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Effect of Different Tillage and Organic Inputs on Soil Properties and Yield of Cotton on Vertisols

Esampally Ravali [a++*], N.M. Konde [b#], S.M. Bhoyar [b†], Nilam Kanase [b#], Akanksha Singh [c‡], Mohini D. Thite [a^] and Tanvi Shrirao [a++]

[a] Department of Soil Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola 444 104, Maharashtra. India.
[b] Dr. PDKV, Akola, India.
[c] FibL, Switzerland.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present investigation was carried out at Research Farm, Department of Soil Science, Dr. PDKV, Akola during *Kharif* 2023-24 to study the effect of different tillage practices and organic inputs on soil properties and yield of cotton on *Vertisols*. Intensive tillage accelerates the loss of soil

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[++] PG Student;
[#] Assistant Professor;
[†] Professor and Head;
[‡] Senior Scientist;
[^] Ph. D Student;
**Corresponding author: Email: esampallyravali@gmail.com;*

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organic carbon (SOC) and reduces soil quality and yields, particularly in rainfed areas. This is further worsened by imbalanced fertilization and insufficient recycling of organic residues. Conservation tillage, when combined with organic inputs like FYM, vermicompost and phospho-compost, can help to restore soil structure, increase SOC and promote sustainable agricultural practices. The study aimed to assess the effect of different tillage practices and organic inputs on soil properties and on yield of cotton. The factorial randomized block design with two factors and four tillage treatments as factor A and four sources of manure as factor B were adopted. The treatments were composed of factor A consisting of four tillage operations [conventional tillage (T_1), reduced tillage (T_2), minimum tillage (T_3) and zero tillage (T_4)] and factor B consisting of organic manures such as farmyard manure (10 t ha^{-1}) (M_1), vermicompost (5 t ha^{-1}) (M_2), phospho-compost (5 t ha^{-1}) (M_3) and no manure (M_4) replicated thrice. The results clearly indicated that conventional tillage resulted in the significantly highest seed cotton yield (14.10 ha^{-1}), stalk yield (27.78 ha^{-1}), total uptake of N (46.46 ha^{-1}), P (7.86 ha^{-1}) and K (33.05 ha^{-1}) relative to other tillage practices examined. Among the organic manure treatments the highest seed cotton yield (11.21 ha^{-1}), stalk yield (21.95 ha^{-1}), total N (37.27 ha^{-1}), P (6.57 ha^{-1}) and K (31.25 ha^{-1}) uptake by cotton was observed with phospho-compost application. Based on the observed results, it was notable that the available soil N, P and K were significantly influenced by the distinct tillage practices and organic manures. Among the tillage practices, the highest content of available soil N (182.14 kg ha^{-1}), P (17.14 kg ha^{-1}) and K (312.95 kg ha^{-1}) were exhibited by the reduced tillage. The use of vermicompost resulted in the highest available soil N (185.93 kg ha^{-1}) and K (316.68 kg ha^{-1}), while the highest available soil P (18.22 kg ha^{-1}) was observed with phospho-compost. The results revealed that conventional tillage combined with phospho-compost improves cotton yield and nutrient uptake, while reduced tillage along with the application of vermicompost and phospho-compost improves soil fertility. Therefore, combined use of tillage and organic inputs could be beneficial for enhancing soil properties and higher productivity of cotton in *Vertisols* as well as the whole of Maharashtra.

Keywords: Cotton; vertisols; tillage; organic manures; soil properties; yield.

1. INTRODUCTION

Cotton (*Gossypium spp*.) is one of the important predominant crops under cultivation in the semi-arid regions of India and some other parts of the world. It is commonly referred to as "white gold," a very valuable commodity that is crucial to the economics of many nations and is regarded as the king of all fibre crops. It is an important source of fibre, oil and animal feed [1]. The main goal of cotton cultivation to the farmers is to obtain the fibre, elongated and thickened single cell of the seed epidermis. The Indian Textile Industry consumes a diverse range of fibres and yarns and the ratio of cotton usage to non-cotton fibres in India is around 60:40, while it is 30:70 for the rest of the world [2-4].

