International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; SP-9(8): 1159-1165
www.biochemjournal.com
Received: 07-05-2025
Accepted: 10-06-2025

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Effect of soil and foliar application of humic acid on cotton yield and soil fertility in Vertisols

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DOI: https://www.doi.org/10.33545/26174693.2025.v9.i8Sq.5330

Abstract
The present study was conducted during the year 2024-25 at Research Farm, Department of Soil Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, to evaluate the effect of soil and foliar application of humic acid on yield of cotton and available nutrients in soil. The experimental soil was characterized as Montmorillonitic, hyperthermic, with high clay content and typical swell-shrink behaviour. The experiment comprised seven treatments arranged in randomized block design with three replications.

The highest seed cotton yield was recorded with application of 100% RDF through soil + foliar spray of EnHA @ 0.5%, which was statistically at par with treatment receiving 75% RDF through drip + EnHA @ 0.2% through drip. The highest stalk yield of cotton was obtained with application of 100% RDF through drip, which was statistically at par with the treatments receiving 75% RDF through drip + EnHA @ 0.2% through drip and 75% RDF through drip + HA @ 0.2% through drip. The lowest seed cotton yield and stalk yield were in control. A significant improvement in soil organic carbon (SOC) was recorded with the application of 75% RDF through drip + HA @ 0.2% through drip followed by 75% RDF through drip +EnHA @ 0.2% through drip. In terms of available nutrient status, the significantly highest available nitrogen and available phosphorus were found with 75% RDF through drip + EnHA @ 0.2% through drip, followed by 75% RDF through drip + HA @ 0.2% through drip. Similarly, the highest available potassium and available sulphur were also observed with 75% RDF through drip + EnHA @ 0.2% through drip.

Keywords: Humic acid, cotton yield, available nutrient status

Introduction

Cotton (*Gossypium* spp.) is one of the most important commercial fibre and cash crops globally and holds a prominent place in Indian agriculture, contributing significantly to the rural economy and industrial sector. India ranks among the top cotton-producing countries, with the crop cultivated over approximately 12.5 million hectares across various agro-climatic zones. Major cotton-growing states include Maharashtra, Gujarat, Telangana, Andhra Pradesh, and Madhya Pradesh, with Maharashtra alone contributing a substantial share of the total area under cotton cultivation. The crop is grown predominantly under rainfed conditions in the black cotton soils of the Deccan Plateau, known for their high clay content, shrink-swell nature, and variable fertility. Cotton is cultivated primarily for its lint used in the textile industry, while the cottonseed is processed for oil extraction and livestock feed. Cottonseed contains around 18-22% oil and 20-25% protein, making it a valuable dual-purpose crop. In addition to its economic importance, cotton plays a crucial role in the cropping systems of dryland agriculture, especially when grown in rotation with cereals and legumes.

Despite the extensive area under cotton cultivation, productivity remains low in many regions due to poor soil health, nutrient imbalance, and limited organic matter content, particularly in Vertisols (black cotton soils). To address these issues, integrated nutrient management approaches incorporating organic amendments like humic acid are gaining importance. Humic acid and enriched humic acid, are organic compounds. They are known to improve soil physio-chemical properties and increase crop yields. Foliar and soil application of humic acid has shown promising improvement in plant growth, nutrient absorption, and overall soil fertility.

When combined with recommended doses of fertilizers (RDF), humic acid contributed to better nutrient availability and sustainable crop production. This is especially relevant in black cotton soils, which are often deficient in available nitrogen, phosphorus, sulphur and prone to nutrient fixation due to their high cation exchange capacity (CEC). this background, the present investigation was undertaken to evaluate the effect of soil and foliar application of humic acid, in conjunction with different levels of RDF, on seed cotton yield, stalk yield, and soil nutrient status under black cotton soil conditions. The study aims to promote sustainable cotton production through improved nutrient management practices, particularly in dryland farming regions.

