RESEARCH ARTICLE Agricultural Science Digest, Volume 45 Issue 3: 403-409 (June 2025)

Response of Rainfed Bt Cotton to Different Crop Residues Application on Yield, Soil Fertility and Nutrient Uptake under Deep Black Vertisols

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ABSTRACT

Background: Poor soil fertility is a yield limiting factor in cotton production for realizing higher seed cotton yield. Chemical fertilizers are an important input to get higher crop productivity, but over reliance on chemical fertilizers is associated with declines in some soil properties and crop yields over time and causes serious problems, such as soil degradation. Therefore, an integrated use of inorganic fertilizers with organic manures is a sustainable approach for efficient nutrient usage which enhances efficiency of the chemical fertilizers while reducing nutrient losses.

Methods: A field experiment was conducted in the Agricultural Research Station, Kovilpatti under dryland situation to evaluate the effect of organic and inorganic nutrients on crop yield, quality and soil fertility status in rainfed Bt cotton. Different crop residues *viz.,* sunflower, pulse haulm, sorghum and cotton residues were collected and composted using TNAU biomineralizer and applied to the experimental trial.

Result: It was observed that the application of recommended dose of fertilizer (RDF) (120:60:60 N:P:K kg/ha) along with vermicompost @ 2.5 t/ha registered the higher seed cotton yield (1600 kg/ha), dry matter production (2444 kg/ha, net income (Rs.11168 ha^{-1}), B:C ratio (1.40) and rain water use efficiency (2.02 kg ha^{-1} mm) and also increased the plant nutrient uptake. Integrated application of organic and inorganic plant nutrients increased the soil available nutrients in the deep clay soil and sustain the productivity of seed cotton yield in semiarid region of southern district.

Key words: Cotton, Crop residues, Soil fertility, TNAU biomineralizer, Vertisols.

INTRODUCTION

Cotton is cultivated in more than 11.5 million hectares (Mha) area and nearly 60 per cent of the cotton is rain dependent. The rainfed cotton is predominantly grown on vertisols. Inadequate and imbalanced nutrient supply in these soils represents a key soil related constraints limiting seed cotton yield. Because of the high cost of complex fertilizers cotton farmers apply huge quantity of nitrogenous fertilizers, which resulting in tremendous growth of cotton crop and it leads to deficiencies of major and micronutrients (Blaise and Prasad, 2005). In recent years micronutrients deficiencies have surfaced up and are becoming serious yield limiting factors (Rattan *et al*., 2008). Most of the Indian black cotton soils on which cotton is grown are very low in soil organic carbon due to rapid oxidation process in dry regions of the country (Srinivasarao *et al*., 2011).

In dryland farming system, it is now a standard practice to maintain an appreciable amount of crop residues on the soil surface for prevention of soil erosion and increase in moisture storage. Residues in the soil help to reduce runoff of nutrients and sediments and to reduce irrigation requirements by reducing evaporation rates (Silva and Moore, 2017). As residues decompose they contribute organic matter to the soil, as well as nutrients, improving over time, soil tilth and fertility. As residues decompose, they also serve as a source of metabolic energy and nutrients for microorganisms and soil arthropods, contributing to recycle nutrients in the soil and thus help to increase biodiversity and the activity of beneficial organisms in the soil. Vermicompost is described as an excellent soil amendment and a biocontrol agent which make it the best organic fertilizer and more eco-friendly as compared to chemical fertilizers. It is an ideal organic manure for better growth and yield of many plants and to increase the productivity of crops.

The nutrient content of the crop residues namely sunflower residues (0.42:0.12:1.72% NKP), pulse haulm residues (1.63:0.15:2.00% NKP), sorghum stover residues (0.40:0.23:2.17% NKP), cotton residues and vermicompost (2.1:1.5:1.4% NKP). The construction of nutrient budgets is

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How to cite this article: Sanjivkumar, V., Baskar, K., Manoharan, S., Solaimalai, A., Chary, G.R. and Gopinath, K.A. (2025). Response of Rainfed Bt Cotton to Different Crop Residues Application on Yield, Soil Fertility and Nutrient Uptake under Deep Black Vertisols Agricultural Science Digest. 45(3): 403-409. doi: 10.18805/ag.D-5501.

