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Optimizing Growth and Yield of Cotton: Exploring Pruning and Drip Fertigation Techniques on ELS Cotton CO14

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ABSTRACT

Background: Cotton, a perennial crop, can greatly benefit from pruning, which assists in rejuvenating aged plants and enhancing yields comparable to those of the primary crop. However, research on pruning (ratooning) cotton remains limited. In this study, we investigated the effects of pruning and drip fertigation on yield and yield characteristics of ELS cotton CO14.

Methods: The study was conducted in a farmer's field in Nallur village, Bhavanisagar block, Erode district, Tamil Nadu, India, using a split-plot design replicated thrice. Main plots received fertigation treatments (M_1-75% NPK, M_2-100% NPK, M_3-125% NPK, M_4-STCR), while subplots were designated for different pruning techniques (S_1-15 cm, S_2-30 cm, S_3-45 cm).

Result: Findings showed that drip fertigation with M_3-125% NPK resulted in highest plant height (109.35 and 113.06), LAI (4.06 and 4.02), higher counts of sympodial branches plant^{-1} (19.73 and 14.46), squares plant^{-1} (128.00 and108.27), bolls plant^{-1} (59.44 and 45.98), boll setting percentage (46.66 and 42.51), yield (28.56 and 19.34 q/ha) and HI (0.46 and 0.43) in main crop and pruned crop. Concerning pruning techniques, cotton pruned at S_3-45 cm height exhibited significantly greater counts of sympodial branches plant^{-1} (13.76), squares plant^{-1} (103.44), flowers plant^{-1} (16.66), bolls plant^{-1} (36.88), boll setting percentage (35.35), yield (16.87 q/ha) and HI (0.40). Interaction analysis between main and subplot treatments revealed that 125% fertigation with 45 cm pruning height led to significantly higher counts of sympodial branches plant^{-1} (15.60) and flowers plant^{-1} (18.58). Thus, it is recommended to implement fertigation at 125% NPK+pruning at a 45 cm cut height to attain superior yields and yield characteristics.

Key words: Fertigation, Pruning, yield characters, Yield.

INTRODUCTION

Cotton is globally significant for its natural fiber and industrial applications, originating from perennial shrubs or trees in tropical and subtropical regions (Zhang *et al*., 2020). Extra Long Staple cotton, known for its exceptionally long fibers, represents about 2% of global production. Challenges such as longer duration, limited suitability for rainfed conditions, specific weather requirements and higher production costs hinder its widespread cultivation. Despite these obstacles, ELS cotton has gained popularity in Tamilnadu since 2008 due to the region's bimodal rainfall. However, production and productivity have declined, attributed to inadequate adoption of new technologies. Research by Divya *et al*. (2016) and Dhamayanthi and Manivannan (2019) underscores the necessity for improved management practices to optimize production potential.

Environmental conditions and agronomic methods significantly impact the growth and development of cotton (O'Berry *et al*., 2009). Effective nutrition management is crucial for maximizing seed cotton yield, given the plant's simultaneous production of vegetative and reproductive structures during active development phases. Nitrogen, phosphorus and potassium play pivotal roles in growth and development, enhancing both yield and fiber quality in cotton (Shah *et al*., 2017).

Drip fertigation proves to be an invaluable asset in contemporary agriculture, facilitating sustainable and water-efficient methods that enhance productivity and conserve resources (Umilsingh *et al*., 2023. Fertigation offers flexibility in fertilizer application, meeting crop nutrient needs at different growth stages (Salih *et al*., 2012, Gowtham, 2016, Naik *et al*., 2023). By applying fertilizers in split doses, nutrients are delivered at the right times and amounts, maximizing yield while minimizing losses (Kakade *et al*., 2018 and Sunitha *et al*., 2023).

Cotton's perennial nature and indeterminate growth distinguish it, typically cultivated annually. In low rainfall areas, like marginal regions and parts of Central and Eastern Kenya, ratoon cotton methods are adopted to boost seed cotton yields during droughts.

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Pruning is crucial for rejuvenating mature plants, optimizing energy use for healthier shoots and more fruiting points. Standardizing practices, including pruning and nutrient management, is key for meeting ELS cotton demand.

