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Effect of Tillage and Integrated Plant Nutrient Supply Strategies for Enhancing Seed Cotton Yield and Soil Quality Indicators of Vertisol in Semi Arid Region of Maharashtra

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The present investigation was conducted during 2010-11 to study the effect of tillage and integrated plant nutrient supply strategies on productivity of rainfed cotton and soil quality indicators in Vertisols at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The experiment was laid out in a factorial randomized block design and replicated thrice with two factors viz., tillage (conventional and conservation) and integrated nutrient management which included incorporation of FYM, crop residues, *in situ* green manuring of sunhemp, glyricidia leaf manuring in combination with 50 per cent inorganic fertilizers and 100 % RDF (80:40:40 kg N, P_2O_5 and K_2O ha $^{-1}$). The results indicated that numerically higher seed cotton yield with slight improvement in physical and chemical properties were observed under conservation tillage, whereas a significant improvement in soil biological properties were observed in conservation tillage compared to conventional tillage. The application of 100% RDF recorded highest seed cotton yield followed by 50 % N either through FYM or in situ green manuring + 50% RDF which were at par with each other. The integrated use of 50% RDF + 50 % N through FYM recorded highest availability of NPK, improvement in physical as well as biological properties of soil. Hence, the conjunctive use of FYM, crop residue, *in situ* green manuring and glyricidia leaf manuring along with 50% RDF under conservation tillage was found beneficial in improving physical, chemical and biological indicators and productivity of cotton grown in Vertisols.

Key words: Cotton, FYM, green manure, integrated nutrient management, soil indicators, tillage, Vertisol

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Cotton is one of the most important fibre and cash crop of India. It plays a key role in Indian economy. India ranks first in the world having an area of 10.15 million ha with the production of 31.00 million bales. Vidarbha is a major cotton and cotton –based cropping system growing region in Maharashtra where it is grown predominantly as rainfed crop on medium to deep Vertisols. The cotton productivity in Vidarbha region is low compared to National average. The reasons for low productivity includes erratic distribution of rainfall, imbalanced fertilizer use, poor quality seed, low adoption of improved agro-techniques and decline in soil health.

The soils of cotton growing areas are low in organic carbon, available nitrogen, phosphorus and high in K (Rattan *et al.,* 1999). Increase in production and productivity can be achieved only through enhanced soil fertility which can be sustained if the nutrients removed from soil are replenished by way of addition. Supplying the entire quantity of nutrients required for cotton through fertilizer may not be possible due to continuous increase in prices of chemical fertilizers. Nutrient requirement of cotton would have to be met through organic sources in combination with inorganic fertilizers. Intensive cropping with increased use of NPK fertilizers have not only increased food production, but also resulted in the depletion of soil nutrients and reduction in soil productivity. Soil health degradation has emerged as a major factor responsible for stagnation in agricultural production. The degradation of soil health in many cultivated areas is manifested in terms of loss of soil organic matter, depletion of native soil fertility due to imbalanced and unscientific use of fertilizer which is now one of the major constraints in improving crop productivity.

Conservation tillage allows crop residues as surface mulch, is effective in conserving soil and water and maintains good soil structure, organic matter contents and maintains desirably high and economic level of productivity. Conservation tillage can rebuild organic carbon levels in soil and increases the carbon sequestration in soil (Novak *et al.,* 2009). Under such condition integrated plant nutrient supply and management is best future strategies for enhancing soil quality and crop productivity (Swarup, 2010).

However, such information is limited on rainfed cotton on Vertisol under semi-arid climatic conditions of Maharashtra. Therefore, the present study was carried out to assess the effect of the conservation tillage and integrated plant nutrient supply through green manuring, crop residues, FYM and chemical fertilizers on soil quality indicators and cotton productivity on a Vertisol in Viadrabha region of Maharashtra.

Materials and Methods

The field experiment was conducted on Research Farm, Dept. of Soil Science & Agrl. Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during 2010-11. The soil of the experimental site was Vertisol, calcareous in nature and moderately alkaline in reaction (pH- 8.1). The rainfall received was 925 mm during crop growth period as against 843.3 mm average annual rainfall. The fertility status of soil indicates that the soil was medium in organic carbon (5.6 g kg^{-1}), low in available N (220.6 kg ha^{-1}), and medium in P (14.34 kg ha^{-1}) and high in available K (385.8 kg ha^{-1}).