2. Material and Methods

Akola is situated in the subtropical region at 22°42‟North latitude and 77^{0}02‟ East longitude and altitude of 307.42 m above the sea level. A field experiment was conducted at Research Farm, Department of Soil Science, Dr. PDKV, Akola (MS) during kharif season of 2024-25 using a Randomized Block Design (RBD) with seven treatment and replicated thrice. The treatments comprised of 100% RDF through drip (T1),75% RDF through drip + EnHA @ 0.2% through drip (T2), 75% RDF through drip + HA @ 0.2% through drip (T3), 100% RDF through soil (T4), 100% RDF through soil + foliar spray of EnHA @ 0.5% (T5), 100% RDF through soil + foliar spray of HA @ 0.5% (T6), Absolute control (T7). The recommended dose of fertilizers for Cotton was 120:60:60 NPK kg ha^{-1}. Representative soil samples from 0-20 cm depth were collected from each plot of experimental area both before sowing and after harvest of the crop. The soil at the experimental site was swell shrink, montmorillonite with clayey texture. It exhibited low permeability and high moisture retention. Initial analysis revealed pH (8.10), electrical conductivity (0.23 dSm^{-1}), Organic carbon (4.47 g kg^{-1}), low nitrogen (153.3 kg ha^{-1}), phosphorus (16.59 kg ha^{-1}), and high potassium levels (365 kg ha^{-1}). Statistical analysis was performed according to the procedures outlined by Gomez and Gomez (1984).

3. Results and Discussion

3.1 Seed cotton and stalk yield of cotton

The effect of soil and foliar application of humic acid on seed cotton yield was found statistically significant (Table 1). The highest seed cotton yield (25.20 q ha^{-1}), which was found statistically at par with 100% RDF through drip (23.90 q ha^{-1}) and 75% RDF through drip + EnHA @ 0.2% through drip (23.06 q ha^{-1}). while the lowest seed cotton yield (17.73 q ha^{-1}) was recorded under absolute control. Similar findings were reported by Nandkumar *et al.* (2004) [11], who observed that foliar application of humic acid in combination with NPK fertilizers enhanced seed cotton yield. These results are in agreement with the findings of Haroon *et al.* (2010) [8], Anjum *et al.* (2011) [3], Ahmed *et al.* (2013) [1], Vanita and Mohandas (2014) [14], and Lingaraju *et al.* (2016) [10], who also reported positive effects of humic acid on cotton productivity. However, The highest stalk yield was observed with application of 100% RDF through drip (67.88 q ha^{-1}) which was statistically at par with 75% RDF through drip + EnHA at 0.2% through drip (61.57 q ha^{-1}) and 75% RDF through drip + HA @ 0.2% (59.98 q ha^{-1}) and lowest in absolute control (52.30 q ha^{-1}). Similar finding was reported Butani *et al.* (2007) [6] who reported that foliar application of humic acid with fertilizers recorded maximum yield. Comparable findings were also reported by Shabana Ehsan *et al.* (2014) [18], Ramesh *et al.* (2017) [13] and Pavani *et al.* (2022). Application of RDF along with foliar spray of humic acid resulted in increased seed cotton and cotton stalk yield. This improvement might be attributed to the enhancement of photosynthesis and enzymatic activity, as well as the reduction in square and boll shedding.

Table 1: Effect of soil and foliar application of humic acid on seed cotton and stalk yield

Tr.	Treatment details	Yield (q ha^{-1})	
		Seed cotton	Cotton stalk
T_1	100% RDF through drip	23.90	67.88
T_2	75% RDF through drip + EnHA @ 0.2% through drip	23.06	61.57
T_3	75% RDF through drip + HA @ 0.2% through drip	21.81	59.98
T_4	100% RDF through soil	22.41	64.09
T_5	100% RDF through soil + foliar spray of EnHA @ 0.5%	25.20	65.77
T_6	100% RDF through soil + foliar spray of HA @ 0.5%	22.59	63.26
T_7	Absolute control	17.73	52.30
	SE(m)±	0.70	2.56
	CD at 5%	2.20	8.00

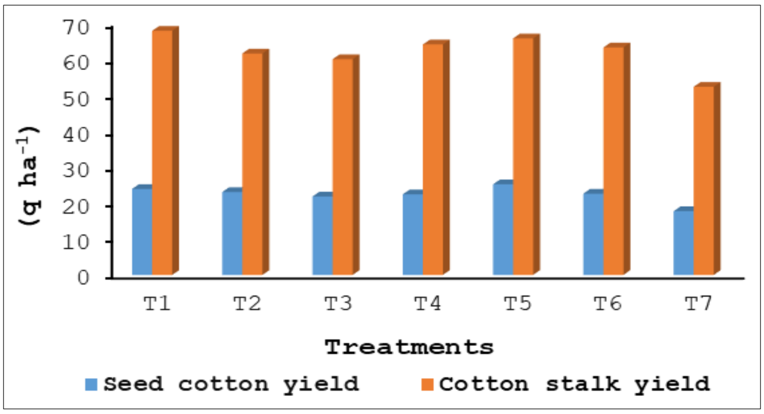

Fig 1: Effect of soil and foliar application of humic acid on yield of cotton.

