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Effect of levels of fertilizers on yield and nutrient uptake by Bt-cotton under HDPS in rainfed condition

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Abstract

A field experiment was conducted during the kharif season of 2025–26 at the Research Farm, Cotton Research Centre, Dr. Panjabrao Deshmukh Krishi Vidyapeeth (Dr. PDKV), Akola, Maharashtra to study the effects of different fertilizers levels on yield and nutrient uptake by Bt-cotton (RCH 971 BG II) under High-Density Planting System (HDPS) in rainfed condition. The experiment was laid out in a Factorial Randomized Block Design (FRBD) with two factors: Factor A- Spacing (90×15 cm and 90×30 cm) and Factor B-Fertilizers levels (100% RDF: $90:45:45$ NPK kg ha⁻¹, 125% RDF: $120:60:60$ NPK kg ha⁻¹, 150% RDF: $140:70:70$ NPK kg ha⁻¹, 175% RDF: $160:80:80$ NPK kg ha⁻¹ and Absolute control). Results revealed that wider spacing 90×30 cm produced significantly higher seed cotton yield and maximum total nutrient uptake compared to closer spacing 90×15 cm. Among fertilizer levels, application of 125% RDF ($120:60:60$ NPK kg ha⁻¹) recorded the highest seed cotton yield, cotton stalk yield, total nitrogen uptake, phosphorus uptake and potassium uptake. The results indicate that 125% RDF combined with 90×30 cm spacing is the most effective nutrient management strategy for maximizing yield and nutrient uptake by Bt-cotton under rainfed condition.

Keywords: Bt-cotton, HDPS, fertilizer levels, seed cotton yield and nutrient uptake

Introduction

Cotton (*Gossypium spp.*) is one of the most commercially significant fibre crops in India, often called "white gold" for its contribution to the textile sector and the livelihoods of millions of rural farmers. India holds the world's largest cotton area and is the second-largest producer, with over 90% of cultivation dominated by *Gossypium hirsutum* L. (upland cotton) (Waghmare *et al.*, 2022)^[19]. The arrival of Bt cotton in 2002 brought a major technological shift, and today Bt hybrids cover an estimated 95–96% of India's total cotton area of 11–12 million hectares (ISAAA, 2023)^[8].

Cotton production in India during 2024-25 is estimated to produce 299.26 lakh bales of 170 kg from 113.6 lakh hectares with a productivity of 448 kg lint/ha, as estimated by the Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, New Delhi. In India, Gujarat, Maharashtra and Telangana are the major cotton-growing and producing states in the country. These states are estimated to grow 72.64% area under cotton and are estimated to produce 72.76% of the country's cotton production (ICAR-CICR, 2025)^[7].

Rainfed cotton accounts for roughly 65–70% of India's total cotton area, with Maharashtra commanding the largest share of approximately 40–42 lakh hectares (Government of India, 2024)^[5]. Despite this dominance, average cotton productivity in India lags well behind global benchmarks due to irregular rainfall, deteriorating soil health, skewed nutrient management, and inadequate fertilizer use.

High-Density Planting System (HDPS) in cotton offers several advantages, including higher productivity per hectare, early crop maturity, and improved efficiency in water and nutrient use, making it suitable for rainfed areas. Under HDPS, the increased plant population imposes greater nutrient demand on already nutrient-deficient soils; hence, optimizing graded levels of fertilizers (N, P and K) is critical for improving soil fertility status, seed cotton yield, stalk yield and nutrient uptake by Bt-cotton under rainfed conditions.

Most of the research has indicated that Bt-cotton under HDPS requires approximately 25% more fertilizer than standard recommendations, with the optimum often identified at 125% of the recommended dose (Basha *et al.*, 2017; Deshmukh *et al.*, 2016; Sankaranarayanan *et al.*, 2018) [2, 3, 17]. Despite growing interest in HDPS, systematic research examining the combined influence of crop spacing and graded fertilizer levels on yield and nutrient uptake by Bt-cotton in the rainfed soils of Maharashtra remains sparse. This study was therefore undertaken to evaluate the response of yield and nutrient uptake by Bt-cotton to different fertilizer levels under HDPS in rainfed conditions.