The experiment was laid out in a factorial randomized block design with two factors viz., tillage and nutrient management replicated thrice. The two levels of tillage were conventional tillage (one ploughing, two harrowing, hoeing and weeding) and conservation tillage (one harrowing and weedings). The eight levels of nutrient management included F1 : 100%RDF (80 :40 :40 kg NPK ha^{-1}), F2 : 50%RDF + 50% N through *in situ* green manuring (sunhemp), F3 :50 % RDF+ 50 % N (FYM), F4 :50 % RDF + 50 % N (wheat straw), F5: 50 % RDF+ 50 % N (GLM), F6: 50 % RDF+ 25 % N (FYM) + 25 % N (wheat straw), F7: 50 % RDF+ 25 % N (FYM)+ 25 % N (GLM) and F8: 50 % RDF+ 25 % N (wheat straw)+ 25 % N (GLM). The recommended dose of fertilizer to cotton was 80:40:40 NPK kg ha^{-1}.

The N, P and K were applied in the form of urea, single super phosphate and muriate of potash. Treatment wise basal doses (half nitrogen and full phosphorus and potassium) of fertilizers were calculated and applied at the time of sowing and remaining half dose of nitrogen was applied one month after emergence of cotton crop by ring method and thoroughly mixed in the soil. *In situ* green manuring of sunhemp (*Crotalaria juncea* L.) was done by growing one row of sunhemp in between two rows of cotton. Sunhemp was uprooted at 30 days after sowing and buried *in situ* equivalent to 50 % N and covered it with the soil. FYM, wheat straw and glyricidia foliage lopping applied as a source of nutrient in soil.

The representative soil samples from 0-30 cm depth were collected by using soil auger after harvest of cotton. These samples were analyzed for soil physical and chemical properties as per standard methods (Jackson, 1973). The fresh soil samples collected during grand growth stage of cotton were immediately used for estimating biological properties. Soil microbial biomass carbon was estimated following Jenkinson and Powlson (1976) and soil microbial biomass nitrogen was measured by modified direct extraction method (Jenkinson and Ladd, 1981). Soil dehydrogenase assay was estimated by incubation with triphenyl tetrazolium chloride (TTC) and calcium carbonate method (Casida *et al,.* 1964).

Results and Discussion

Physical properties

The effect of tillage management on soil physical properties was found to be non-significant (Table 1). The numerically lower values of bulk density and higher hydraulic conductivity were recorded in conventional tillage as compared to conservation tillage. Conventional tillage results in more loosening and mixing of soil, which decrease the proportion of larger sized aggregates (2 to 5 mm) and increase the proportion of smaller aggregates (1 to 0.1 mm) increasing the total pore space and decreasing the bulk density of soil. Jabro *et al.* (2012) also reported no significant improvement in BD due to 22 years of tillage under dryland conditions. Similarly Patil and Sheelavantar (2006) also observed reduction in bulk density and increase in infiltration rate due to deep tillage in black soils of semi arid region. The improvement in hydraulic conductivity may be due to significant change in soil pore geometry in conventional tillage. These results are in conformity with the findings reported by Reddy *et al.* (2002).

The slightly higher values of MWD and AWC were recorded in conservation tillage as compared to conventional tillage. Increased intensity of tillage due higher input of energy decreased mean weight diameter. These results are in conformity with the findings reported Mohanty and Painuli (2003) and Blaise (2011). Conservation tillage leaves more crop residue on surface soil which increases organic carbon in soil and improves physical properties of soil and increase AWC of soil. The conventional tillage destroyed the original soil structure, breaking up the macro aggregates into micro aggregates, which are considered to be sensitive to the changes in organic matter levels caused by tillage (Tisdall and Oades, 1982). Bauer and Black (1981) reported little differences in soil structural characteristics among tillage systems in arid and semi-arid regions due to low precipitation and high temperature that result in a lower potential for soil organic carbon accumulation.

