



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(7): 96-100
Received: 02-05-2026
Accepted: 11-06-2026

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Integrated nutrient management effects on soil moisture dynamics and compaction in high-density Bt and non-Bt cotton

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DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i7b.5902>

Abstract

A field experiment was conducted at College Farm, Agricultural College, Rajendranagar, Hyderabad, during *kharif* 2019-20 and 2020-21 to study the effect of genotypes and integrated nutrient management practices on soil moisture dynamics and soil bulk density of HDPS cotton. Experiment was laid out in Split plot design, with two genotypes as main plots (M) and nine Integrated Nutrient Management practices as sub-plots (S). Soil with Bt genotype held more soil moisture content as compared to non-Bt at all crop intervals, with a non-significant difference. Among integrated nutrient management treatments, Soil moisture content was maximum in treatment with 100% RDF + soil application of *Jeevamrutha* @ 500 L ha⁻¹ at 15 days interval up to harvest with a non-significant difference compared to rest of the treatments during 2019-20 and 2020-21. Finally, Bt cotton had recorded soil moisture content than non Bt at all the stages of crop growth. Between integrated nutrient management practices, S₅ had recorded maximum soil moisture content.

Keywords: HDPS Cotton, *Jeevamrutha*, INM, Soil Moisture and Bulk density

1. Introduction

Cotton (*Gossypium hirsutum* L.) is one of the major cash crops of India, popularly known as 'White gold' and 'King of fibres' for its role in the national economy in terms of foreign exchange earnings and employment generation (Vinay *et al.*, 2023) ^[21]. Cotton provides fibre, feed, fuel and vegetable oil (Kumar *et al.*, 2017) ^[13]. It is the world's leading source of natural textile fibre and fifth largest oilseeds crop which covers 40% of the global textile need and 3.3% of edible oil respectively (Nagender *et al.*, 2017a) ^[15].

Cotton is grown mainly in tropical and subtropical regions of more than 80 countries in the world. This crop provides livelihood to 60 million people in India by way of support of agriculture, processing and textiles and it contributes to 29% of the national GDP (Khadi *et al.*, 2010) ^[12]. In India it is grown in an area of 13.28 m ha with production of 35.24 m bales, and productivity of 491 kg ha⁻¹. In India, during 2020-21 higher area (4.54 m ha) and production (10.1 m bales) was recorded in Maharashtra and productivity was recorded from Punjab (690 kg ha⁻¹). Telangana ranked second in area (2.35 m ha) with a production of 5.7 m bales with a productivity of 418 kg ha⁻¹ (CCI, 2021) ^[6].

Bt cotton in India was introduced in the year 2002 and the Bt period (2002-03 to 2010-11) brought a significant increase in the growth of cotton acreage, production and productivity from 13 million bales to 40 million bales in the past 13 years. However, this Bt period also registered a marked increase in the instability in production (Narala and Reddy, 2010) ^[17] as the cost of cotton production is escalating due to increased labour demand, increased labour costs, increased seed costs, and increased costs for cotton picking and nutrient requirements. Country's population is growing at 1.9% and demands for food and fibre continue to grow and putting pressure on the limited arable land available (Nagender *et al.*, 2017b) ^[16]. All these facts point to the dire need for sustainable practices. So, to sustain the productivity, high density planting systems, with narrow and ultra-narrow spacing, developing suitable management options for improving yields and also to improve input use efficiency is the need of hour.

A high density planting system (HDPS) leading to more rapid canopy closure and decreased soil water evaporation, is becoming popular to address water scarcity challenges. In many countries, narrow row plantings have been adopted after showing improvement in cotton productivity (Ali *et al.*, 2010) [9]. The adoption of HDP, along with good fertilizer management and better genotypes, is a viable approach to break the current trend of stagnating yields under primarily rainfed *hirsutum* (upland) cotton growing areas.