Drip fertigation maximizes water and nutrient efficiency, enhancing yields. Effective pruning maintains seed yield and fiber quality across ratoon cycles, reducing costs and promoting flowering. This study focuses on inducing sprouting through various pruning techniques and fertigation levels to initiate a second fruiting cycle in the CO14 extra long staple cotton variety.

Materials and Methods

The field study was conducted in farmer's field located in Nallur village, Bhavanisagar block, Erode district, Tamil Nadu, India. The experimental site falls within the Western agro-climatic zone of Tamil Nadu, situated at 11.35°N latitude, 77.168°E longitude and an altitude of 312 meters above mean sea level. The study was conducted during winter 2021 and summer 2022 and soil type found at the experiment site was calcareous clay loam, with a pH of 7.85, low available N (196 kg ha^{-1}), medium P (12 kg ha^{-1}) and high K (593 kg ha^{-1}). The study was laid out in a split plot design with three replications. The main plot consisted of fertigation treatments, while pruning techniques were assigned to the subplot. The gross and net plot sizes were 6.3 m×6.0 m and 4.5 m×4.8 m, respectively. Cotton CO14 was grown with a spacing of 90×60 cm, considered as the main crop. The main crop was pruned using garden secateurs at three different heights from ground level after third picking (150 DAS) and considered as pruned crop. Weak and desiccated shoots were thinned out from the pruned stumps, followed by earthing up.

Fertigation treatments in the main plot included M_1-75% NPK, M_2-100% NPK, M_3-125% NPK and M_4-STCR based fertigation, while pruning techniques in the subplot comprised S_1-15 cm, S_2-30 cm and S_3-45 cm. Drip lines equipped with in-line drippers spaced at 45 cm intervals, with a water discharge of 4 LPH, were utilized. Irrigation scheduling was set at 1.0 IW/CPE under drip fertigation, with irrigation administered once every four days. Fertigation was carried out through a venturi injector to individual plots. The fertilizer solution was prepared and stored in plastic containers connected to the suction device of the venturi. Fertigation was administered according to the prescribed schedule for cotton at each irrigation. The recommended dose of fertilizer (RDF) 150:60:60 NPK kg ha^{-1} was applied in the form of commercial fertilizers such as urea, DAP and MOP, respectively, for the main crop. Additionally, 25% of nitrogen alone was applied after pruning with respect to each fertigation treatment. For STCR the fertigation was administered at a rate of 134:30:30 NPK kg ha^{-1}.

Various biometric observations on growth was taken on 90 days after sowing (DAS) and 90 days after pruning (DAP) for main crop and pruned crop. Yield and yield characters at harvest were recorded, statistically analyzed and discussed below. For the main crop, statistical analysis was conducted and main plot (fertigation) treatments alone taken into account, as subplot treatments were applied after harvest and considered as pruned crop. For the pruned crop, statistical analysis was performed for both main plot and subplot treatments.

Results and Discussion

Plant height

The study found significant impacts of drip fertigation and pruning techniques on plant height, LAI, yield and yield characteristics of both main crop and pruned crop cotton plants. Fertigation at 125% NPK resulted in the tallest plants (105.93 cm for main crop, 108.20 cm for pruned crop), though similar results were seen with 100% NPK fertigation. The lowest plant heights occurred in plots treated with STCR (M_4) (92.34 cm for main crop, 95.80 cm for pruned crop). Drip fertigation, especially at higher nutrient levels, likely enhanced nutrient uptake and utilization due to increased irrigation frequency and soil moisture. This facilitated better root growth and canopy development, as supported by previous studies (Ayyadurai and Manickasundaram, 2014; Kakade *et al*., 2017).

Regarding pruning techniques, pruning at 45cm height resulted in the tallest pruned crop plants (111.65 cm), followed by 30 cm pruning, with the shortest plants from 15 cm pruning. Research by Macharia (2013) indicated that initially, ratoon plants grew taller with increasing cut height and later, directly seeded cotton plants surpassed ratoon plants in height by the end of the rainy season. This early growth advantage of ratoon crops was attributed to their pre-existing root systems, facilitating water and mineral absorption and utilizing carbohydrates from the stump, which supported sustained growth compared to directly seeded crops developing new root systems.

The interaction effect between fertigation and pruning techniques was not observed.