Irrespective of the application of the organics in different treatments, their combined use along with 50 % RDF was found beneficial in decreasing the BD and improving HC, MWD and AWC over the use of 100 % RDF. However, the improvement of BD and

Table 1. Effect of tillage and integrated nutrient management on physical properties of soil

Treatment	BD(mg m-3)	HC(cm hr-1)	MWD(mm)	AWC(%)
A. Tillage				
T_1-Conservation tillage	1.37	0.68	0.64	28.24
T_2-Conventional tillage	1.36	0.69	0.63	26.41
SE (m) ±	0.01	0.01	0.01	0.05
CD at 5 %	NS	NS	NS	NS
B. Integrated nutrient Management				
F_1-100% RDF (80:40:40 NPK kg ha-1)	1.38	0.66	0.61	25.51
F_2-50% RDF + *In situ* green manuring (sunhemp)	1.37	0.69	0.63	27.44
F_3-50% RDF + 50% N (FYM)	1.35	0.71	0.67	30.71
F_4-50% RDF + 50% N (Crop residue)	1.36	0.66	0.62	27.64
F_5-50% RDF + 50% N (Green leaf manuring)	1.36	0.70	0.63	28.46
F_6-50% RDF+ 25% N (FYM) + 25% N (Wheat sraw)	1.37	0.69	0.64	26.60
F_7-50% RDF + 25% N (FYM) + 25% N (GLM)	1.37	0.67	0.64	26.31
F_8-50% RDF+25% N (WS) + 25% N (GLM)	1.36	0.67	0.63	26.20
SE (m) ±	0.01	0.01	0.01	0.10
CD at 5 %	NS	0.03	0.02	NS
C. Interaction effect	NS	NS	NS	NS

AWC was statistically non-significant. The lower BD and higher AWC were recorded in the treatment 50 % N through FYM + 50% RDF. Reduction of the bulk density in organic manure applied plots along with 50 % RDF might be due to higher organic carbon, more pore space and good soil aggregation (Selvi *et al*., 2005). The improvement in AWC in soil might be attributed to increased organic matter status of the soil and improved soil structure. The beneficial effect of different organics such as FYM, crop residue and green manuring on AWC was also reported by Bellakki and Badanur (1997).

The significantly highest HC was observed in treatment 50% N through FYM + 50% RDF followed by treatment 50% N through Glyricidia green leaf manuring + 50% RDF, 50% RDF + *in situ* green manuring (sunhemp) and 50% RDF + 25% N (FYM) + 25% N (wheat straw) which were at par with 50 % N (FYM) + 50 % RDF. The application of 50 % N (FYM) + 50% RDF significantly increased the HC and MWD to the tune of 7.6 and 9.8 % over 100% RDF. It is well known that better aggregation and increased porosity as consequence of addition of organics have favorable influence on hydraulic conductivity. The results are in consensus with many past studies which reported the beneficial effect of different organics such as FYM, crop residue and green manuring on hydraulic conductivity (Reddy *et al.,* 2002 and Selvi *et al*., 2005).

The significantly highest MWD was observed in the treatment receiving 50% N through FYM + 50% RDF which was superior over rest of the treatments. The treatments receiving organic sources in combination of 50 % RDF were superior over 100 % RDF (except wheat straw and GLM) clearly suggesting importance of use of organic sources in improving physical quality of soil as compared to use of chemical fertilizers only. The increased soil

Table 2. Effect of tillage and integrated nutrient management on organic carbon and residual fertility of vertisols

Treatment	Org. C(g kg-1)	Available nutrient (kg ha-1)		
A. Tillage		N	P	K
T_1-Conservation tillage	5.65	227.6	14.74	401.4
T_2-Conventional tillage	5.64	226.9	14.57	401.2
SE (m) ±	0.01	0.42	0.07	1.0
CD at 5 %	NS	NS	NS	NS
B. Integrated nutrient Management				
F_1-100% RDF (80:40:40 NPK kg ha-1)	5.62	223.6	14.87	392.3
F_2-50% RDF + *In situ* green manuring (sunhemp)	5.65	228.2	14.55	403.8
F_3-50% RDF + 50% N (FYM)	5.67	234.7	15.20	407.2
F_4-50% RDF + 50% N (Crop residue)	5.63	223.4	14.49	401.9
F_5-50% RDF + 50% N (Green leaf manuring)	5.65	231.5	14.51	399.8
F_6-50% RDF+ 25% N (FYM) + 25% N (Wheat sraw)	5.64	225.6	14.72	404.0
F_7-50% RDF + 25% N (FYM) + 25% N (GLM)	5.65	227.1	14.80	405.2
F_8-50% RDF+25% N (WS) + 25% N (GLM)	5.64	224.1	14.12	396.2
SE (m) ±	0.01	0.8	0.15	2.0
CD at 5 %	0.02	2.4	0.43	5.9
C. Interaction effect	NS	NS	NS	NS

aggregation might be due to the cementing effect of humic substances produced from the organic matter in soil. The similar results in MWD were also observed due to integrated use of FYM and RDF by Selvi *et al*. (2005).