Materials and Methods

A field experiment was conducted during the Kharif season of 2025–26 at the Research Farm, Cotton Research Centre, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India. The soil order of the experimental plot was an Inceptisol, moderately alkaline in reaction (pH 8.14), with an electrical conductivity of 0.264 dS m⁻¹, organic carbon of 4.52 g kg⁻¹, low available nitrogen (162.38 kg ha⁻¹) and phosphorus (11.88 kg ha⁻¹), and high available potassium (360.20 kg ha⁻¹).

The experiment was laid out in a Factorial Randomized Block Design (FRBD) with two factors and three replications. Factor A consisted of two spacing levels — M1 (90 × 15 cm) and M2 (90 × 30 cm) — and Factor B comprised five fertilizer levels — S1: 100% RDF (90:45:45 NPK kg ha⁻¹), S2: 125% RDF (120:60:60 NPK kg ha⁻¹), S3: 150% RDF (140:70:70 NPK kg ha⁻¹), S4: 175% RDF (160:80:80 NPK kg ha⁻¹) and S5: Absolute control. The University-recommended dose of fertilizer (RDF) for Bt-cotton under rainfed condition was 90:45:45 kg N:P₂O₅:K₂O ha⁻¹. The Bt-cotton hybrid RCH 971 BG II (Rasi Swift) was sown at a seed rate of 3 kg ha⁻¹ by the dibbling method.

Fertilizer application followed a split dose schedule. The full dose of phosphorus along with 20% each of nitrogen and potassium was applied basally at sowing, and the remaining nitrogen and potassium were applied in two equal splits at 25–30 DAS and 55–60 DAS. Sources of fertilizer were urea (46% N), single superphosphate (16% P₂O₅) and muriate of potash (60% K₂O).

At harvest, seed cotton yield and stalk yield were recorded from each net plot and expressed as q ha⁻¹. Plant samples collected at harvest were shade-dried, then oven-dried at 65 °C and ground for

analysis. Total nitrogen was estimated by the micro-Kjeldahl method (Piper, 1966) [15], total phosphorus by the vanado-molybdate yellow colour method after di-acid (HNO₃:HClO₄) digestion (Jackson, 1973) [9], and potassium by flame photometry (Piper, 1966) [15]. Total nutrient uptake (kg ha⁻¹) was computed by multiplying nutrient content (%) by the dry matter yield (q ha⁻¹).

Results and Discussion

1. Seed Cotton Yield

Seed cotton yield varied significantly with both spacing and fertilizer levels (Table 1; Fig. 1). Among spacing treatments, wider spacing M2 (90 × 30 cm) recorded a significantly higher seed cotton yield of 30.47 q ha⁻¹ compared to 28.60 q ha⁻¹ under closer spacing M1 (90 × 15 cm). The higher yield under wider spacing may be attributed to reduced inter-plant competition for sunlight, moisture and nutrients, which encouraged better root growth, improved boll development and greater dry matter accumulation. These findings are consistent with those of Deshmukh *et al.* (2016) [3], Arun *et al.* (2021) [1] and Zaman *et al.* (2021) [20], who reported that appropriate crop geometry along with optimum nutrient management improved seed cotton productivity.

Among the fertilizer treatments, S2 (125% RDF) produced the highest seed cotton yield of 39.08 q ha⁻¹, which was significantly superior to S3 (150% RDF: 35.03 q ha⁻¹), S1 (100% RDF: 34.32 q ha⁻¹), S4 (175% RDF: 26.60 q ha⁻¹) and S5 (absolute control: 12.66 q ha⁻¹). The superior performance of 125% RDF may be attributed to an optimum supply of nutrients that supported vigorous plant growth, efficient root development, improved boll formation and enhanced dry matter production. Fertilizer levels beyond 125% RDF (i.e., S3 and S4) did not produce proportionate yield, indicating declining marginal returns beyond the optimum. These observations align with those of Ganvir *et al.* (2020) [4], Hemalatha *et al.* (2024) [6] and Sankaranarayanan *et al.* (2018) [17], who also identified 125% RDF as the optimum fertilizer level for Bt-cotton under HDPS.