India has obtained the first rank in the world in cotton acreage with 124.69 lakh hectares area under cultivation, the 2nd place in the world with an estimated production of 323.11 lakh bales (5.50 million metric tonnes) during the cotton season 2023-24. In terms of productivity, it is on the 33rd rank with the average yield of 441 kg ha^{-1}. India is also the 2nd largest consumer of cotton in the world with an estimated consumption of 317 lakh bales (5.39 million metric tonnes) [2-4]. Maharashtra is the leading state in terms of the area under cotton cultivation *i.e.,* 42.22 lakh hectares.

Tillage is the oldest art associated with the development of agriculture and involves operations to modify the physical characteristics of soil. It is the most difficult and time-consuming work in crop production, accounting for about 30 percent of the total expenditure. However, there is potential to reduce the cost and this can only be achieved through the understanding of the tillage objectives and the operations carried-out at the right time with proper implementation. By definition, "Conservation tillage is a type of tillage that aims to reduce soil and water loss. It typically involves keeping at least 30% of crop residue or mulch on the soil surface year-round. This practice helps to prevent soil erosion, preserves water in the root zone and enhances soil fertility and productivity." (Derpsch, 2005). Conservation tillage eliminates power-intensive soil tillage, thus reducing the drudgery and labour required for crop production by more than 50% of the small-scale farmers. Reduced tillage practices, also known as conservation tillage, is one of the best management agricultural practice alternatives to conventional tillage and has increased globally over the last two decades [5].

Intensive tillage, leads to the loss of surface crop residues and soil organic carbon (SOC), degrading soil quality and lowering yields, especially in rainfed areas. This is worsened by imbalanced fertilization and the lack of organic residue recycling. Conservation tillage, on the other hand, involves minimal soil disturbance, improving soil structure by promoting better aggregation and increasing soil organic carbon. When organic amendments like FYM (farmyard manure), vermicompost and phospho-compost are applied, it enhance soil biological properties, resulting in healthier and more sustainable soils.

Organic sources like FYM, vermicompost and phospho-compost are well-known for improving soil quality and productivity. These sources contain most of the nutrients required by the crops, which could help to improve physical properties (soil structure, maximum water holding capacity, hydraulic conductivity) and create a more favourable soil environment for root growth development. The proliferation of microbial activity in soil leads to the conversion of unavailable nutrients to available forms, which increases crop yields in the long run through the improvement of the soil physical, chemical and biological properties. Application of farmyard manure (FYM) is thought to significantly increase soil organic carbon (SOC) contents, infiltration rate, water retention capacity, soil aggregation and aggregation stability in water [6]. Vermi-compost, produced by earthworms, is an incredible nutrient-rich organic supplement that contains both micro and macronutrients, vitamins, growth hormones and enzymes [7]. Phospho-compost has been reported to improve soil pH, organic matter, total soil nitrogen and available soil phosphorus [8].

Vertisols are types of soil which undergo swelling and shrinking phenomena as a result of the changes in the moisture levels. *Vertisols* have high water retention capacity but low infiltration rate and high cation exchange capacity. To sustain reasonable levels of organic cotton production, it is essential to improve and maintain the organic matter (OM) in these soils. This can significantly enhance the soil physical attributes. Further, OM can augment nutrient's supply, particularly of soil nitrogen, phosphorus and sulphur. Thus, a proper management program of OM is necessary to maintain the fertility status of the soil under organic production systems.

In this context, the present investigation was implemented to study the effect of different tillage practices and organic inputs on soil properties and the yield of cotton in the *Vertisols* of Research Farm, Department of Soil Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra.