Submitted: 29-09-2021 **Accepted:** 01-02-2022 **Online:** 08-03-2022

an important step in understanding the efficient nutrient management in agro-ecosystems, of integrated nutrient management involving organic manure and chemical fertilizer has received considerable attention. Therefore, a field study was conducted to assess the impact of organic manure as well as their combinations with inorganic plant nutrients, on the productivity of seed cotton yield under rainfed situation.

MATERIALS AND METHODS

The Kovilpatti block belongs to Thoothukudi district, it comes under rainfed agriculture. Geographically it is situated between 8°48′ and 9°20′ North latitude and 78°25′ east longitude at 90 MSL. Kovilpatti is a semi arid region with an annual rainfall of 737 mm. The normal maximum and minimum temperature is 35°C and 22°C respectively. This experiment was conducted at black soil farm of Agricultural Research Station, Kovilpatti. This research work was initiated during the year 2009-'14. Under rainfed condition, every year premonsoon sowing has been carried out at the last week of September in black soil farm (Vertisols) with Bt cotton (Tulasi).

Site characterization

The Kovilpatti region is the representative of dryland agriculture in Southern parts of Tamil Nadu. The experimental soil was clay in texture and belongs to Kovilpatti Soil Series (*Typic chromusterts*). The mechanical fraction *viz.,* clay content 46.4 to 61.2 per cent, 10.0 to 17.5 per cent silt and 12.6 to 24.5 per cent coarse sand. The soil bulk density varies from 1.21 to 1.36 mg m^{-3} with field capacity of 35 per cent and permanent wilting point of 14 per cent (Sunflower as an indicator plant). The soil has sub angular blocky structure with pH generally neutral to a tendency towards alkalinity at lower depths (7.8 to 8.2) (Fig 1). Regarding soil fertility status of the experimental site, the soil available nutrients *viz.,* low in available nitrogen (125 kg ha^{-1}), low to medium in available phosphorus (9.9 to 15.6 kg ha^{-1}), high in soil available potassium (870 kg ha^{-1}), low in available zinc (1.2 ppm) and low in available magnesium.

The experimental trial was conducted in randomized block design (RBD) with three replications under rainfed condition. The treatments comprised of T_1- Control, T_2- 120: 60: 60 NPK kg ha^{-1}, T_3-T_2 + Sunflower residue compost @2.5 t/ha, T_4-T_2 + Pulse haulmresidue compost @2.5 t/ha, T_5-T_2 + Sorghum stover residue compost @2.5 t/ha, T_6-T_2 + Cotton residue compost @2.5 t/ha, T_7-T_2 + Vermi compost@ 5 t/ha and T_8-T_2 + FYM @ 12.5 t/ha. Crop residues *viz.,* sunflower residue, pulse haulm residue, sorghum stover residue and cotton residue were composted with TNAU Bio mineralizer @ 2 kg/tonne of crop residue. TNAU biomine ralizer is a microbial consortium which is developed to accelerate the composting process. The application of TNAU biomineralizer consortium will reduce the period of composting and facilitates the quick decomposition of the organic biodegradable wastes into nutrient rich compost. Crop residues involves the non-economic plant parts that are left in the field after harvest and also discarded during crop processing. Crop residue management through composting will reduce a portion of the cost spent on the purchase of chemical fertiliser for crop cultivation with the following the non-economic benefits *viz.,* improving soil fertility and moisture, increasing soil stability, reduce the soil, air pollution and eliminating the thrash burning issues that dooms the environment.

Observations recorded

Cotton seed yield (kg ha^{-1})

The harvested plants of cotton from each net plot were tied in bundles and left in the open field with labelling treatment wise to complete drying. Thus, the weight of pure seeds was taken in kg per plot and converted into kg ha^{-1}.

Plant dry matter production (kg ha^{-1})

Plants were uprooted and dried in hot air oven at 70°C till constant weight was recorded with the help of electronic balance.