Leaf area index

Leaf area index (LAI) is a critical indicator of crop canopy development. According to Wang *et al*. (2018), LAI peak values increase with higher fertilizer levels under drip irrigation. Consistently, our study found that LAI was highest in M_3 (125% NPK) treatments, significantly surpassing other fertigation levels in both main crop (3.88) and pruned crop (4.13). The next highest LAI values were observed with 100% NPK fertigation at 90 DAS for main crop and 90 DAP for pruned crop. Conversely, the lowest LAI values were recorded in M_4 (STCR) treatments for both main crop (3.46) and pruned crop (3.61), which did not significantly differ from other fertigation treatments.

Pruning techniques did not significantly affect LAI, although S_3 (45 cm) pruning resulted in higher LAI, followed by S_2, while the lowest LAI was associated with 15 cm pruning in pruned crops.

Number of symbodial branches plant^{-1}

Table 1 shows, fertigation at 125% NPK recorded significantly utmost numbers of symbodial branches and it was on par with 100% NPK in main crop (18.99) and as well as in pruned crop (14.69). Lowest numbers of symbodial branches was recorded in STCR based NPK recommendation in main crop (16.73) and pruned crop (12.23). The observed increase in yield attributes under drip fertigation may be attributed to enhanced nutrient availability and uptake, leading to improved photosynthesis, leaf expansion and nutrient translocation to reproductive parts. Comparable results were reported by Yadav and Chauhan (2016), Jayakumar *et al*. (2014), Veeraputhiran and Chinnusamy (2005) and Grieesha (2003). In pruned crop, pruning at 45 cm exhibited a higher numbers of symbodial branches (14.24) and it was followed by 30 cm pruning (13.37). Interaction analysis revealed that 125% fertigation with 45 cm pruning height resulted in significantly higher symbodial branches. Conversely, the study indicated that the lowest numbers of symbodial branches was recorded with STCR-based fertigation along with 15 cm pruning.

The number of squares plant^{-1}

The number of squares exhibited significant variation among fertigation treatments, with 125% fertigation in both main (125.67) and pruned crop (104.87) and 100% fertigation showing comparable results in both crops (Table 2). The lowest number of squares was observed in STCR-based fertigation in main (102.86) and pruned crop (87.07). This increase in squares under fertigation treatments could be attributed to enhanced nutrient availability and absorption by the crop, facilitated by optimal moisture supply and frequent nutrient application through fertigation, leading to improved assimilate translocation from source to sink (Jayakumar *et al*., 2014). Pruning at a height of 45 cm resulted in the highest number of squares (100.09), while the lowest numbers was observed with 15 cm pruning. No significant interaction was observed between fertigation and pruning.

Number of bolls plant^{-1}

The total number of bolls on cotton plants at maturity serves as a crucial yield determinant, influenced significantly by both physiological and environmental factors. The augmentation in the number of fruiting points and bolls plant^{-1} directly correlates with a higher count of sympodial branches plant^{-1} (Basker, 2014). Notably, in terms of fertigation, $M_3$125% NPK recorded significantly highest number of bolls plant^{-1} at 55.01 and 41.18 in main and pruned crop and it was followed by M_2 100% NPK, which yielded 49.86 and 32.96 bolls main and pruned crop. This observed trend could potentially be attributed to enhanced square formation and boll retention resulting from continuous nutrient and moisture supply, as suggested by Turner *et al*. (1986) and Grieesha (2003). Conversely, the lowest number of bolls plant^{-1}, 43.54 and 27.46 in main and pruned crop, was recorded in M_4. In pruned crop,

Table 1: Effect of fertigation and pruning level on the plant height, leaf area index and number of sympodial branches inmain crop and pruned crop (Pooled meandata of two years-winter 2021 and summer 2022).