Intensive cropping and indiscriminate fertilizer application depleted available NPK in almost all soils in India. Hence replenishment of shovelled out nutrients is very essential, especially when exhaustive crops like cotton is cultivated. The commercial cultivation of Bt hybrids is more profitable and relatively safe for the environment due to 50-75% reduction in pesticide application. But Bt cotton is known to draw huge quantities of nutrients especially nitrogen than the hybrids and varieties, which will have serious repercussions on the already depleted soil fertility status. Trends of high nitrogen requirement by fast expanding Bt hybrids in India on one hand and rapid depletion of nutrients in the soils warrants improvement in cotton yield through agronomic management by integrated nutrient management to restore the soil fertility and sustain crop productivity and fully harness its economic benefits (Vani *et al.*, 2020) [20]. Integrated use of chemical fertilizers and organic manures is not only essential for achieving higher yields but also plays crucial role in improving soil health (Vinay *et al.*, 2022) [22]. Hence, for maintaining soil physicochemical and biological properties and increasing soil productivity, use of FYM, vermicompost, *Jeevamrutha* alone or in combination may prove to be beneficial. (Patil and Udmale, 2016) [18].

Keeping the above facts in view, the present study was initiated to maximize the growth and yield of high density planted cotton under different Genotypes and Integrated Nutrient Management practices.

2. Materials and Methods

The field experiment was conducted at College Farm, Agricultural College, Rajendranagar, Southern zone of Telangana State. The farm is geographically situated at 17°32'N Latitude, 78°41' E Longitude and altitude of 542.6 m above mean sea level. The soil of the experimental site was sandy clay loam in texture, slightly alkaline in reaction and non-saline. The fertility status of the experimental soil was low in organic carbon (0.51%), low in available N (138 kg ha⁻¹), high in phosphorus (65 kg ha⁻¹) and medium in potassium (286 kg ha⁻¹). The experiment was conducted during *khari* 2019-20 and 2020-21 in split plot design with two genotypes viz., M₁-Bt (KCH – 14K59 BG II), M₂-Non-Bt (ADB – 542) as main plots and nine integrated nutrient management practices viz., S₁-No fertilizer, S₂-75% RDF, S₃-100% RDF, S₄-75% RDF + Soil application of *Jeevamrutha* @ 500 L ha⁻¹ at 15 days interval up to harvest, S₅-100% RDF + Soil application of *Jeevamrutha* @ 500 L ha⁻¹ at 15 days interval up to harvest, S₆-75% RDF + Foliar spray of *Jeevamrutha* @ 5% at 15 days interval up to harvest, S₇-100% RDF + Foliar spray of *Jeevamrutha* @ 5% at 15 days interval up to harvest, S₈-Soil application of *Jeevamrutha* @ 500 L ha⁻¹ at 15 days interval up to harvest (Alone), S₉-Soil application of *Jeevamrutha* @ 500 L ha⁻¹ + Foliar spray of *Jeevamrutha* @ 5% at 15 days interval up to harvest, as sub-plots replicated thrice. Fertilizer management was done as per the framed treatments following standard protocols of Bt and Non Bt cotton. In Bt cotton (RDF: 120:60:60 NPK ha⁻¹), Nitrogen and Potassium were applied in four equal splits (*i.e.*, at 20, 40, 60 and 80 DAS) whereas entire dose of Phosphorus was applied as basal. In Non Bt cotton (RDF: 90:45:45 NPK ha⁻¹),

Nitrogen and Potassium were supplied in only three equal splits (*i.e.*, at 30, 60 and 90 DAS) and Phosphorus was applied at basal. Urea, DAP and MOP were the sources of N, P₂O₅ and K₂O respectively. *Jeevamrutha* was made by mixing 200 litres of water with 10 kg fresh cow dung and 10 liters of cow urine (*desi*), 2 kg jaggery, 2 kg flour of chickpea, and 100 g antennae soil in a barrel. The fermented mixture was kept in the shade and was stirred thoroughly twice a day (morning and evening) in clockwise direction with the help of wooden stick for three days. It will produce a mild foul odour after three days which indicates its readiness to use. *Jeevamrutha* @ 500 L ha⁻¹ was applied manually directly in the soil in four treatments (S₄, S₅, S₈ and S₉) from 15 DAS to harvest of cotton crop with 15 days interval. Foliar spray of *Jeevamrutha* @ 5% was applied in the three treatments (S₆, S₇ and S₉) with Knapsack sprayer from 15 DAS to harvest of cotton crop with 15 days interval. Spacing adopted 60 cm x 30 cm, gross plot size and net plot size were 6.0 m x 4.2 m and 3.6 m x 3.0 m respectively during both seasons. Soil moisture content (%) was estimated by gravimetric method (Black, 1965) [5]. In this method, soil samples from each treatment were collected with an auger at 30 days intervals from sowing to harvest. The fresh weight of soil samples was recorded immediately after sampling and then oven-dry weight of samples was recorded after drying samples at 105 °C in oven and moisture content was estimated by using following formula

$$\text{SMC (\%)} = \frac{\text{Fresh weight of soil sample} - \text{oven-dry weight of soil}}{\text{Oven-dry weight of soil}} \times 100$$