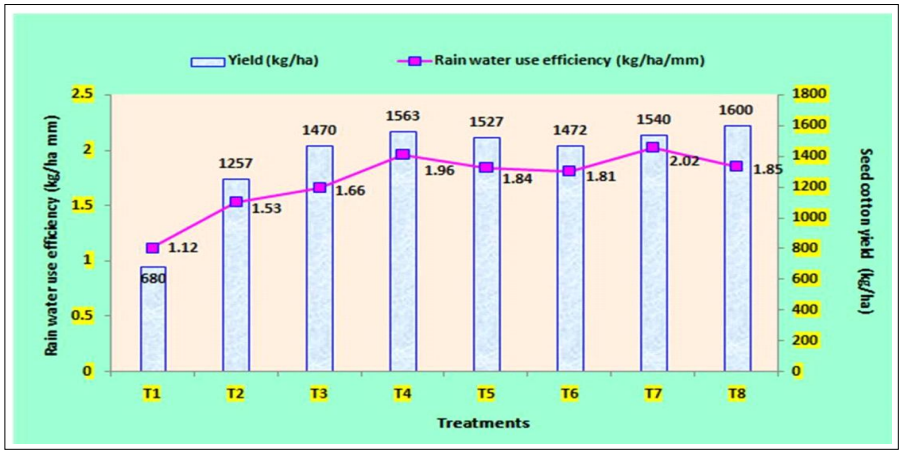


Fig 1: Effect of integrated nutrient management for sustainable productivity on yield (kg ha^{-1}) and rain water use efficiency (kg ha^{-1} mm) in rainfed Bt cotton.

Quality parameters

Staple length (mm)

The mean staple length was determined by HVI where the weight ratio method was adopted and expressed in mm (Sundaram, 1979).

Micronaire value (10^{-6} g inch^{-1})

It is the measure of fibre weight in mg per g unit length of fibre and expressed in 10^{-6} g/cm^{-1} or 10^{-6} g/inch^{-1}. It is determined by micronaire instrument in which 50 g of the sample is taken and compressed in a cylinder of specified dimension. Air at specific pressure is passed through the material. The amount of airflow is measured on a scale, calibrated directly to read the weight per unit length of the fibre. Finer cottons have lower micronairevalue (Sundaram, 1979). To find out the Fibre strength (g tex^{-1}) by the ratio of the breaking strength of a bundle of fibres to its weight. It was expressed in tenacity at 1/8″ gauge on stelometer. In metric system, this value is expressed as tenacity and it is expressed in terms of g tex^{-1}. Where, tex denotes weight in g of 1 kilometre of the fibre (Sundaram, 1979).

Uniformity ratio

Is the ratio of 50 per cent spanlength to the 2.5 per cent span length and expressed in percentage (Sundaram and Iyengar, 1968).

$$\text{Uniformity ratio (\%)} = \frac{\text{50 per cent span length}}{\text{2.5 per cent span length}}$$

Sowing, plant sampling and soil analysis

Sowing was done by hand dibbling and recommended dose of fertilizer (120 : 60 : 60 NPK kg ha^{-1}) was applied using urea, DAP and muriate of potash as basal application, as per the fertilizer schedule in individual plots. The collected soil samples are processed through a 2: mm size sieved and analysed for the various soil available nutrients. For soil organic carbon content. Soil was passed through 0.2 mm sieve size. The determination of soil pH was done by Potentiometry method in 1:2 water suspension by Jackson (1973), electrical conductivity by Conductometry method by Jackson (1973), soil available nitrogen by Alkaline Permanganate method (Subbiah and Asija (1956), available phosphorus by Olsen' s method, Olsen *et al.,* (1954), available potassium by Neutral normal ammonium acetate by Stanford and English (1949) and soil organic carbon by Walkley and Black (1934).

Plant sample laboratory analysis

Plant samples were collected from all the experimental plots, then dried in a hot air oven at 60°C and ground in Willey mill using stainless steel blades and used for the analysis of total major plant nutrients. The collected data from the experimental trial is statistically analysed, Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Cotton yield and yield attributes

In integrated nutrient management practices under rainfed agriculture, basal application of (T_7) recommended dose of fertilizer (RDF) (120:60:60 N:P_2O_5:K_2O kg/ha) along with vermicompost @ 2.5 t/ha recorded the highest cotton yield and yield attributes *viz.,* number of sympodial branches plant^{-1} (22.9 no's), number of bolls plant^{-1} (24.4 no's), dry matter production (2444 kg/ha and cotton seed yield (1600 kg/ha) (Table 1). In integrated nutrient management system, the recommended dose of fertilizer with 2.5 t of vermicompost per ha increased the seed cotton yield by 135 per cent over absolute control. The cotton yield and yield attributes are found to be significant among all the treatments. Integrated application of organic and inorganic fertilizers increased the growth attributes of cotton. This result confirmed with the work of Gebaly (2011) and Balamurugan and Sudhakar (2012).

Table 1: Effect of integrated nutrient management for sustainable productivity on yield and yield attributes in rainfed Bt cotton.