Treatments	Plant height (cm)		Leaf area index		Number of symbodial branches plant^{-1}	
	Main crop	Pruned crop	Main crop	Pruned crop	Main crop	Pruned crop
Fertigation						
M_1	92.42	96.17	3.44	3.64	16.88	12.62
M_2	97.69	101.44	3.63	3.90	17.96	13.40
M_3	105.93	108.20	3.88	4.13	18.99	14.69
M_4	92.34	95.80	3.46	3.61	16.73	12.23
S.Ed.	1.49	1.54	0.05	0.06	0.26	0.20
CD	6.39	6.62	0.23	0.27	1.12	0.87
Pruning technique						
S_1	-	89.56	-	3.72	-	12.09
S_2	-	100.00	-	3.83	-	13.37
S_3	-	111.65	-	3.90	-	14.24
S.Ed.	-	2.20	-	0.07	-	0.18
CD	-	4.43	-	0.15	-	0.36
Fertigation × Pruning technique (M at S)						
S.Ed.	-	3.35	-	0.12	-	0.32
CD	-	7.00	-	NS	-	NS
Pruning technique × Fertigation (S at M)						
S.Ed.	-	3.11	-	0.10	-	0.25
CD	-	6.25	-	NS	-	NS

pruning also emerged as a significant factor impacting the number of bolls plant^{-1}. Among different pruning heights, plants pruned at a height of 45 cm exhibited the highest number of bolls plant^{-1}, namely 34.82, followed S_2 with 32.56 bolls plant^{-1}. Conversely, S_1 recorded the lowest number of bolls plant^{-1} at 29.71. However, no significant variations were observed in the number of bolls due to interaction between fertigation and pruning heights.

Boll setting percentage

Table 2 shows that higher drip fertigation at M_3 (125%) likely optimized nutrient concentrations in the root zone, potentially increasing boll setting percentage. This observation is align with the findings of Bharambe *et al.* (1997) and Veeraputhiran *et al.* (2002). Significant increases were observed with M_3 125% NPK in pruned crops (39.24%). In the main crop, no significant differences were found among fertigation treatments, but the highest boll setting percentage (46.30%) occurred with M_3 125% NPK. Boll setting was highest in plants pruned at 45 cm (34.65%), it was on par with 30 cm in pruned crops, with no interaction effects noted. These results align with findings of Macharia's (2013).

Single boll weight (g)

Boll weight, being primarily governed by genetics, varies predominantly according to genotypes, with management practices exerting minimal influence. In the current investigation, treatments involving the application of 125% NPK and pruning at 45 cm height exhibited numerically higher boll weights (Table 3) in both main crop and pruned crop. However, no interaction effects were observed in the study.

Seed cotton yield (q ha^{-1})

Table 3 illustrates the significant impact of fertigation and pruning height on seed cotton yield. The highest yields were achieved with 125% fertigation (M_3) at 28.08 q ha^{-1} in main crop and 18.84 q ha^{-1} in pruned crop, followed by 100% fertigation with yields of 24.64 q ha^{-1} and 16.03 q ha^{-1}, respectively. Conversely, the lowest yields of 22.49 q ha^{-1} and 14.95 q ha^{-1} were observed under STCR (M_4) fertigation in both main and pruned crops. Adoption of 125% fertigation resulted in a 19.90% and 20.64% increase in yield compared to STCR in main and pruned crops, attributed to improved nutrient availability and assimilates translocation facilitated by optimal moisture and frequent nutrient supply. Lower yields under STCR may be attributed to a decrease in synthesis of metabolites and a reduction in the absorption and translocation of nutrients, as suggested by Jayakumar *et al*. (2015).

Significant yield variations were noted in pruned crops based on pruning height. Plants pruned at 45 cm (S_3) achieved the highest yield of 17.00 q ha^{-1}, followed by those pruned at 30 cm (S_2), while the lowest yield of 15.43 q ha^{-1} was recorded in plants pruned at the lowest height (S_1). Higher yields at 45 cm pruning heights are linked to increased sympodial branches and higher square and boll production, consistent with findings by Srinivasa and Thimmagowda (1997) and Macharia (2013). Khadar and Prakash (2014) and Carvalho *et al*. (1994) also found that

Table 2: Effect of fertigation and pruning level on the number of squares, number of bolls and boll setting per centinmain crop and pruned crop (Pooled meandata of two years-winter 2021 and summer 2022).