2. MATERIALS AND METHODS

A field experiment was conducted at the Research Farm Department of Soil Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the *Kharif* season of 2023-24. Soil of the experimental field was classified as *Vertisols*, particularly montmorillonitic, hyperthermic a family of Typic Haplustert. It has smectite clay minerals with swell-shrink properties. The experiment was laid out in a factorial randomized block design with two factors. Factor A consists of four tillage treatments [conventional tillage(T_1), reduced tillage(T_2), minimum tillage(T_3) and zero tillage(T_4)] and factor B consists of organic manures such as farmyard manure (10 t ha^{-1}) (M_1), vermicompost (5 t ha^{-1}) (M_2), phosphocompost (5 t ha^{-1}) (M_3) and no manure (M_4). All the treatments were replicated three times.

The initial soil samples (0-20 cm) were collected from each plot in all three replications. Available soil nitrogen (N) was determined by the alkaline permanganate method using an automatic distillation system [9]. Available soil phosphorous (P) was measured by Olsen's method with a ultra-violet (UV) double-beam spectrophotometer [10]. Available soil Potassium (K) was assessed using the neutral normal ammonium acetate method with a flame photometer [11]. The soils are moderately alkaline in reaction with pH of 8.03, low in available soil nitrogen: N (175.30 kg ha^{-1}) and Phosphorus: P (13.40 kg ha^{-1}) and sufficient in available soil potash (306 kg ha^{-1}).

The plant samples were collected randomly from every plot at harvest of the crop. After cleansing and air-drying the plant samples, they have kept in polythene bags with the right labelling for further chemical analysis. Total soil nitrogen was determined by micro-Kjeldhal's distillation method [12] Total soil phosphorous with spectrophotometer [13] and total soil potassium by a flame photometer [12]. Cotton was picked from the net plots in all the replications and yield per hectare was calculated. The data was subjected to statistical analysis as per Gomez and Gomez [14].

3. RESULTS AND DISCUSSION

3.1 Yield of Cotton

3.1.1 Effect of tillage on yield of cotton

The data in respect of seed cotton and stalk yield of cotton as influenced by different tillage and organic manures is placed in Table 1 and depicted in Fig. 1. The seed cotton yield (14.10 q ha^{-1}) and stalk yield (27.78 q ha^{-1}) were noticed significantly higher in conventional tillage followed by reduced tillage, which noted a seed cotton yield of (10.22 q ha^{-1}) and stalk yield of (19.70 q ha^{-1}), while the lowest seed cotton yield (4.87 q ha^{-1}) and stalk yield (9.13 q ha^{-1}) were observed in zero tillage among all tillage practices. The lower trend of crop yield is most, likely due to the hardness of black cotton soil, poor hydraulic conductivity and poor soil aeration under conservation agriculture practices. Similar results were achieved by Saleem et al., [15] who reported that the conventional tillage showed the highest plant height (121 cm), total bolls per plant (22.9 bolls), boll weight (2.74 g) and seed yield (2031 kg ha^{-1}) of the cotton crop, as compared to zero tillage.

3.1.2 Effect of organic manures on yield of cotton

Based on an assessment of data, it was noticeable that the seed and stalk yield of cotton were significantly superior with the application of phospho-compost and found the lowest in the absence of organic manures. The significantly highest seed cotton yield (11.21 q ha^{-1}) and stalk yield (21.95 q ha^{-1}) were noticed higher in treatment with phospho-compost (M_3) followed by seed cotton yield (10.60 q ha^{-1}) and stalk yield (20.76 q ha^{-1}) in treatment with vermicompost (M_2), both the treatments were on par with each other. The lowest seed cotton yield (7.33 q ha^{-1}) and stalk yield (14.02 q ha^{-1}) were observed in the no manured plot (M_4). It may infer that the increase in seed cotton yield may be due to more availability and efficient use of nutrients. As phospho-compost improves phosphorus availability in the soil. Phosphorus plays a crucial role in root growth and the development of reproductive parts (such as flowers and seeds). This leads to better plant establishment and higher cotton yield. The results obtained during experimentation corresponded to the findings of Solunke et al., [16] who stated that FYM @ 10 t ha^{-1} and vermicompost @ 2 t ha^{-1} recorded significantly higher seed cotton yield. Results are in line with the findings of Nawlakhe et al., [17] who reported that seed cotton yield and stalk yield were significantly superior with an application of vermicompost @ 2 t ha^{-1} over others, except FYM @ 5 t ha^{-1} which was at par with the findings with an application of vermicompost. Similar results were reported by Rannavare et al., [18] who stated that the application of vermicompost (2 t ha^{-1}) and