The significant interaction effect confirms that optimum fertilizer application under suitable crop geometry creates a favourable environment for efficient resource utilization and higher productivity (Arun *et al.*, 2021; Singh *et al.*, 2017) [1, 18].

Table 1: Yield of Bt-cotton as influenced by different treatments

Tr. N.	Treatment	Seed Cotton Yield (q ha ⁻¹)	Cotton Stalk Yield (q ha ⁻¹)
A	Factor A (Spacing)		
M1	90 × 15 cm	28.60	42.48
M2	90 × 30 cm	30.47	45.41
	SE (m)±	0.55	0.81
	CD at 5%	1.62	2.40
B	Factor B (Fertilizers Levels)		
S1	100% RDF (90:45:45 NPK kg ha ⁻¹)	34.32	50.45
S2	125% RDF (120:60:60 NPK kg ha ⁻¹)	39.08	57.45
S3	150% RDF (140:70:70 NPK kg ha ⁻¹)	35.03	52.55
S4	175% RDF (160:80:80 NPK kg ha ⁻¹)	26.60	40.70
S5	Absolute control	12.66	18.60
	SE (m)±	0.86	1.28
	CD at 5%	2.57	3.80
	Interaction (M X S)		
	SE (m)±	1.22	1.81
	CD at 5%	3.63	5.37