Treatments	Number of squares		Number of bolls plant^{-1}		Boll setting per cent	
	Main crop	Pruned crop	Main crop	Pruned crop	Main crop	Pruned crop
Fertigation						
M_1	104.37	87.84	43.54	27.86	42.27	31.83
M_2	109.91	98.23	49.86	32.96	43.87	33.67
M_3	125.67	104.87	55.01	41.18	46.30	39.24
M_4	102.86	87.09	44.28	27.46	40.50	31.59
S.Ed.	1.76	1.50	0.93	0.51		0.58
CD	7.58	6.47	4.01	2.21		2.48
Pruning technique						
S_1	-	88.80	-	29.71	-	33.29
S_2	-	94.63	-	32.56	-	34.31
S_3	-	100.09	-	34.82	-	34.65
S.Ed.	-	1.16	-	0.41	-	0.60
CD	-	2.34	-	0.83	-	1.20
Fertigation × Pruning technique (M at S)						
S.Ed.	-	2.18	-	0.76	-	0.99
CD	-	4.55	-	NS	-	NS
Pruning technique × Fertigation (S at M)						
S.Ed.	-	1.65	-	0.58	-	0.84
CD	-	3.32	-	NS	-	NS

Table 3: Effect of fertigation and pruning level on single boll weight, yield and harvest indexinmain crop and pruned crop (Pooled meandata of two years-winter 2021 and summer 2022).

Treatments	Single boll weig		Yield (q ha^{-1})		Harvest index	
	Main crop	Pruned crop	Main crop	Pruned crop	Main crop	Pruned crop
Fertigation						
M_1	4.55	3.52	22.70	14.96	0.46	0.37
M_2	4.65	3.77	24.64	16.03	0.47	0.38
M_3	4.68	3.84	28.08	18.84	0.49	0.42
M_4	4.57	3.57	22.49	14.95	0.44	0.38
S.Ed.	0.07	0.07	0.43	0.34	0.01	0.01
CD	NS	NS	1.87	1.48	NS	NS
Pruning technique						
S_1	-	3.62	-	15.43	-	0.38
S_2	-	3.68	-	16.16	-	0.39
S_3	-	3.72	-	17.00	-	0.39
S.Ed.	-	0.07	-	0.34	-	0.01
CD	-	NS		0.68	-	NS
Fertigation × Pruning technique (M at S)						
S.Ed.	-	0.12	-	0.57	-	0.01
CD	-	NS	-	NS	-	NS
Pruning technique × Fertigation (S at M)						
S.Ed.	-	0.10	-	0.48	-	0.01
CD	-	NS	-	NS	-	NS

higher boll numbers and yields were associated with pruning at 45 cm and specific nutrient treatments.

Interaction effects between fertigation and pruning height on seed cotton yield were non-significant. However, the combination of 125% fertigation and 45 cm pruning (M_3S_3) yielded the highest at 19.84 q ha^{-1}, whereas the lowest yield of 14.16 q ha^{-1} was observed with M_4 fertigation and S_1 pruning (M_4S_1).

Harvest index

There was no significant difference observed in the harvest index among fertigationin main crop and pruned crop and pruning height treatments, as well as their interactionsin pruned crop (Table 3). Treatment M_3 (125%) exhibited a higher harvest index of 0.49 and 0.42, while treatment M_4 (STCR) had the lowest harvest index at 0.44 and 0.37 in main crop and pruned crop. Regarding pruning height, a higher harvest index of 0.39 was recorded with a 45 cm pruning height, whereas the lowest harvest index of 0.38 was found under a 15 cm pruning height.

Conclusion

In this study, pruned cotton refers to re-growth from a stump above the ground left after cutting the previous season's main cotton crop, with the remaining stalk burnt. The performance of pruned cotton depends significantly on adopting appropriate management practices from the previous season's crop and for the pruned crop itself. These practices include land preparation, maintaining plant population, selecting suitable varieties, adequate fertilization, optimal pruning height and effective weed, pest and disease management. Both fertigation treatment at 125% NPK and pruning techniques notably influenced the growth and development of both main and pruned cotton crops. Increasing fertigation to 125% NPK and pruning height to 45 cm resulted in higher seed cotton yield and improved yield traits in pruned cotton. The findings suggest that combining 125% NPK drip fertigation with pruning at a 45 cm height is an effective agronomic approach for achieving superior seed cotton yield and yield traits in pruned cotton crops.

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Conflict of interest

Authors have declared that there was no conflict of interest exists.

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