Treatments	Plant height (cm)	No. of sympodia /plant	No. of bolls/ plant	Seed kapas yield (kg/ha)	DMP (kg/ha)	Yield increases over control (%)
T_1- Absolute control	43.6	9.9	8.1	680	1285	
T_2- NPK (120 : 60 : 60) kg ha^{-1}	81.1	18.8	18.0	1257	1930	85
T_3- T_2+Sunflower residue compost @2.5 t/ha	86.1	19.3	18.4	1470	2126	116
T_4- T_2+Pulse haulm residue compost @2.5 t/ha	96.4	21.7	20.6	1563	2310	130
T_5- T_2+Sorghum stover residue compost @2.5 t/ha	93.6	19.7	18.9	1527	2213	125
T_6- T_2+Cotton residue compost @2.5 t/ha	89.8	19.2	19.3	1472	2149	116
T_7- T_2+Vermicompost @ 2.5 t/ha	92.9	22.9	24.4	1600	2444	135
T_8- T_2+FYM @ 12.5 t/ha	100.2	20.4	19.9	1250	2234	84
SEd	0.88	0.23	0.19	18.00	27.09	
CD (0.05)	1.89	0.50	0.41	38.60	58.10	

Yield and economics

Regarding to economics of Bt cotton, application of RDF (120:60:60 N:P_2O_5:K_2O kg/ha) along with vermicompost @ 2.5 t/ha (T_7) registered higher net income (Rs.11168 ha^{-1}), BC ratio (1.40) and rain water use efficiency (2.02 kg ha^{-1} mm) (Fig 1) followed by application of (T_4) RDF along with pulse haulm residues compost @2.5t/ha recorded higher net income (Rs.9846 ha^{-1}), B:C ratio (1.37) and rain water use efficiency (1.96 kg ha^{-1} mm) (Table 2). Vallabh and Brajendra Singh Rajawat (2015) reported that the application of vermicompost @5 tonnes/ha in cotton crop resulted in higher yield, gross return, per cent increases in yield and B:C ratio. It may due to the organically amended plots which able to retain soil moisture during the dryspell period and stabilized the metabolic pathway through the crop growth stages under rainfed areas.

Cotton quality

The data pertaining to quality parameters of cotton *viz.,* Staple length, micronaire, fibre strength and uniformity ratio presented in Table 3 and depicted in different organic and inorganic treatment application did not influence on fibre strength and uniformity ratio. Whereas, the treatment applied with recommended dose of fertilizers (120:60:60 N:PK kg/ha) along with the vermicompost @2.5 tha^{-1} registered higher staple length (27.0 mm) and micronaire value (5.55 $\times$ 10^{-6} g $inch^{-1}$) and showed significant in rainfed cotton respectively.

Solunke and Sangita (2010) reported that the effect of organic manures, inorganic fertilizers and plant protection on quality and economics of desi cotton. The results stated that quality parameters like fibre technology properties like 2.5 per cent span length, micronaire value, bundle strength and uniformity ratio were not influenced significantly due to use of different organics (FYM and Vermicompost). Similar results are studied by Gudadhe *et al.* (2013).

Soil fertility status

The pH of the experimental soil ranged from 8.00 to 8.35. The highest pH value was observed in the absolute control (T_1) and it was decreased when applied with organic plant nutrient applied. The lowest value of pH (8.00) was observed in the treatment received RDF along with vermicompost @ 2.5 t/ha (Fig 2). Ojha *et al.* (2014) reported that the application of organic plant nutrients reduced the soil pH due to microbial degradation and production of organic acids from applied organic manures. While the plots received inorganic fertilizers alone showed not significant in the soi pH among the treatments. The values of EC of soil were statistically non significant under various organic treatments. The EC of the experimental soil ranged from 0.15 to 0.36 dSm^{-1}. The lowest value of soil EC (0.15 dSm^{-1}) was observed in the treatment received RDF along with vermicompost @2.5 t/ha. Halemani *et al.* (2004) studied that the plot applied with organic manures along with

Table 2: Effect of integrated nutrient management on yield economics of rainfed Bt cotton.

