{ab}	8.1 ^{ab}	9.0 ^{bc}	10.1 ^{bcd}	21.7 ^{abc}	19.0 ^{bc}	21.7 ^{bc}	20.7 ^{bcd}
Recommended intercropping (1:3 ratio of cotton + GG)	9.3 ^d	8.1 ^{ab}	8.9 ^{bc}	8.8 ^{ef}	12.2 ^e	18.8 ^{bc}	17.7 ^c	16.0 ^e
SEd	1.0	0.7	0.9	0.9	1.8	1.9	2.2	1.5
SEm±	0.7	0.5	0.6	0.6	1.3	1.3	1.6	1.1
CD (5%)	2.2	1.6	1.8	1.9	3.7	3.0	4.9	3.2
CV%	10	11	11	12	11	11	13	12

Table 3: Effect of multitier cropping system on boll weight and seed cotton yield at harvest stage during the study period of 2020-2022.

Treatments	Boll weight (g)				Seed cotton yield (kg/ha)			
	2020	2021	2022	Pooled	2020	2021	2022	Pooled
Sole <i>Bt</i> cotton (90 cm × 45 cm)	4.5 ^a	4.1 ^a	4.6 ^a	4.4 ^a	1262 ^a	918 ^a	1127 ^a	1103 ^a
Paired planting of <i>Bt</i> cotton + two rows of GG	3.7 ^b ^c	3.4 ^c	4.0 ^{ab}	3.7 ^b ^c	840 ^c	734 ^c	996 ^{ab}	857 ^{bc}
Paired planting of <i>Bt</i> cotton + two rows of RG	3.9 ^{bc}	3.2 ^c	3.4 ^b	3.5 ^{cd}	959 ^{bc}	827 ^{abc}	799 ^c	861 ^b ^c
Paired planting of <i>Bt</i> cotton + two rows of FM	3.7 ^{bc}	3.5 ^{bc}	4.0 ^{ab}	3.7 ^{bc}	1038 ^b	891 ^{ab}	993 ^{ab}	974 ^{ab}
Paired planting of <i>Bt</i> cotton + one row of GG + one row of RG	4.1 ^{ab}	3.4 ^c	3.5 ^b	3.7 ^{bc}	893 ^{bc}	847 ^{abc}	803 ^c	848 ^{bc}
Paired planting of <i>Bt</i> cotton + one row of RG + one row of FM	3.7 ^{bc}	3.2 ^c	3.5 ^b	3.5 ^{cd}	911 ^{bc}	784 ^{bc}	827 ^c	841 ^b ^c
Paired planting of <i>Bt</i> cotton + one row of FM + one row of GG	3.8 ^{bc}	3.5 ^{bc}	3.8 ^b	3.7 ^{bc}	1036 ^b	876 ^{ab}	975 ^b	962 ^{ab}
Farmers practice (120 cm × 60 cm)	4.3 ^{ab}	4.0 ^{ab}	3.9 ^b	3.9 ^b	781 ^{cd}	842 ^{abc}	858 ^{bc}	827 ^{bc}
Recommended intercropping (1:3 ratio of cotton + GG)	3.4 ^c	3.0 ^c	3.3 ^b	3.2 ^d	636 ^d	746 ^c	891 ^{bc}	757 ^c
SEd	0.2	0.3	0.4	0.2	92	54	69	72
SEm±	0.1	0.2	0.3	0.1	65	38	48	50
CD (5%)	0.5	0.5	0.8	0.4	193	116	147	152
CV%	7	11	12	11	12	8	9	10

**Fig 3:** Effect of multitier cropping system on correlation analysis between growth and yield parameters of cotton.

was observed in cotton+redgram combination intercropping systems, significantly higher cotton equivalent yields were recorded in these treatments due to higher redgram yields. Similar results were reported by Rajpoot *et al.* (2014) and Remesa *et al.* (2016).

In interpreting relationships among the parameters, the data underwent correlation analysis, revealing significant correlations ($P < 0.05$) as depicted in Fig 3. The correlogram highlighted vital relationships, particularly negative correlations observed between growth attributes

and seed cotton equivalent yield. As discussed in the section on multivariate statistical analysis in this study, seed cotton equivalent yield exhibited negative correlations with plant height (coefficients of -0.07), number of monopodia (coefficients of -0.32) and positively correlated with number of sympodia (coefficients of 0.08), number of bolls/m² (coefficients of 0.35), boll weight (coefficients of 0.05) and seed cotton yield (coefficients of 0.44). Similar findings were reported by Nikhil *et al.* (2018); Aishwarya *et al.* (2022) and Kiran *et al.* (2024).

CONCLUSION

The research findings indicate that implementing a multi-tier cropping system, specifically the paired row planting of cotton with two rows of redgram (*T₃*) in a distinct tier arrangement, could lead to increased yield and profits in *Bt* cotton hybrids under rainfed conditions.

Conflict of interest

All authors declare that they have no conflicts of interest.

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