Table 1. Effect of tillage and organic inputs on seed cotton yield (q ha^{-1}) and stalk yield of cotton (q ha^{-1})

Treatments	Yield (q ha^{-1})	
Treatments	**Seed cotton yield (q ha^{-1})**	**Stalk yield (q ha^{-1})**
a) Tillage practices		
T_1 - Conventional tillage	14.10	27.78
T_2 - Reduced tillage	10.22	19.70
T_3 - Minimum tillage	9.47	18.04
T_4 - Zero tillage	4.87	9.13
SE (m)±	0.456	0.44
CD @ 5%	1.317	1.26
b) Organic manures		
M_1 – FYM	9.22	17.90
M_2 – Vermicompost	10.60	20.76
M_3 – Phospho-compost	11.21	21.95
M_4 - No manure	7.64	14.02
SE (m)±	0.456	0.44
CD @ 5%	1.317	1.26
Interaction of tillage and organic manures (a X b)		
SE (m)±	0.912	0.87
CD @ 5%	2.634	2.52

application of FYM (5 t ha-1) registered significant maximum seed cotton yield and stalk yield over sunhemp in-situ green manuring (5 t ha^{-1}).

3.1.3 Interaction effect of tillage and organic manures

Data with respect to the interaction of tillage and organic manures on seed cotton yield and stalk yield is presented in Tables 2 and 3, respectively. Conventional tillage combined with phospho-compost produced the highest seed cotton (16.77 q ha^{-1}) and stalk yield (33.38 q ha^{-1}), showing that active tillage enhances nutrient uptake when paired with organic inputs. Reduced tillage also performed well with organic inputs, particularly phospho-compost and vermicompost, yielding nearly on par results. In contrast, zero tillage resulted in the lowest yields, even with organic inputs, indicating that tillage is necessary to maximize the benefits of manure. The no-manure plots consistently showed the lowest yields across all tillage practices, highlighting the importance of organic inputs for optimal crop productivity.

3.2 Total Uptake of Nitrogen, Phosphorous and Potassium Contents

3.2.1 Effect of tillage on total uptake of nitrogen, phosphorous and potassium

The significantly higher N, P and K uptake were recorded in conventional tillage over other tillage practices at the harvest stage (Table 4 and Fig. 2). The higher uptake of N (46.46 kg ha^{-1}), P (7.86 kg ha^{-1}) and K (33.05 kg ha^{-1}) was recorded under conventional tillage, followed by reduced tillage with nitrogen uptake of 32.61 kg ha^{-1}, phosphorous uptake of 5.54 kg ha^{-1} and potassium uptake of 25.89 kg ha^{-1}. The lowest uptake of N (15.36 kg ha^{-1}), P (2.38 kg ha^{-1}) and K (13.83 kg ha-1) was observed under zero

Table 2. Interaction effect of tillage and organic inputs on seed cotton yield (q ha^{-1})

	Seed cotton yield (q ha^{-1})				
Treatments	**T_1 Conventional tillage**	**T_2 Reduced tillage**	**T_3 Minimum tillage**	**T_4 Zero tillage**	**Mean B**
M_1 – FYM	13.61	10.11	8.55	4.61	9.22
M_2 – Vermi Compost	16.22	10.61	10.05	5.51	10.60
M_3 – Phospho- compost	16.77	11.66	11.05	5.33	11.20
M_4 - No manure	9.77	8.50	8.22	4.05	7.63
Mean A	14.10	10.22	9.47	4.87	
	Factor A	**Factor B**	**Int. A x B**		
SE (m) ±	0.456	0.456	0.912		
CD @ 5 %	1.317	1.317	2.634		