The interaction effect between tillage and integrated nutrient management was found to be non significant during the experimentation.

Residual soil fertility

The organic carbon and residual soil fertility was increased in conservation tillage (Table 2). However, the results were statistically non significant. The slight increase in organic carbon content under conservation tillage as compared with conventional tillage is due to the fact that conservation tillage involves minimum surface tillage, leaving crop residues to accumulate at the soil surface and increase carbon sequestration by reducing oxidation of SOC in soil as compared to conventional tillage. Similar findings were reported by Sainju *et al*. (2009). Sonune *et al.* (2010) also reported slight differences in organic carbon between tillage methods in five years under semi arid rainfed conditions.

The organic carbon of soil was significantly influenced by integrated nutrient management (Table 2). The significantly highest organic carbon was obtained in treatment 50% RDF + 50 % N through FYM followed by 50% RDF + *in situ* green manuring (sunhemp), 50% RDF+ 50% N through GLM and 50% RDF + 25% N (FYM) + 25% N (GLM) which were at par with each other. The increase in organic carbon in these treatments might be attributed to additions of organic matter and better root growth (Tolanur and Badanur, 2003a). Significant increase in organic carbon was also observed by Bellakki and Badanur (1997) with incorporation of FYM or sunhemp either alone or in combination with fertilizer as compared with RDF.

The effect of integrated nutrient management on available N, P and K was found to be significant (Table 2). The highest available nitrogen (234.7 kg ha^{-1}) was recorded with the application of 50% N through FYM + 50% RDF which was superior over all other treatments. Increase in available N in this treatment might be attributed to direct addition of N through FYM to the available pool of the soil. In the other treatments, the enhancement in available N was in the order of 50% RDF + 50% N (Green leaf manuring) > 50% RDF + *In situ* green manuring (sunhemp) > 50% RDF + 25% N (FYM) + 25% N (GLM) > 50% RDF+ 25% N (FYM) + 25% N (Wheat sraw) >50% RDF+25% N (WS) + 25% N (GLM) > 100% RDF > 50% RDF + 50% N (wheat straw). The considerable enhancement in the treatments which involved combined application of organic sources and chemical fertilizers might also be attributed the greater multiplication of microbes caused by additions of organic materials for conversion of organically bound N to inorganic form (Tolanur and Badanur, 2003b). The quite higher availability of NPK in combinations of wheat straw and FYM (25 % N through each) over wheat straw (50 % N) + 50 % RDF clearly indicated that conjoint use of FYM and wheat straw was beneficial in enhancing the efficiency of wheat straw in terms of availability of N, P and K. Similar enhancement in soil fertility with conjoint use of crop residues with FYM was also reported by Kumar *et al.* (2008). The application of FYM along with wheat straw made it superior compared to wheat straw + 50 % RDF which could be attributed to the regulated N release from FYM by maintaining proper C: N ratio and N was made available for longer periods.

Lowest available nitrogen was recorded in treatment 50% N through crop residue + 50% RDF which was due to the immobilization of nutrients during the growing period of cotton. It was observed that considerable improvement in available N status

Table 3. Effect of tillage and integrated nutrient management on SMBC, SMBN and DHA of soil