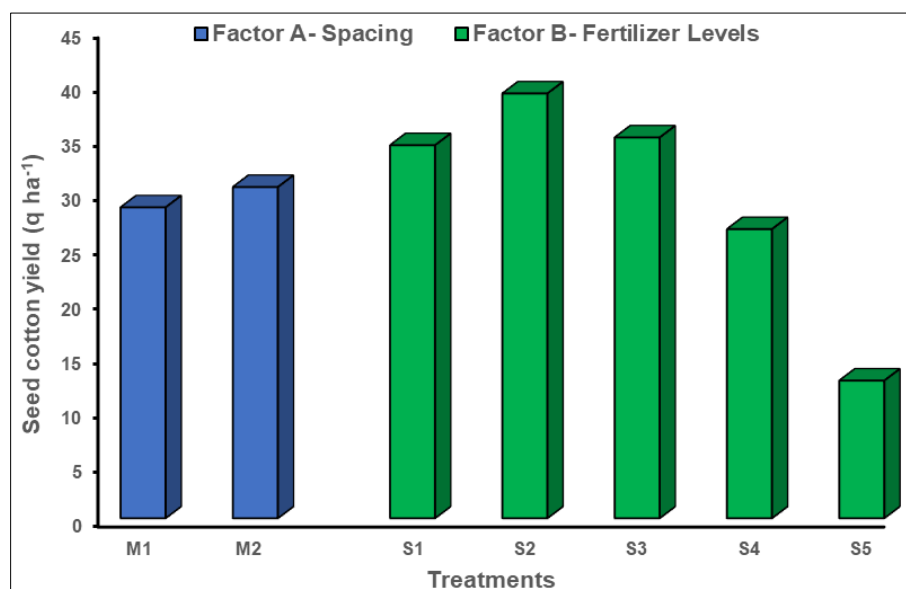


Fig 1: Effect of spacing and fertilizers levels on the seed cotton yield

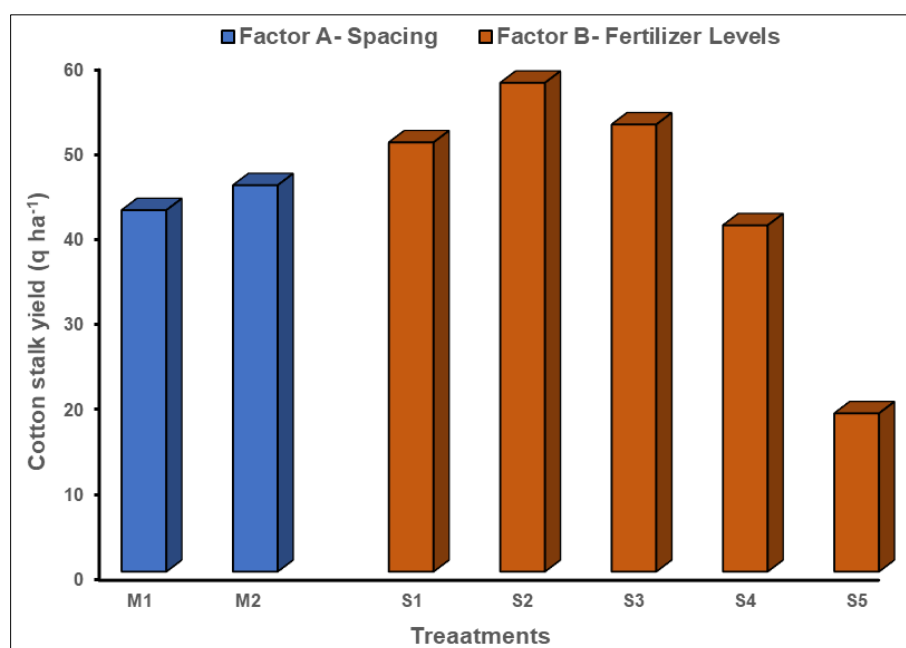


Fig 2: Effect of spacing and fertilizers levels on the cotton stalk yield

2. Cotton stalk yield

Cotton stalk yield shown in Table 1 and Figure 2 was also significantly influenced by both spacing and fertilizer levels. Wider spacing M2 (90 × 30 cm) recorded significantly higher stalk yield (45.41 q ha⁻¹) than closer spacing M1 (90 × 15 cm) (42.48 q ha⁻¹). Among fertilizer levels, S2 (125% RDF) produced the highest stalk yield (57.45 q ha⁻¹), while the absolute control registered the lowest (18.60 q ha⁻¹).

The superior biomass production under 125% RDF was attributed to optimum nutrient availability promoting vigorous vegetative growth and dry matter accumulation (Lavanya *et al.*, 2022; Kakade *et al.*, 2017) ^[11, 12].

3. Total nutrient uptake by Bt-Cotton

3.1 Effect of spacing and fertilizers on the total N, P and K uptake

Total uptake of N, P and K by Bt-cotton was significantly influenced by both spacing and fertilizers levels (Table 2 and Figures 3, 4 and 5). Among spacing treatments, wider spacing

(M2: 90 × 30 cm) recorded significantly higher total nitrogen uptake (92.36 kg ha⁻¹), phosphorus uptake (26.98 kg ha⁻¹) and potassium uptake (72.20 kg ha⁻¹) compared to closer spacing (M1: N = 86.28, P = 25.15, K = 67.44 kg ha⁻¹). The improved nutrient uptake under wider spacing may be attributed to reduced competition among plants for nutrients, moisture and growing space, which encouraged better root proliferation and higher dry matter accumulation. These observations agree with Arun *et al.* (2021) ^[1], Malik *et al.* (2021) ^[13] and Sandeep *et al.* (2024) ^[16]. Among the fertilizer treatments, S2 (125% RDF) recorded the highest total nitrogen uptake (117.60 kg ha⁻¹), phosphorus uptake (34.08 kg ha⁻¹) and potassium uptake (91.24 kg ha⁻¹), followed by S3 (150% RDF) with N = 106.69, P = 31.70 and K = 84.06 kg ha⁻¹. The lowest uptake was recorded under S5 (absolute control) for all three nutrients. The superior nutrient uptake under 125% RDF may be attributed to optimum nutrient supply encouraging vigorous plant growth, better root development, higher dry matter production and improved nutrient absorption efficiency. Fertilizer doses beyond 125% RDF did not produce proportionate increases

in uptake, indicating reduced nutrient-use efficiency at higher levels. Similar findings were reported by Jyothi and Hebsur (2017)^[10], Arun *et al.* (2021)^[1] and Lavanya *et al.* (2022)^[12].