Table 3. Interaction effect of tillage and organic inputs on stalk yield (q ha^{-1})

	Stalk Yield (q ha^{-1})				
Treatments	**T_1 Conventional tillage**	**T_2 Reduced tillage**	**T_3 Minimum tillage**	**T_4 Zero tillage**	**Mean B**
M_1 – FYM	26.95	19.62	16.34	8.72	17.91
M_2 – Vermi Compost	32.60	20.69	19.31	10.47	20.77
M_3 – Phospho- compost	33.38	22.87	21.56	10.03	21.96
M_4 - No manure	18.18	15.64	14.96	7.30	14.02
Mean A	27.78	19.70	18.04	9.13	
	Factor A	**Factor B**	**Int. A x B**		
SE (m) ±	0.44	0.44	0.87		
CD @ 5 %	1.26	1.26	2.52		

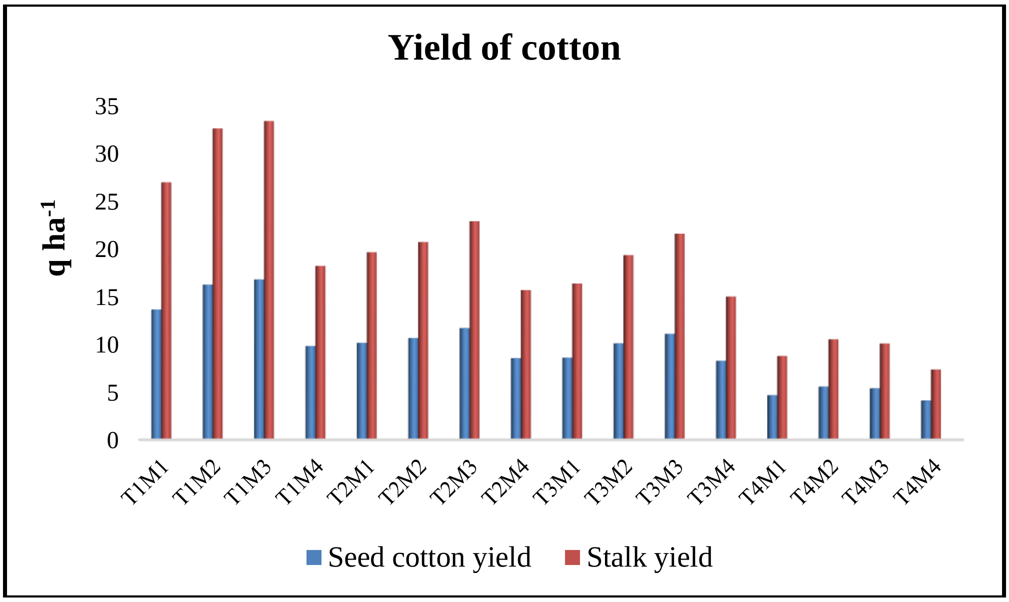

Fig. 1. Seed cotton yield and stalk yield of cotton as influenced by interactive effect of tillage and organic manures

tillage. Conventional tillage results in higher nutrient uptake (N, P, K) because it loosens the soil, improves aeration, enhances water infiltration and promotes root growth, allowing plants to access more nutrients. Overall, the total uptake of N, P and K showed an increasing trend in the order of zero tillage < minimum tillage < reduced tillage < conventional tillage. Similar observations for uptake of nitrogen & phosphorous were noted by Deibert et al. [19]. The results corroborate with the findings of Ishaq et al., [20] who stated that the uptake of nitrogen, phosphorous and potassium by cotton was higher under conventional tillage than minimum tillage and deep tillage treatments.