3.2 Effect of soil and foliar application of humic acid on soil properties.

Effect of soil and foliar application of humic acid on soil pH, electrical conductivity, and organic carbon are presented in Table 2.and depicted in fig.2

3.2.1 pH

The data showed that the effect of humic acid was not found significant in relation to pH. The highest pH value (8.07) was recorded with application of 75% RDF through drip irrigation combined with EnHA @ 0.2% through drip followed by 100% RDF through soil + foliar spray of EnHA @ 0.5%. The lower pH (7.87) was observed in absolute control. Soil pH was not significantly influenced by humic acid treatments may be due to humic acid is an organic acid, it can combine with cations in the soil to form humate, and then form a buffer system of mutual transformation between humic acid and humate, so it can play a role in regulating soil pH. Similar result results reported by Hu *et al*. (2020) [9].

Electrical conductivity

Soil electrical conductivity (EC) was significantly influenced by different treatments. The highest EC (0.25 ds m^{-1}) was observed with 100% RDF through drip irrigation followed by 75% RDF through drip + HA @ 0.2% through drip while it was significantly increase over control. The similar findings were noted by Gumus and Seker (2015) [7], and stated that humic acid improves soil fertility and structure, it may cause a temporary rise in EC due to increased ionic concentration in the soil solution.

Organic Carbon

The organic carbon content of the soil was significantly influenced with the application of humic acid in combination with RDF. Among the treatments, the highest organic carbon (4.62 g kg^{-1}) was recorded with the application of 75% RDF through drip along with humic acid @ 0.2%, which was statistically at par with 75% RDF through drip + EnHA @ 0.2% through drip (4.56 g kg^{-1}). The lowest OC content (4.27 g kg^{-1}) was recorded in the absolute control. Humic substances themselves are rich in stable organic compounds, and when added to soil, they act as an additional carbon source, thereby increasing the organic carbon content. Furthermore, RDF ensures adequate nutrient supply for optimal plant growth and humic acid stimulates soil microbial growth and activity, which enhances the decomposition of organic residues and conversion into stable organic matter, contributing to increased OC. Consistent with this trend, Sangeetha *et al*. (2006) [14] reported improved organic carbon content in soil following the combined use of humic acid and NPK.

Table 2: Effect of soil and foliar application of humic acid on chemical properties of soil

Tr.	Treatment details	pH	EC (ds m^{-1})	Organic carbon (g kg^{-1})
T_1	100% RDF through drip	8.00	0.25	4.38
T_2	75% RDF through drip + EnHA @ 0.2% through drip	8.07	0.22	4.56
T_3	75% RDF through drip + HA @ 0.2% through drip	8.00	0.25	4.62
T_4	100% RDF through soil	8.07	0.23	4.45
T_5	100% RDF through soil + foliar spray of EnHA @ 0.5%	8.06	0.23	4.36
T_6	100% RDF through soil + foliar spray of HA @ 0.5%	8.03	0.23	4.39
T_7	Absolute control	7.87	0.21	4.27
	SE(m)±	0.17	0.007	0.05
	CD at 5%	NS	0.02	0.17

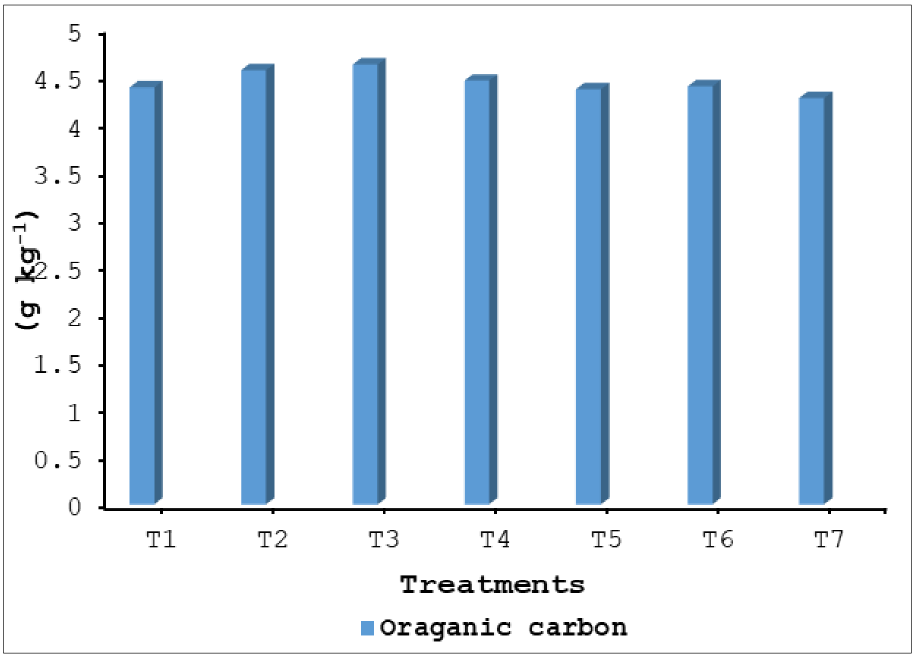

Fig 2: Effect of soil and foliar application of humic acid on organic carbon in soil