Bulk density (g cm³) was estimated by Dhakshinamurthy and Gupta, 1968 [7] method. With help of wooden mallet, carefully press bulk density ring into earth. Remove soil surrounding ring using a spade, then transfer soil in ring to an aluminium container and dry in 105°C oven for 24 hours. Calculate volume of soil (ring) by measuring height and diameter of ring

$$\text{Volume of soil (V)} = \pi r^2 h \text{ (cm}^3\text{)}$$

h = height of the ring

r = radius of the ring

Bulk density of soil (g cm⁻³): W/V

Where,

W = Weight of dry soil (g)

V = Volume of the soil (cm³)

The data were analyzed statistically applying analysis of variance technique for split plot design. The significance was tested by 'F' test (Gomez and Gomez, 1984) [10].

3. Results and Discussion

3.1 Soil Moisture Content (%)

Ensuring optimum soil moisture content at critical stages of crop is necessary for good growth and development. Thus, an overview of soil moisture content at different stages of crop growth is essential. From table 1 and 2, it can be inferred that soil moisture content at different stages was not-significantly influenced by genotypes and integrated nutrient management as well as due to their interaction.

Bt, KCH-14K59 BG II had recorded higher soil moisture content (13.5, 13.0, 13.2, 11.2, 12.8 and 12.8%) as compared to M₂ [Non-Bt, ADB-542] (13.4, 12.4, 12.7, 10.8, 9.3 and 12.0%) at 30, 60, 90, 120, 150 DAS and harvest, with a non-significant difference. Bt cotton had better root volume and higher uptake which increased vegetative growth and leaf area thus reducing

evaporation from soil when in turn stored the moisture content of soil. These results are in line with Singh *et al.* (2018) ^[19] & Basavanneppa *et al.* (2015) ^[3]. Non-Bt cotton has lower root volume which might be the reason for less moisture content as reported by Beura and Rakshit (2011) ^[14].

Soil moisture content was maximum in treatment with 100% RDF + Soil application of *Jeevamrutha* @ 500 L ha⁻¹ at 15 days interval up to harvest (S₅) (14.0, 13.5, 13.6, 11.6, 13.1 and 13.1%) and at par with S₇ [100% RDF + Foliar spray of *Jeevamrutha* @ 5% at 15 days interval up to harvest] (14.0, 14.0, 13.3, 13.4, 11.4, 12.9 and 12.9%) with a non-significant difference. While, soil moisture content was lowest with S₁ [No fertilizer] (12.7, 12.2, 12.4, 10.4, 11.7 and 11.7%) at 30, 60, 90, 120, 150 DAS and harvest. Application of *Jeevamrutha* positively increased organic matter with more water holding capacity leading to higher soil moisture content whereas continuous use of chemical fertilizers decreased water holding capacity. Similar results were reported by Gachande *et al.* (2017) ^[18] and Gokale *et al.* (2011).

3.2 Soil Bulk Density (g cm³)

An assessment of data of two years, (Table 3) showed that there

was no significant influence on soil bulk density by genotypes and integrated nutrient management practices. However, non-Bt, ADB-542 documented lower bulk density (1.22 g cm³) compared to Bt, KCH-14K59 BG II in *kharif* 2019-20 and 2020-21. Genotypes didn't impact the soil properties significantly as study is carried out for only two years and long term study is needed to conclude the result. These findings are in agreement with Ahamd *et al.* (2017) and Beura and Rakshith (2011) ^[14].

Out of nine integrated nutrient management practices, S₄-75% RDF + Soil application of *Jeevamrutha* @ 500 L ha⁻¹ at 15 days interval up to harvest, S₉-Soil application of *Jeevamrutha* @ 500 L ha⁻¹ + Foliar spray of *Jeevamrutha* @ 5% at 15 days interval up to harvest and S₅-100% RDF + Soil application of *Jeevamrutha* @ 500 L ha⁻¹ at 15 days interval up to harvest treatments noticed lower bulk density (1.22 g cm³), of soil in two years of research with non-significant difference among the treatments. Integrated nutrient management practices didn't show any significant results in short term and they might impact the soil health in long term. These findings are in agreement with Hamed *et al.* (2019) ^[11] & Muthukrishnan *et al.* (2017) ^[14].

