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Combined effect of nutrient management and Mepiquat chloride on HDPS cotton: Growth and yield analysis

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Abstract
A field experiment was conducted during *kharif*, 2023 at the College Farm, Rajendranagar, to evaluate the combined effects of nutrient management and Mepiquat Chloride (MC) on growth regulation and yield of HDPS cotton. The study was laid out in a Randomized Block Design with nine treatments consisting of 100% RDF, 50% RDF substituted with nano-DAP and two MC formulations (Chamatkar and Egnitus) applied either at 40 & 55 DAS or 50 & 65 DAS. Application of 50% RDF + 50% nano-DAP produced the tallest plants (105 cm) and longest internodes (5.57 cm), but this excessive vegetative vigour resulted in poor biomass partitioning and the lowest seed cotton yield (1263 kg ha^{-1}). Among the treatments, 100% RDF + Egnitus @ 80 ml acre^{-1} and 100% RDF + Chamatkar @ 0.6 ml L^{-1} at 50 & 65 DAS recorded the highest boll number, boll weight and seed cotton yield. The study concludes that 100% RDF combined with MC application at 50 & 65 DAS using either Chamatkar @ 0.6 ml L^{-1} or Egnitus @ 80 ml acre^{-1} is the most effective strategy for optimizing canopy architecture and maximizing HDPS cotton productivity.

Keywords: Cotton, growth retardant, Mepiquat chloride, nano-DAP, nutrient efficiency

Introduction

Cotton (*Gossypium hirsutum* L.) is one of India's most important cash crops, supplying nearly 59% of the raw material for the textile industry. In India, *G. hirsutum* hybrids dominate 88% of the 123.70 lakh ha cotton area (Cotton Outlook, 2024). About 70% of cotton in Central and Southern India is rainfed. Maharashtra has the largest cotton area (42.22 lakh ha), while Telangana cultivates 18.01 lakh ha, producing 48.95 lakh bales. Cotton is inherently perennial and indeterminate, making its growth highly responsive to environmental conditions. Under fertile and irrigated conditions, Modern Bt hybrids display strong apical dominance and excessive vegetative vigour under high fertility, resulting in poor boll retention and increased fruit shedding (Zhang *et al.*, 2023; Li *et al.*, 2023) [18, 9]. This results in a low boll-to-biomass ratio, excessive shading in the canopy, enhanced shoot elongation, leaf senescence, fruit shedding and ultimately reduced yield. Managing this luxuriant growth through manual practices like topping or thinning is labour-intensive and costly (Siebert & Stewart, 2006). Uniform and synchronized boll setting, especially in the middle and upper canopy, is essential for achieving high yields and facilitating efficient harvesting. To address these concerns, the Central Institute of Cotton Research (CICR), Nagpur, developed the High-Density Planting System (HDPS) using early maturing, semi-compact genotypes. Canopy manipulation using plant growth regulators (PGRs) is an important complementary practice in these systems. PGRs regulate plant architecture, improve boll retention, influence photosynthesis and assimilate partitioning and enhance overall yield (Tung *et al.*, 2020) [16]. Their effectiveness depends on application timing, dosage, environmental factors and genotype response (Kim *et al.*, 2003) [6].
Mepiquat chloride (MC), a widely used growth retardant, functions by inhibiting gibberellic acid synthesis, thereby reducing internodal elongation and promoting compact plant structure.

However, the success of MC application is highly dependent on timing. Early or excessive application can restrict vegetative growth too strongly, reducing photosynthetic area and lint yield. Late or insufficient application, on the other hand, fails to control vigorous growth, resulting in shading, boll loss and harvesting difficulties. Therefore, optimizing MC application remains a critical need, especially under HDPS, where plant competition is higher.

Nutrient management with traditional phosphorus fertilizers like DAP has low nutrient use efficiency (10-25%) due to fixation in soils (Wang *et al.*, 2012; Gunaratne *et al.*, 2016) [17, 4], whereas nano-DAP enhances phosphorus use efficiency up to 80% (Rathnayaka *et al.*, 2018; Kumar *et al.*, 2023) [14, 7]. Nano-DAP has emerged as an effective alternative with improved solubility, high surface area and controlled nutrient release. Combining precise mepiquat chloride applications for canopy control with improved nutrient efficiency offers a promising strategy for enhancing cotton yield and sustainability, particularly in high-density planting systems.