3.3 Effect of soil and foliar application of humic acid on available nutrients in soil

3.3.1 Available nitrogen

A significant increase in available nitrogen in soil after harvest of cotton was recorded with application of different treatments. The highest available nitrogen (166.00 kg ha^{-1}) was observed with 75% RDF through drip irrigation along with EnHA @ 0.2% through drip, which was at par with application of 75% RDF through drip + HA @ 0.2% through drip, (164.00 kg ha^{-1}). The lowest available nitrogen (151.00 kg ha^{-1}) was recorded under the absolute control.

The observed increase in nitrogen availability can be explained by the fact that humic acid application stimulates microbial growth, resulting in a significant increase in urease activity, which enhances nitrogen mineralization and availability especially within the plant rhizosphere. Arjumend *et al*. (2015) [4] revealed that the application of humic acid along with inorganic fertilizers led to higher nitrogen availability. Similar results were also reported by Ahmed *et al*. (2021) [2] and Savita *et al*. (2018) [16].

3.3.2 Available phosphorus

Available phosphorus content in the soil was significantly influenced by 75% RDF through drip + EnHA @ 0.2% (20.00 kg ha^{-1}) which was statistically at par with 75% RDF through drip + HA @ 0.2% (19.61 kg ha^{-1}) and significantly superior to all other treatments. The lowest available phosphorus (16.21 kg ha^{-1}) was observed in absolute control. Selim *et al*. (2010) [17], who observed that the addition of humic substances increased phosphorus availability, particularly in the deeper soil layers, due to their ability to chelate cations and reduce phosphorus fixation. These findings are further supported by the studies of Sarwar *et al*. (2012) [15], and Yan *et al*. (2022) [21], who also reported that enhanced phosphorus availability in soil following the application of humic substances. The consistent results across these studies suggest that humic and enriched humic acids play a crucial role in improving phosphorus dynamics in the soil, thereby enhancing its availability to plants.

3.3.3 Available potassium

A significant increase in available potassium content in soil after harvest of cotton was recorded with the application of 75% RDF through drip irrigation along with EnHA @ 0.2% through drip (380 kg ha^{-1}), followed by the application of 75% RDF through drip + HA @ 0.2% through drip (375 kg ha^{-1}). The lowest available potassium (360 kg ha^{-1}) was recorded under the absolute control (T7). The highest available potassium content was recorded in the treatment T2 (75% RDF through drip irrigation along with EnHA @ 0.2%), this might be due to application of EnHA, refers to humic acid enriched with mono-potassium phosphate (KH_2PO_4), which serves as an additional source of readily available potassium along with humic substances. Wang *et al*. (2022) [20] found that humic acid application significantly improved the release of potassium due to its chelating ability, enhancing nutrient solubility. Further supporting evidence was provided by Yan *et al*. (2022) [21], and Nandkumar *et al*. (2004) [11], who also reported improved potassium availability in soils treated with humic substances, either through soil application or fertigation.

3.3.4 Available sulphur

Available sulphur content in the soil was significantly influenced by 75% RDF through drip + EnHA @ 0.2% (10.52 mg kg^{-1}) which was statistically at par with 75% RDF through drip + HA @ 0.2% through drip (10.48 mg kg^{-1}) and significantly superior over all other treatments. The lowest available sulphur (9.77 mg kg^{-1}) was recorded in the absolute control.

Similar results reported by Baskar and Sankaran (2004) [5] that lignite humic acid, when integrated with recommended NPK, improves sulphur dynamics.

Table 3: Effect of soil and foliar application of humic acid on soil available nutrients.