Treatments	Net income (Rs./ha)	B:C ratio
T_1- Absolute Control	2801	0.78
T_2- NPK (120 : 60 : 60) kg ha^{-1}	5989	1.19
T_3- T_2+Sunflower residue compost @2.5 t/ha	6489	1.24
T_4- T_2+Pulse haulm residue compost @2.5 t/ha	9846	1.37
T_5- T_2+Sorghum stover residue compost @2.5 t/ha	8546	1.31
T_6- T_2+Cotton residue compost @2.5 t/ha	7339	1.27
T_7- T_2+Vermicompost @ 2.5 t/ha	11168	1.40
T_8- T_2+FYM @ 12.5 t/ha	9675	1.35

Table 3: Effect of integrated nutrient management for sustainable productivity on quality parameters of rainfed Bt cotton.

Treatments	Staple length (mm)	Micronaire (10-6 g $inch^{-1}$)	Fiber strength (g tex^{-1})	Uniformity ratio (%)
T_1- Absolute Control	24.1	5.10	25.7	78
T_2- NPK (120 : 60 : 60) kg ha^{-1}	26.4	5.30	27.1	80
T_3- T_2+Sunflower residue compost @2.5 t/ha	25.3	5.19	26.9	80
T_4- T_2+Pulse haulm residue compost @2.5 t/ha	26.7	5.45	28.1	80
T_5- T_2+Sorghum stover residue compost @2.5 t/ha	26.6	5.20	27.0	80
T_6- T_2+Cotton residue compost @2.5 t/ha	25.0	5.27	27.1	80
T_7- T_2+Vermicompost @ 2.5 t/ha	27.0	5.55	28.2	81
T_8- T_2+FYM @ 12.5 t/ha	26.1	5.40	27.6	80
SEd	0.25	0.05	0.38	1.02
CD (0.05)	0.42	0.13	NS	NS

inorganic plant nutrient were reduced the electrical conductivity in soil under rainfed condition.

In soil fertility status under rainfed condition, the treatment received with application of (T_7) RDF (120:60:60 NPK kg/ha) along with vermicompost @ 2.5 t/ha recorded higher available major nutrients *viz.,* available nitrogen (161 kg ha^{-1}), available phosphorus (22.4 kg/ha^{-1}), available potassium (426 kg ha^{-1}) and organic carbon (2.8 g/kg^{-1}). In case of available micronutrients *viz.*, DTPA zinc recorded higher with application of (T_8) RDF along with farmyard manure @12.5t ha^{-1}, it may be due to secretion of organic acids from added organic manures and it solubilize the micronutrients to water soluble and exchangeable forms +in soil which further increase the uptake of micronutrients in soil (Fig 3).

Manchala (2017) reported that the available nitrogen status of soil increases with the increase in doses of well

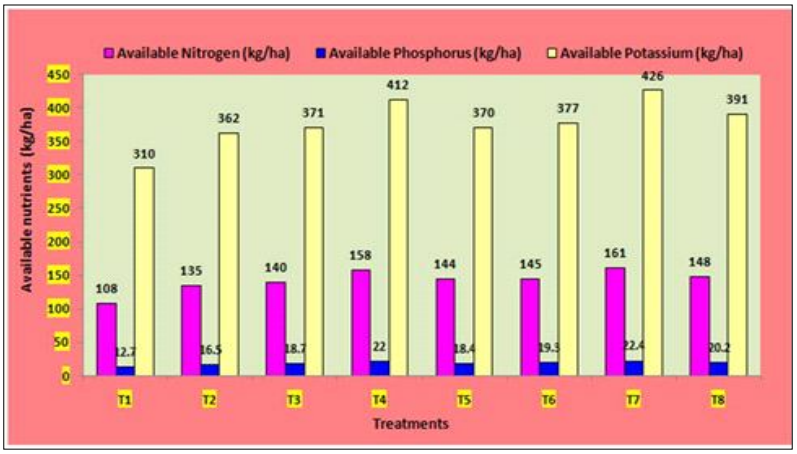


Fig 2: Effect of integrated nutrient management for sustainable productivity on soil available major nutrients of rainfed Bt cotton.