Materials and Methods

The experiment was carried out at college farm, Rajendranagar, during *kharif*, 2023. Farm was geographically located at 18º10' N Latitude and 79º59' E Longitude and is at an altitude of 536 meters above mean sea level, categorized under Southern Agro Climatic Zone of Telangana. The experiment was laid out in a Randomized Block Design (RBD) with nine treatments and replicated thrice. Treatments includes T_1: 100% RDF + Chamatkar @ 0.6 ml L^{-1} at 40 & 55 DAS, T_2: 100% RDF + Chamatkar @ 0.6 ml L^{-1} at 50 & 65 DAS, T_3: 100% RDF + Chamatkar @ 1 ml L^{-1} at 40 & 55 DAS, T_4: 100% RDF + Chamatkar @ 1 ml L^{-1} at 50 & 65 DAS, T_5 : 100% RDF + Egnitus @ 80 ml $acre^{-1}$ at 40 & 55 DAS, T_6: 100% RDF + Egnitus @ 80 ml $acre^{-1}$ at 50 & 65 DAS, T_7: 50% RDF + 50% nano DAP + Chamatkar @ 1 ml L^{-1} at 40 & 55 DAS, T_8: 50% RDF + 50% nano DAP + Egnitus @ 80 ml $acre^{-1}$ at 40 & 55 DAS, T_9: 50% RDF + 50% nano DAP. Cotton hybrid RCH-929 was sown by a pneumatic planter with a spacing of 90 cm x 15 cm. The recommended dose of fertilizers, 120-60-60 N: P_2O_5: K_2O kg ha^{-1} was applied in the form of urea, single super phosphate and muriate of potash respectively, in treatments T_1 to T_6. Whereas in T_7, T_8 and T_9 where only 50% of RDF was applied other 50% through nano DAP. Nano-DAP (4 ml L^{-1}) was applied thrice at 40, 60 and 80 DAS to ensure sustained phosphorus supply (Kumar *et al.*, 2023) [7]. Biometric measurements of growth and yield parameters were done in each plot. The data concerning various parameters from the experiment were subjected to statistical analysis using the analysis of variance (ANOVA) method for randomized block design, following the approach described by Gomez and Gomez (1984) [3].

Results and Discussion

Growth characters

The growth behaviour of HDPS cotton was strongly influenced by the combined effects of nutrient management and the timing and concentration of Mepiquat Chloride (Table 1). T_9 (50% RDF + nano-DAP) exhibited the tallest plants (105 cm), highest node count (28.09), and longest internodes (5.57 cm) due to uninterrupted vegetative elongation supported by nano-scale P delivery. However, this excessive elongation resulted in the lowest biomass (17.02 g vegetative; 13.81 g reproductive), indicating nutrient dilution under HDPS. In contrast, treatments in which Mepiquat Chloride was applied early at 40 & 55 DAS, especially at higher concentration (T_3 and T_7), showed a pronounced reduction in vegetative growth, resulting in shorter plants (66.8, 64.5 cm), fewer nodes (18.12, 18.10), shorter internodes (2.92, 2.84 cm) and correspondingly lower vegetative and reproductive biomass due to strong inhibition of gibberellin-mediated elongation at an earlier developmental stage. Late MC application (50 & 65 DAS) in T_6 and T_2 allowed more node initiation before growth modulation, resulting in higher node counts (25.81 and 25.65) and longer internodal length (3.54, 3.51 cm) while effectively restricting height during boll development (Collins *et al.*, 2017) [1]. This balance translated into the highest biomass accumulation at harvest (T_6 recorded 29.37 g vegetative and 31.52 g reproductive biomass per plant, followed closely by T_2: 29.17 g and 30.74 g), demonstrating efficient partitioning towards reproductive sinks under controlled vegetative growth. Collins *et al.* (2017) [1], Luo *et al.* (2023) [10] and Meng *et al.* (2023) [11] observed similar results in cotton under high-density planting.

Yield attributes and yield

Among the treatments, 100% RDF + Egnitus @ 80 ml $acre^{-1}$ at 50 & 65 DAS recorded the highest boll number (32.73 $plant^{-1}$), maximum boll weight (5.73 g) and consequently superior seed cotton yield (2267 kg ha^{-1}). This treatment was statistically at par with 100% RDF + Chamatkar @ 0.6 ml L^{-1} at 50 & 65 DAS, which recorded with 32.50 bolls $plant^{-1}$, 5.71 g boll weight and 2229 kg ha^{-1} seed cotton yield (Table 2). The superior performance of these treatments could be attributed to the timely application of Mepiquat Chloride at 50 & 65 DAS, coinciding with the squaring-to-early flowering stage, which effectively restricted excessive vegetative growth and promoted reproductive efficiency. Similarly reported by Khetre *et al.* (2018) [5], Priyanka *et al.* (2019) [13] and Patel *et al.* (2021) [12].

Conversely, early application at 40 & 55 DAS, especially with higher Mepiquat Chloride concentration with 50% RDF + 50% nano DAP + Chamatkar @ 1 ml L^{-1} at 40 & 55 DAS and showed poor performance due to the combined effect of nutrient limitation and early application of Mepiquat Chloride, leading to restricted vegetative growth before sufficient leaf canopy development. The lowest values for all parameters were recorded with 50% RDF + 50% nano DAP, which produced only 19.65 bolls $plant^{-1}$, 4.17 g boll weight and 1263 kg ha^{-1} seed cotton yield. This inferior performance might be due to partial nutrient supply, as 50% RDF substitution by nano DAP was insufficient to meet the crop's nutrient requirement under dense planting. Early canopy restriction before sufficient leaf area development reduces photosynthetic capacity and reduces carbohydrate availability for boll-setting. Although nano DAP improves phosphorus use efficiency, its effectiveness depends on adequate basal nutrition. Similarly, Lakshmanan *et al.* (2025) [8] emphasized that under HDPS, premature canopy restriction adversely affects light interception and yield formation, whereas applications at 50 & 65 DAS (early flowering stage) provided the best balance between canopy control and boll retention.