3.2.2 Effect of organic manures on total uptake of nitrogen, phosphorous and potassium

Based on the data assessment, it was noticed that the effect of organic manures on uptake of N, P and K was found to be significant. The highest uptake of N (37.27 g ha^{-1}), P (6.57 kg ha^{-1}) and K (31.25 kg ha^{-1}) was noted with an application of phosphocompost followed by the application of vermicompost with nitrogen uptake of 34.41 kg ha^{-1}, phosphorous uptake of 5.74 kg ha^{-1} and potassium uptake of 27.60 kg ha^{-1}. Phospho-compost improves root growth and increases plants ability to absorb water and nutrients, which improves nutrient uptake for better growth and yield. However, the lowest uptake of nitrogen (23.76 kg ha^{-1}), phosphorous (3.53 kg ha^{-1}) and potassium (15.31 kg ha^{-1}) was identified in treatment with no organic manures. The results confirm with the findings of Age et al., [21] who reported that significantly higher uptake of N, P and K by cotton was recorded with the application of 100 % P through phospho-compost over other treatments and revealed that the increase in total potassium uptake was due to the incorporation of decomposed material like FYM, phospho-compost, vermicompost and glyricidia green leaf manuring along with inorganic fertilizers.

3.2.3 Interaction effect of tillage and organic manures

Data with respect to the interaction of tillage and organic inputs on the total uptake of nitrogen, phosphorous and potassium is presented in Tables 4, 5 and 6, respectively**,** and depicted in Fig. 2. Conventional tillage with phospho-compost resulted in the highest nitrogen (57.29 kg ha^{-1}), phosphorus (10.23 kg ha^{-1}) and potassium uptake (43.73 kg ha^{-1}), indicating that active soil disturbance, combined with nutrient-rich organic inputs, enhances nutrient absorption. Reduced tillage also showed strong nutrient uptake when paired with phospho-compost or vermicompost, but lower than conventional tillage. In contrast, zero tillage led to the lowest nutrient uptake, even with organic inputs, suggesting that some soil disruption is necessary to fully benefit from organic inputs.

Table 4. Interaction effect of tillage and organic inputs on total uptake of nitrogen (kg ha^{-1})

Total nitrogen uptake (kg ha^{-1})					
Treatments	**T_1 Conventional tillage**	**T_2 Reduced tillage**	**T_3 Minimum tillage**	**T_4 Zero tillage**	**Mean B**
M_1 – FYM	43.96	32.87	27.12	14.46	29.60
M_2 - Vermi Compost	53.70	34.33	32.86	16.75	34.41
M_3 – Phospho- compost	57.29	36.77	37.08	17.93	37.27
M_4 - No manure	30.88	26.47	25.37	12.30	23.76
Mean A	46.46	32.61	30.61	15.36	
	Factor A	**Factor B**	**Int. A x B**		
SE (m) ±	0.03	0.03	0.05		
CD @ 5 %	0.08	0.08	0.15		

Table 5. Interaction effect of tillage and organic inputs on total uptake of phosphorous (kg ha^{-1})

Total phosphorous uptake (kg ha^{-1})					
Treatments	**T_1 Conventional tillage**	**T_2 Reduced tillage**	**T_3 Minimum tillage**	**T_4 Zero tillage**	**Mean B**
M_1 – FYM	7.22	5.27	4.27	2.19	4.74
M_2 - Vermi Compost	9.31	6.09	4.92	2.63	5.74
M_3 – Phospho- compost	10.23	6.83	6.28	2.92	6.57
M_4 - No manure	4.68	3.96	3.69	1.77	3.53
Mean A	7.86	2.92	4.79	2.38	
	Factor A	**Factor B**	**Int. A x B**		
SE (m) ±	0.08	0.08	0.15		
CD @ 5 %	0.22	0.22	0.44		

Table 6. Interaction effect of tillage and organic inputs on total uptake of potassium (kg ha^{-1})