Table 1: Soil moisture content (%) estimation at 30, 60 and 90 DAS as influenced by Genotypes and Integrated Nutrient Management

Treatments	30 DAS			60 DAS			90 DAS		
	2019-20	2020-21	Pooled mean	2019-20	2020-21	Pooled mean	2019-20	2020-21	Pooled mean
Main plot									
M ₁	11.5	15.5	13.5	11.9	14.1	13.0	12.7	13.8	13.2
M ₂	11.3	15.3	13.4	11.5	13.4	12.4	12.2	13.2	12.7
SE (m) ±	0.30	0.44	0.22	0.26	0.40	0.23	0.27	0.34	0.30
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub plot									
S ₁	10.9	14.4	12.7	11.1	13.3	12.2	12.0	12.9	12.4
S ₂	11.4	15.3	13.3	11.2	13.6	12.4	12.3	13.4	12.8
S ₃	11.8	16.0	13.9	12.3	13.9	13.1	12.6	13.6	13.1
S ₄	11.5	15.9	13.7	11.8	13.9	12.9	12.5	13.5	13.0
S ₅	12.0	16.3	14.2	12.7	14.3	13.5	13.0	14.2	13.6
S ₆	11.5	15.5	13.5	11.2	13.9	12.6	12.5	13.5	13.0
S ₇	11.8	16.1	13.9	12.4	14.3	13.3	13.0	13.9	13.4
S ₈	11.1	14.5	12.8	11.1	13.4	12.3	12.1	13.2	12.6
S ₉	11.1	14.6	12.8	11.2	13.5	12.3	12.2	13.3	12.8
SE (m) ±	0.52	0.60	0.45	0.52	0.62	0.41	0.44	0.52	0.40
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
M × S									
SE (m) ±	0.75	0.92	0.65	0.74	0.92	0.59	0.65	0.77	0.61
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
S × M									
SE (m) ±	0.73	0.85	0.64	0.74	0.88	0.58	0.62	0.74	0.56
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: Main plots – Genotypes: M₁: Bt, KCH – 14K59 BG II, M₂: Non- Bt, ADB-542, Sub plots: Integrated Nutrient Management: S₁-No fertilizer, S₂-75% RDF, S₃-100% RDF, S₄-75% RDF + Soil application of *Jeevamrutha* @ 500 L ha⁻¹ at 15 days interval up to harvest, S₅-100% RDF + Soil application of *Jeevamrutha* @ 500 L ha⁻¹ at 15 days interval up to harvest, S₆-75% RDF + Foliar spray of *Jeevamrutha* @ 5% at 15 days interval up to harvest, S₇-100% RDF + Foliar spray of *Jeevamrutha* @ 5% at 15 days interval up to harvest, S₈- Soil application of *Jeevamrutha* @ 500 L ha⁻¹ at 15 days interval up to harvest (Alone), S₉-Soil application of *Jeevamrutha* @ 500 L ha⁻¹ + Foliar spray of *Jeevamrutha* @ 5% at 15 days interval up to harvest.

Table 2: Soil moisture content (%) estimation at 120, 150 DAS and harvest as influenced by Genotypes and Integrated Nutrient Management

Treatments	120 DAS			150 DAS			Harvest		
	2019-20	2020-21	Pooled mean	2019-20	2020-21	Pooled mean	2019-20	2020-21	Pooled mean
Main plot									
M ₁	9.6	12.7	11.2	11.8	14.8	13.3	11.6	14.8	12.8
M ₂	9.5	12.1	10.8	11.4	13.4	12.4	11.0	13.4	12.0
SE (m) ±	0.18	0.24	0.21	0.25	0.29	0.36	0.25	0.29	0.34
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub plot									
S ₁	9.3	11.4	10.4	10.8	13.0	11.7	10.6	12.9	11.7