Table 2: Total nutrient uptake by Bt-cotton as influenced by different treatments

Tr. No.	Treatment	N Uptake (kg ha ⁻¹)	P Uptake (kg ha ⁻¹)	K Uptake (kg ha ⁻¹)
A	Factor A (Spacing)			
M1	90 × 15 cm	86.28	25.15	67.44
M2	90 × 30 cm	92.36	26.98	72.20
	SE (m)±	1.64	0.58	1.44
	CD at 5%	4.87	1.73	4.27
B	Factor B (Fertilizer Levels)			
S1	100% RDF (90:45:45 NPK kg ha ⁻¹)	102.95	29.72	79.82
S2	125% RDF (120:60:60 NPK kg ha ⁻¹)	117.60	34.08	91.24
S3	150% RDF (140:70:70 NPK kg ha ⁻¹)	106.69	31.70	84.06
S4	175% RDF (160:80:80 NPK kg ha ⁻¹)	82.01	24.30	65.08
S5	Absolute control	37.34	10.53	28.89
	SE (m)±	2.59	0.92	2.27
	CD at 5%	7.69	2.73	6.74
	Interaction (M X S)			
	SE (m)±	3.66	1.30	3.21
	CD at 5%	10.88	3.87	9.54

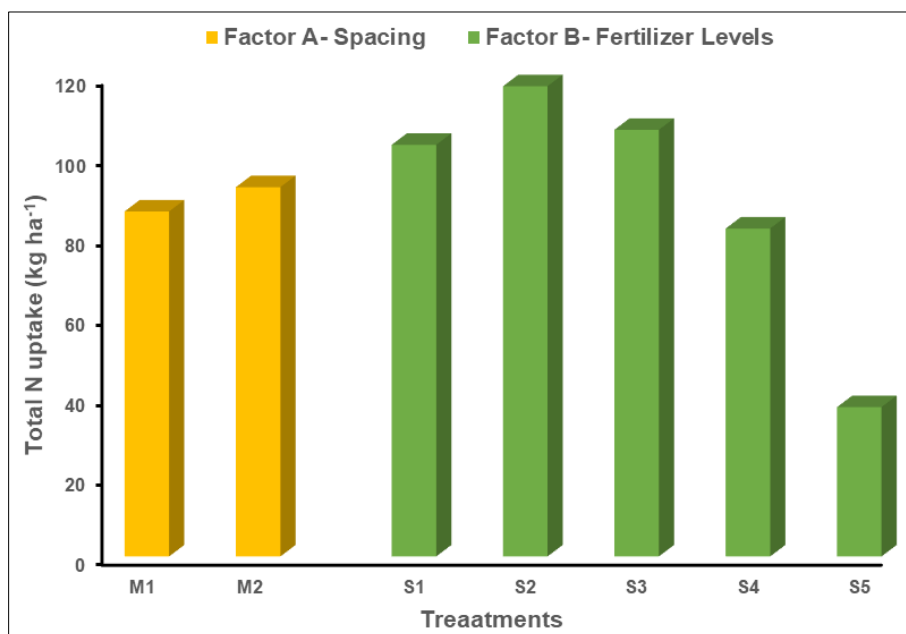


Fig 3: Effect of spacing and fertilizers levels on the total nitrogen uptake by Bt-cotton