Treatment	SMBC (mg kg^{-1})	SMBN (mg kg^{-1})	DHA (µg TPF g^{-1} 24 h^{-1})
A. Tillage			
T_1-Conservation tillage	225.7	34.44	41.81
T_2-Conventional tillage	223.6	31.75	37.76
SE (m) ±	0.4	0.43	0.32
CD at 5 %	1.2	1.26	0.91
B. Integrated nutrient Management			
F_1-100% RDF (80:40:40 NPK kg ha^{-1})	222.1	28.82	33.87
F_2-50% RDF + *In situ* green manuring (sunhemp)	224.5	33.56	42.58
F_3-50% RDF + 50% N (FYM)	227.3	38.43	44.42
F_4-50% RDF + 50% N (Crop residue)	223.7	32.41	38.09
F_5-50% RDF + 50% N (Green leaf manuring)	225.0	32.87	41.12
F_6-50% RDF+ 25% N (FYM) + 25% N (Wheat sraw)	224.6	33.18	38.93
F_7-50% RDF + 25% N (FYM) + 25% N (GLM)	226.5	33.94	40.24
F_8-50% RDF+25% N (WS) + 25% N (GLM)	223.6	31.54	39.04
SE (m) ±	0.8	0.87	0.63
CD at 5 %	2.4	2.51	1.83
C. Interaction effect	NS	NS	NS

was observed in all the treatments which involved combined application of crop residues and inorganic fertilizers over initial values.

The significantly higher available P was found in the treatment of 50% N through FYM + 50% RDF followed by 100% RDF and 25% N through FYM + 25% N through (GLM) + 50% RDF and these treatments were found to be at par with each other. The availability of phosphorus increased in conjunctive use of organic and inorganic fertilizers which might be due to minimization of P fixation in soil, solubilization of native P and direct addition of P in soil (Sharma *et al.,* 2001). In other treatments, the increase of availability of P was in the order of 50% RDF+ 25% N(FYM)+ 25% (WS) > 50% RDF + *In situ* green manuring (sunhemp) > 50% RDF + 50% N (WS) > 50% RDF+25% N (WS) + 25% N (GLM). The lowest available phosphorus (14.12 kg ha^{-1}) was recorded in treatment 25% N (Wheat straw) + 25% N (GLM) + 50% RDF.

The significantly highest available potassium was recorded in treatment 50% N through FYM + 50% RDF followed by 25% N (FYM) + 25% N (GLM) + 50% RDF, 25% N (FYM) + 25% N (WS) + 50% RDF, 50% RDF + i*n situ* green manuring (sunhemp) and 50% RDF + 50% N (wheat straw) and these treatments were found to be at par with 50 % N (FYM) + 50 % RDF. The lowest available potassium was recorded in treatment 100% RDF. The experimental soil was rich in available K content and addition of organic matter through crop residues further enhanced the availability of K in soil. Increase in K availability in integrated use of organic and fertilizers attributed to direct addition of K through fertilizers and crop residues to the available pool of soil with reduction in K fixation and release of K (Sharma *et al.,* 2001).

The interaction effect between tillage and integrated nutrient management was found to be non significant.

Biological properties

The soil microbial biomass carbon (SMBC), soil microbial biomass nitrogen (SMBN) and Dehydrogenase activity (DHA) are sensitive indicators of soil to evaluate the land configuration and other agricultural management practices. These indicators were significantly influenced by tillage (Table 3). Significantly higher SMBC, SMBN and DHA were observed in conservation tillage as compared to conventional tillage. The greater amount of crop residue remaining with conservation tillage might have provided available substrate for maintenance of larger SMB pool and higher C and N mineralization. Conservation tillage practices produces less soil disturbance and higher level of enzymes in surface soil. Dehydrogenase activity decrease with increased intensity of tillage associated with decrease in organic matter content in soil. The results are in consonance with the findings of Muruganandam *et al.* (2009).

The soil microbial biomass carbon (SMBC) was significantly influenced by integrated nutrient management (Table 3). The significantly highest SMBC was obtained in treatment 50% N through FYM + 50% RDF followed by 25% N (FYM) + 25% N (GLM) +50% RDF and 50% N through GLM + 50 % RDF which were found to be at par with each other. This might be due to the supply of additional mineralizable and readily hydrolysable C due to organic manure application which resulted in higher microbial activity and in return higher microbial biomass carbon. The stimulatory effect of organics (FYM, GM and WS) on SMBC in Vertisols is in agreement with the findings of Vineela *et al.* (2008) and Sonune *et al.* (2010).

The significantly highest SMBN and DHA were obtained in treatment 50% N through FYM + 50% RDF which was superior over all other treatments. The SMBN and DHA in this treatment was 33.3 and 31.1 % higher over 100% RDF. The lowest SMBN and DHA were observed under 100% RDF. High soil organic carbon content, more root proliferation and additional supply of organic matter and N by FYM to microorganisms might be responsible for increasing the level of SMBN. Significant increase in DHA with the application of FYM along with 50 % RDF is due to increase in microbial growth with aditions of carbon substrate (Manna *et al.,* 1996). Similar observations were also recorded by Selvi *et al.* (2004) and Verma and Mathur (2009).