S ₂	9.4	12.2	10.8	11.4	13.9	12.3	11.1	13.9	12.3
S ₃	9.7	12.8	11.2	12.2	14.7	12.7	11.6	14.7	12.7
S ₄	9.7	12.6	11.1	11.9	14.3	12.5	11.4	14.3	12.5
S ₅	9.8	13.4	11.6	12.3	15.2	13.1	12.1	15.2	13.1
S ₆	9.6	12.4	11.0	11.6	14.2	12.4	11.3	14.2	12.4
S ₇	9.8	13.0	11.4	12.2	14.8	12.9	11.8	14.8	12.9
S ₈	9.3	11.7	10.5	11.1	13.4	12.0	10.7	13.4	12.0
S ₉	9.4	11.9	10.7	11.2	13.6	12.1	10.8	13.6	12.1
SE (m) ±	0.34	0.43	0.37	0.42	0.50	0.44	0.43	0.49	0.59
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
M × S									
SE (m) ±	0.49	0.62	0.54	0.62	0.72	0.69	0.63	0.72	0.85
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
S × M									
SE (m) ±	0.49	0.61	0.53	0.60	0.70	0.63	0.61	0.70	0.83
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: Main plots – Genotypes: M₁: Bt, KCH – 14K59 BG II, M₂: Non- Bt, ADB-542, Sub plots: Integrated Nutrient Management: S₁-No fertilizer, S₂-75% RDF, S₃-100% RDF, S₄-75% RDF + Soil application of *Jeevamrutha* @ 500 L ha⁻¹ at 15 days interval up to harvest, S₅-100% RDF + Soil application of *Jeevamrutha* @ 500 L ha⁻¹ at 15 days interval up to harvest, S₆-75% RDF + Foliar spray of *Jeevamrutha* @ 5% at 15 days interval up to harvest, S₇-100% RDF + Foliar spray of *Jeevamrutha* @ 5% at 15 days interval up to harvest, S₈- Soil application of *Jeevamrutha* @ 500 L ha⁻¹ at 15 days interval up to harvest (Alone), S₉-Soil application of *Jeevamrutha* @ 500 L ha⁻¹ + Foliar spray of *Jeevamrutha* @ 5% at 15 days interval up to harvest.

Table 3: Bulk density (g cm³) of HDPS cotton as influenced by Genotypes and Integrated Nutrient Management

Treatments	Bulk density (g cm ³)		
	2019-20	2020-21	Pooled mean
Main plot – Genotypes			
M ₁ - Bt (KCH - 14K59 BG II)	1.26	1.22	1.24
M ₂ - Non- Bt (ADB – 542)	1.24	1.20	1.22
SE(m)±	0.03	0.04	0.02
CD (p=0.05)	NS	NS	NS
Sub plot - Integrated Nutrient Management			
S ₁ -No fertilizer	1.28	1.23	1.26
S ₂ - 75% RDF	1.26	1.22	1.24
S ₃ - 100% RDF	1.26	1.22	1.24
S ₄ -75% RDF + Soil application of <i>Jeevamrutha</i> @500 L ha ⁻¹ at 15 days interval up to harvest	1.24	1.20	1.22
S ₅ - 100% RDF + Soil application of <i>Jeevamrutha</i> @ 500 L ha ⁻¹ at 15 days interval up to harvest	1.24	1.20	1.22
S ₆ -75% RDF + Foliar spray of <i>Jeevamrutha</i> @ 5% at 15 days interval up to harvest	1.26	1.21	1.23
S ₇ -100% RDF + Foliar spray of <i>Jeevamrutha</i> @ 5% at 15 days interval up to harvest	1.26	1.22	1.24
S ₈ - Soil application of <i>Jeevamrutha</i> @ 500 L ha ⁻¹ at 15 days interval up to harvest (Alone)	1.25	1.21	1.23
S ₉ -Soil application of <i>Jeevamrutha</i> @ 500 L ha ⁻¹ + Foliar spray of <i>Jeevamrutha</i> @ 5% at 15 days interval up to harvest.	1.24	1.20	1.22
SE(m)±	0.05	0.07	0.03
CD (p=0.05)	NS	NS	NS
Interaction			
M×S			
SE(m)±	0.07	0.10	0.05
CD (p=0.05)	NS	NS	NS
S×M			
SE(m)±	0.06	0.09	0.05
CD (p=0.05)	NS	NS	NS

4. Conclusion

Finally, it can be concluded that Bt, KCH-14K59BG II had recorded higher Soil moisture content throughout crop growth period than the non Bt ADB-542. Between integrated nutrient management practices, 100% RDF + Soil application of *Jeevamrutha* @ 500 L ha⁻¹ at 15 days interval up to harvest recorded maximum moisture content over other treatments.

Acknowledgement

The Corresponding Writer is extremely grateful to PJTSAU, Rajendranagar, Hyderabad, for provided that finance to carry out PhD programme.

Conflict of Interests

Authors have professed that no conflict of interests exists.

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