Total potassium uptake (kg ha^{-1})					
Treatments	**T_1 Conventional tillage**	**T_2 Reduced tillage**	**T_3 Minimum tillage**	**T_4 Zero tillage**	**Mean B**
M_1 – FYM	33.38	24.35	22.88	13.13	23.43
M_2 - Vermi Compost	36.89	29.37	29.33	14.80	27.60
M_3 – Phospho- compost	43.73	33.40	31.41	16.46	31.25
M_4 - No manure	18.18	16.46	15.64	10.94	15.31
Mean A	33.05	25.89	24.80	13.83	
	Factor A	**Factor B**	**Int. A x B**		
SE (m) ±	0.08	0.08	0.16		
CD @ 5 %	0.23	0.23	0.46		

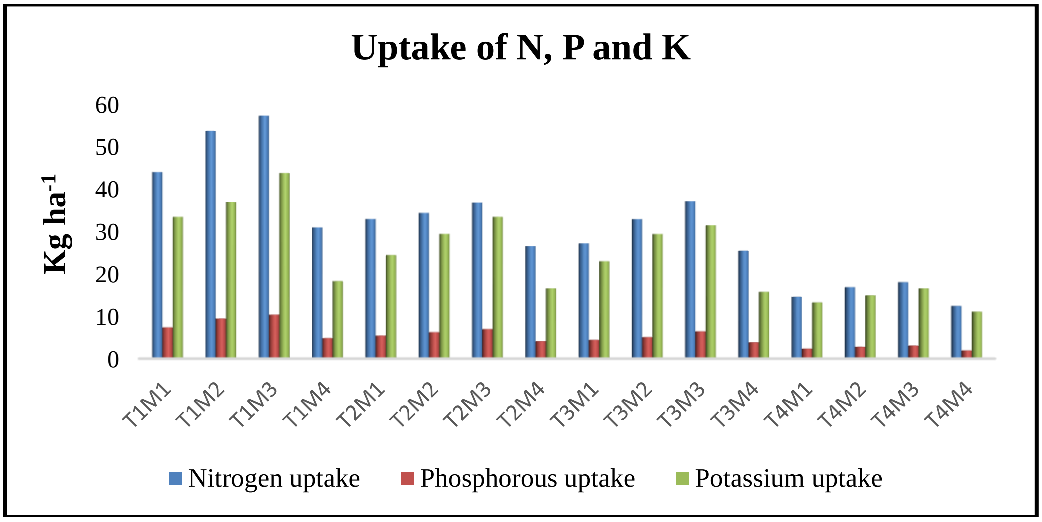

Fig. 2. Total uptake of nitrogen, phosphorus and potassium as influenced by interactive effect of tillage and organic manures

3.3 Available Soil Nitrogen, Phosphorus and Potassium (N, P and K)

3.3.1 Effect of tillage on available soil nitrogen, phosphorous and potassium (N, P and K)

Data with respect to the interaction of tillage and organic inputs on the available soil nitrogen, phosphorous and potassium was found significant**.** The available soil nutrients were influenced and mostly observed higher under reduced tillage and minimum tillage. In respect of residual soil fertility, available N, P and K were influenced significantly by reduced tillage. The significantly highest content of available nitrogen (182.14 kg ha^{-1}), phosphorus (17.14 kg ha^{-1}) and potassium (312.95 kg ha^{-1}) was recorded under reduced tillage followed by minimum tillage. Reduced mechanical disturbance of the soil under conservation tillage resulted in the highest nutrient levels as compared to conventional tillage. The lowest levels of available nitrogen (178.00 kg ha^{-1}), phosphorus (15.49 kg ha^{-1}) and potassium (305.93 kg ha^{-1}) was recorded under zero tillage. The corresponding observations were also noticed by Jadhao et al., [22] who reported that significantly higher levels of available N, P and K were observed under minimum tillage as compared to conventional tillage. Jat et al., [23] also revealed that conservation agriculture-based cropping systems improved soil properties and availability of phosphorous and potassium in the surface soil layer compared to conventional farmer's practice. The results corroborate with the findings reported by Bharambe et al., [24] and Halemani et al., [25].