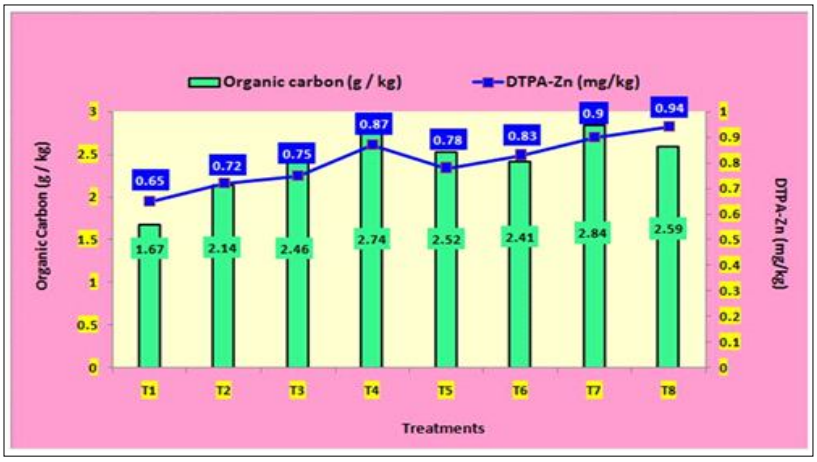


Fig 3: Effect of integrated nutrient management for sustainable productivity on soil organic carbon and zinc in rainfed Bt cotton.

Table 4: Effect of integrated nutrient management for sustainable productivity on total plant nutrient uptake in rainfed Bt cotton.

Treatments	Total nutrient uptake (kg ha^{-1})		
	Nitrogen	Phosphorus	Potassium
T_1- Absolute control	1.55	0.35	6.2
T_2- NPK (120 : 60 : 60) kg ha^{-1}	3.51	1.08	11.7
T_3- T_2+Sunflower residue compost @2.5t/ha	4.03	0.95	12.50
T_4- T_2+Pulse haulm residue compost @2.5t/ha	5.20	1.73	17.36
T_5- T_2+Sorghum stover residue compost @2.5t/ha	4.28	0.84	13.80
T_6- T_2+Cotton residue compost @2.5t/ha	3.02	1.32	10.70
T_7- T_2+Vermicompost @ 2.5 t/ha	6.12	1.90	19.50
T_8- T_2+FYM @ 12.5 t/ha	5.10	1.60	15.60
SEd	0.06	0.02	0.25
CD (0.05)	0.13	0.05	0.54

decomposed organic manures. Significantly higher available nitrogen was observed in the treatment received 10 t FYM ha^{-1} and was at par with application of Vermicompost @ 5 t ha^{-1} treatment. Similar results were also studied by Liu *et al.* (2010) and Godala *et al.* (2012). There was a significant increase in the soil extractable phosphorus with the increase of the compost and vermicompost doses applied. Release of phosphorus from soil was largely due to the activity of soil micro organisms. This experimental results was confirmed by Angelova *et al.* (2013) and Moradi *et al.* (2014).

Plant nutrient uptake

Among the various integrated nutrient management practices in Bt cotton, the total nitrogen uptake (6.12 kg ha^{-1}), total phosphorus uptake (1.90 kg ha^{-1}) and total potassium uptake (19.50 kg ha^{-1}) recorded highest in T_7 treatment. The lowest total plant uptake was registered in the control plot (Table 4). Among the vermicompost levels, application of 75% RDF+25% RDN through vermicompost was significantly higher nitrogen uptake compared to rest of the treatments. Beneficial effects of combined application of FYM and vermicompost with inorganic fertilizers to cotton in respect of total plant nutrient uptake are supported by the observations of Dhawan *et al.* (2005). This might be due to mineralization and slow release of nutrients to cotton crop resulting in higher uptake of nutrients (N, P and K) with the increased seed cotton yield under integrated nutrient management system. Similar results are confirmed by Roy and Singh (2006).

CONCLUSION

Integrated application of organic and inorganic plant nutrients reported significant increases in biological yield performance of Bt cotton over absolute control. However, their influence on quality parameters of Bt cotton under rainfed situation was non significant. Thus, it can be concluded from this experiment that the application of recommended dose of fertilizer (RDF) (120:60:60 N:P:kg/ha) along with vermicompost @2.5 t/ha significant improves the physical and chemical properties of the vertisols, therefore significantly increased the seed cotton yield. There is a statistical positive correlation recorded between the soil NPK status and the grain yield. This indicated that the organic amendments along with application of chemical fertilizers directly involved in enhancing the cycling of soil nutrients under semiarid rainfed condition for doubling farmers income.

ACKNOWLEDGEMENT

This research work was funded by ICAR-All India Co-ordinated Research Project on Dryland Agriculture Scheme, CRIDA, Hyderabad.

Conflict of interest

All authors declare that they have no conflict of interest.

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