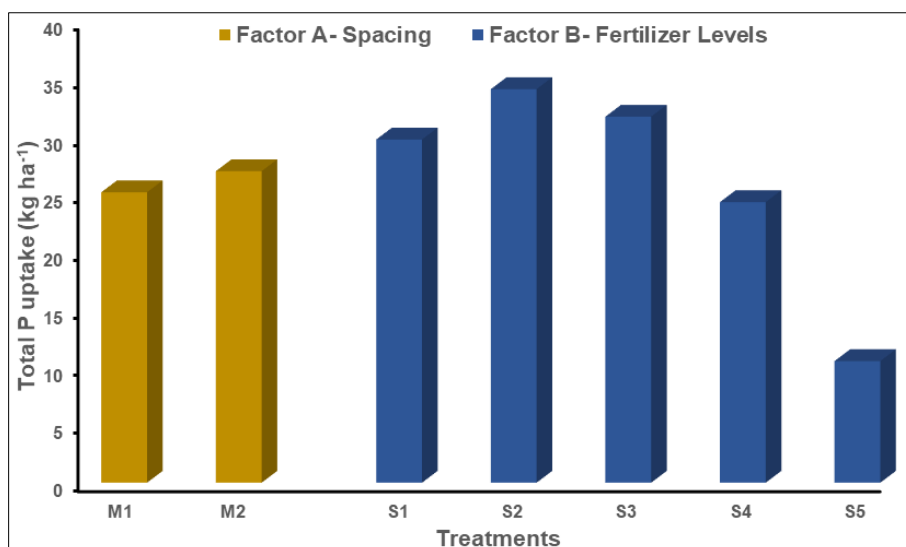


Fig 4: Effect of spacing and fertilizers levels on total phosphorus uptake by Bt-cotton

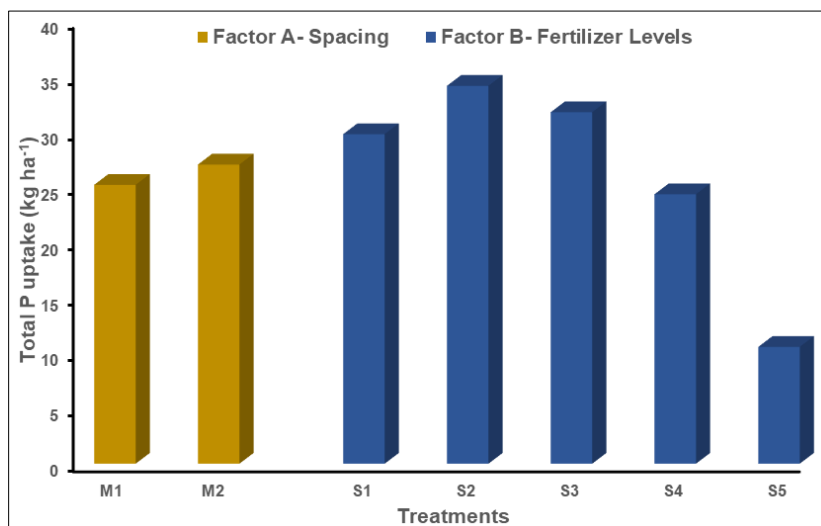


Fig 5: Effect of spacing and fertilizers levels on total potassium uptake

Conclusion

The present investigation clearly demonstrated that spacing and fertilizer levels significantly influenced yield and nutrient uptake by Bt-cotton under HDPS in rainfed condition. Wider spacing (90 × 30 cm) proved superior in terms of seed cotton yield, stalk yield and total nutrient uptake compared to closer spacing (90 × 15 cm). Among the fertilizer levels, application of 125% RDF (120:60:60 NPK kg ha⁻¹) was found to be the most effective for obtaining the highest seed cotton yield, stalk yield and total N, P and K uptake. Therefore, the adoption of 125% RDF (120:60:60 NPK kg ha⁻¹) along with 90 x 30 cm spacing under HDPS was found beneficial as an effective nutrient management strategy for maximizing Bt-cotton productivity and nutrient uptake efficiency under rainfed condition.

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