Tr.	Treatment details	Available nutrients (kg ha^{-1})			Available S (mg kg^{-1})
		N	P	K	
T1	100% RDF through drip	160	19.12	373	10.20
T2	75% RDF through drip + EnHA @ 0.2% through drip	166	20.00	380	10.52
T3	75% RDF through drip + HA @ 0.2% through drip	164	19.61	375	10.48
T4	100% RDF through soil	155	17.98	363	9.80
T5	100% RDF through soil + foliar spray of EnHA @ 0.5%	157	18.85	365	9.95
T6	100% RDF through soil + foliar spray of HA @ 0.5%	156	18.46	367	9.89
T7	Absolute control	151	16.21	360	9.77
	SE(m)±	2.18	0.33	0 .80	0.07
	CD at 5%	6.81	1.05	2.51	0.22

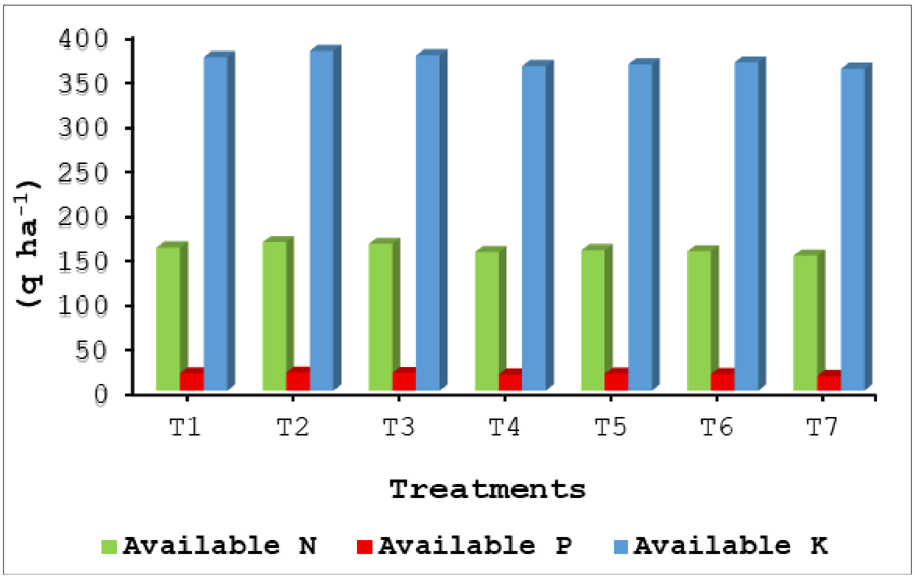

Fig 3: Effect of soil and foliar application of humic acid on available nutrients

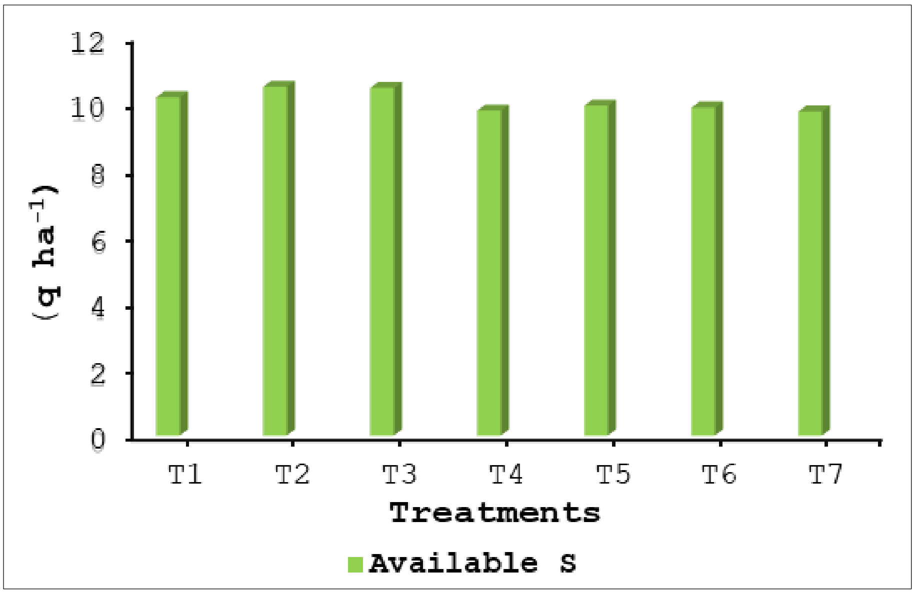

Fig 4: Effect of soil and foliar application of humic acid on available sulphur

Conclusion

Based on results generated during the course of investigation, it is concluded that the soil and foliar application of humic acid in combination with 75% RDF significantly influenced seed cotton yield, soil properties and nutrient availability in soil. Hence, the combined use of humic acid with 75% RDF through drip irrigation is found to be beneficial in enhancing productivity of cotton and fertility of soil.

Acknowledgement

The authors gratefully acknowledge the Department of Soil Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth (PDKV), Akola, for providing the necessary infrastructure and institutional support that facilitated the successful completion of this research work**.**

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