The interaction effect between tillage and integrated nutrient management was found to be non significant on biological properties of soil.

Cotton yield

The data in respect of seed cotton yield as influenced by tillage was found to be non significant (Table 4). However, numerically higher seed cotton yield was obtained with conservation tillage as compared to conventional tillage. Olson and Ebelhar (2009) observed that even 10 years of average yield of maize and soybean were not affected significantly by tillage. Similarly He *et al.* (2009) also observed non significant enhancement due to conservation tillage over conventional tillage in wheat and oat yield during first four years of study. The data in respect of cotton stalk yield as influenced by tillage was found to be non significant. However, numerically higher cotton stalk yield was obtained with conservation tillage as compared to conventional tillage.

The results revealed that the seed cotton yield was significantly influenced by nutrient management. The significantly highest seed cotton yield (13.72 q ha^{-1}) was observed in 100 % RDF followed by 50 % N through FYM + 50 % RDF (12.99

Table 4. Effect of tillage and integrated nutrient management on seed cotton and cotton stalk yield

Treatment	Seed cotton	Cotton stalk
A. Tillage		(q ha^{-1})
T_1-Conservation tillage	11.89	28.78
T2-Conventional tillage	11.67	28.27
SE (m) ±	0.27	0.29
CD at 5 %	NS	NS
B. Integrated nutrient Management		
F_1-100% RDF (80:40:40 NPK kg ha^{-1})	13.72	35.13
F_2-50% RDF + *In situ* green manuring (sunhemp)	12.63	31.25
F_3-50% RDF + 50% N (FYM)	12.99	31.71
F_4-50% RDF + 50% N (Crop residue)	11.35	27.37
F_5-50% RDF + 50% N (Green leaf manuring)	10.93	26.27
F_6-50% RDF+ 25% N (FYM) + 25% N (Wheat sraw)	10.05	24.31
F_7-50% RDF + 25% N (FYM) + 25% N (GLM)	11.22	26.14
F_8-50% RDF+25% N (WS) + 25% N (GLM)	11.34	26.00
SE (m) ±	0.55	0.58
CD at 5 %	1.58	1.67
C. Interaction effect	NS	Sig

q ha^{-1}) and 50 % N through *In situ* green manuring (sunhemp) + 50 % RDF (12.63 q ha^{-1}) which were found to be at par with each other. The results further revealed that 50 % N through crop residue and green leaf manuring and combined use of FYM, crop residue; green leaf manures along with 50 % RDF were statistically on par with each other. The increase in seed cotton yield in INM plots was in the order 50 % RDF + 50 % N (FYM) > 50 % RDF + in situ GM > 50 % RDF+50%N(WS)>50%RDF+25%N(WS)+ 25% N (GLM) > 50 % RDF + 25 % N (FYM) + 25 % (GLM) > 50 % RDF + 50 % N (GLM) > 50 % RDF + 25 % N (FYM) + 25 % N (WS). The lowest seed cotton yield was observed with 25 % N through FYM + 25 % N through crop residue + 50 % RDF (10.05 q ha^{-1}). The results are in close agreement with the findings reported by Mehta *et al.* (2009) and Sonune *et al.* (2009, 2010).

The results revealed that the cotton stalk yield was significantly influenced by nutrient management. The significantly highest cotton stalk yield (35.13 q ha^{-1}) was observed in 100 % RDF. The lowest cotton stalk yield was observed with 25 % N through FYM + 25 % N through crop residue + 50 % RDF (24.31 q ha^{-1}). The application of 100 % RDF recorded higher stalk yield due to higher growth attributing characters directly associated with stalk yield of cotton. The findings are in conformity with the results reported by Awasya *et al.* (2006). Interaction effect of tillage and integrated nutrient management was found non significant on seed cotton yield.

Hence, it is concluded that the integrated nutrient management improved physical, chemical and biological properties of soil and productivity of rainfed cotton grown in Vertisols and conservation tillage was found to be better as compared to conventional tillage.

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