Table 1: Effect of nutrient and Mepiquat chloride on growth characters of cotton under high density planting

	Treatments	Plant height (cm)	No. of main stem nodes plant^{-1}	Internodal length (cm) of top nodes	Vegetative biomass (g plant^{-1})	Reproductive biomass (g plant^{-1})
T_1	100% RDF + Chamatkar @ 0.6 ml L^{-1} at 40 & 55 DAS	75.3	20.53	3.08	20.19	18.43
T_2	100% RDF + Chamatkar @ 0.6 ml L^{-1} at 50 & 65 DAS	92.6	25.65	4.60	29.17	30.74
T_3	100% RDF + Chamatkar @ 1 ml L^{-1} at 40 & 55 DAS	66.8	18.12	2.92	20.12	17.89
T_4	100% RDF + Chamatkar @ 1 ml L^{-1} at 50 & 65 DAS	84.4	23.27	3.98	26.16	26.90
T_5	100% RDF + Egnitus @ 80 ml acre^{-1} at 40 & 55 DAS	76.1	20.94	3.49	23.22	22.61
T_6	100% RDF + Egnitus @ 80 ml acre^{-1} at 50 & 65 DAS	93.5	25.81	4.77	29.37	31.52
T_7	50% RDF + 50% nano DAP + Chamatkar @ 1 ml L^{-1} at 40 & 55 DAS	64.5	18.10	2.84	19.94	17.48
T_8	50% RDF + 50% nano DAP + Egnitus @ 80 ml acre^{-1} at 40 & 55 DAS	75.8	20.70	3.41	23.12	22.04
T_9	50% RDF + 50% nano DAP	105.0	28.09	5.57	17.02	13.81
	SEm$\pm$	2.61	0.74	0.13	1.03	1.19
	CD	7.81	2.21	0.40	3.10	3.57

Table 2: Effect of nutrient and Mepiquat chloride on attributes and yield of cotton under high density planting

	Treatments	Boll number plant^{-1}	Boll weight (g)	Seed cotton yield (kg ha^{-1})
T_1	100% RDF + Chamatkar @ 0.6 ml L^{-1} at 40 & 55 DAS	26.03	4.96	1728
T_2	100% RDF + Chamatkar @ 0.6 ml L^{-1} at 50 & 65 DAS	32.50	5.71	2229
T_3	100% RDF + Chamatkar @ 1 ml L^{-1} at 40 & 55 DAS	22.93	4.62	1495
T_4	100% RDF + Chamatkar @ 1 ml L^{-1} at 50 & 65 DAS	29.47	5.36	2013
T_5	100% RDF + Egnitus @ 80 ml acre^{-1} at 40 & 55 DAS	26.49	5.01	1789
T_6	100% RDF + Egnitus @ 80 ml acre^{-1} at 50 & 65 DAS	32.73	5.73	2267
T_7	50% RDF + 50% nano DAP + Chamatkar @ 1 ml L^{-1} at 40 & 55 DAS	22.52	4.58	1474
T_8	50% RDF + 50% nano DAP + Egnitus @ 80 ml acre^{-1} at 40 & 55 DAS	26.23	4.99	1767
T_9	50% RDF + 50% nano DAP	19.65	4.17	1263
	SEm$\pm$	0.88	0.11	67.62
	CD	2.64	0.32	202.73

Conclusion

The study clearly demonstrated that the growth and yield performance of HDPS cotton is strongly influenced by the interaction between nutrient management and timing and concentration of Mepiquat Chloride application. The results showed that treatments receiving 50% RDF + 50% nano DAP produced the tallest plants with maximum internode length and node number, but this excessive vegetative growth did not translate into higher biomass or yield due to poor dry-matter partitioning under dense planting, highlighting the need for adequate basal nutrition under HDPS. Early high-dose MC treatments (T_3, T_7) recorded significantly shorter plants (66.8 cm and 64.5 cm) because early GA-inhibition at 40 DAS suppresses internode elongation and reduces canopy expansion (Meng *et al.*, 2023; Luo & Tang, 2023) [11, 10]. While delayed application at 50 & 65 DAS consistently provided a more favourable balance between vegetative control and reproductive development. 100% RDF + Egnitus @ 80 ml acre^{-1} at 50 & 65 DAS and 100% RDF + Chamatkar @ 0.6 ml L^{-1} at 50 & 65 DAS can regulate plant growth during the early flowering stage, allow sufficient canopy development for photosynthesis while preventing excessive vegetative competition and provide higher productivity.

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