3.3.2 Effect of organic manures on available soil nitrogen, phosphorous and potassium (N, P and K)

The treatments with organic manures have also influenced the availability of N, P and K significantly. Among the treatments with organic manures, the nutrients were commonly more, where vermicompost and phospho-compost were applied. The significant enhancement in available N (185.93 kg ha^{-1}) and K (316.68 kg ha^{-1}) were noted where vermicompost was applied, whereas the significantly highest available P (18.22 kg ha^{-1}) was noted where phospho-compost was given. However, the lowest values of available N (170.29 kg ha^{-1}), P (12.72 kg ha^{-1}) and K (297.25 kg ha^{-1}) were recorded in treatment with no organic manures. The enhanced nutrient availability in treatments with vermicompost and phospho-compost is due to the faster decomposition of organic matter and the ability of these manures to release specific nutrients more efficiently than untreated soil. Similar findings were also reported by Halemani et al., [25] Liu et al., [26] and Shankar et al., [27] who reported that available N, P and K status of soil at harvest of the crop were increased significantly with application of FYM 10 t ha^{-1} over no FYM. These results are in line with the findings of Das et al., (2003) who, reported that soil available K was increased with the application of FYM over control.

Table 7. Interaction effect of tillage and organic inputs on available nitrogen

Available Nitrogen (kg ha^{-1})					
Treatments	**T_1 Conventional tillage**	**T_2 Reduced tillage**	**T_3 Minimum tillage**	**T_4 Zero tillage**	**Mean B**
M_1 - FYM	181.30	183.40	182.70	179.40	181.70
M_2-Vermi compost	186.20	188.40	186.50	182.60	185.93
M_3-Phospho-compost	183.40	185.30	182.70	181.20	183.15
M_4 - No manure	170.60	171.45	170.30	168.80	170.29
Mean A	180.38	182.14	180.55	178.00	
	Factor A	**Factor B**	**Int. A x B**		
SE (m) ±	0.062	0.062	0.123		
CD @ 5 %	0.178	0.178	0.356		

Table 8. Interactive effect of tillage and organic inputs on available phosphorous

Available Phosphorus (kg ha^{-1})					
Treatments	**T_1 Conventional tillage**	**T_2 Reduced tillage**	**T_3 Minimum tillage**	**T_4 Zero tillage**	**Mean B**
M_1 - FYM	16.75	18.36	18.14	17.13	17.60
M_2 - Vermi compost	15.03	17.48	17.22	15.17	16.23
M_3-Phospho- compost	18.04	18.95	18.36	17.54	18.22
M_4 - No manure	12.31	13.75	12.70	12.12	12.72
Mean A	15.53	17.14	16.60	15.49	
	Factor A	**Factor B**	**Int. A x B**		
SE (m) ±	0.13	0.13	0.27		
CD @ 5 %	0.38	0.38	0.77		

Table 9. Interactive effect of tillage and organic inputs on available potassium

Available Potassium kg ha^{-1}					
Treatments	**T_1 Conventional tillage**	**T_2 Reduced tillage**	**T_3 Minimum tillage**	**T_4 Zero tillage**	**Mean B**
M_1 - FYM	313.10	315.60	314.40	308.50	312.88
M_2 - Vermi compost	317.30	319.40	318.70	311.30	316.68
M_3-Phospho- compost	314.50	316.70	316.20	309.60	314.25
M_4-No manure)	296.40	300.10	298.20	294.30	297.25
Mean A	15.53	17.14	16.60	15.49	
	Factor A	**Factor B**	**Int. A x B**		
SE (m) ±	0.18	0.18	0.36		
CD @ 5 %	0.52	0.52	1.04		

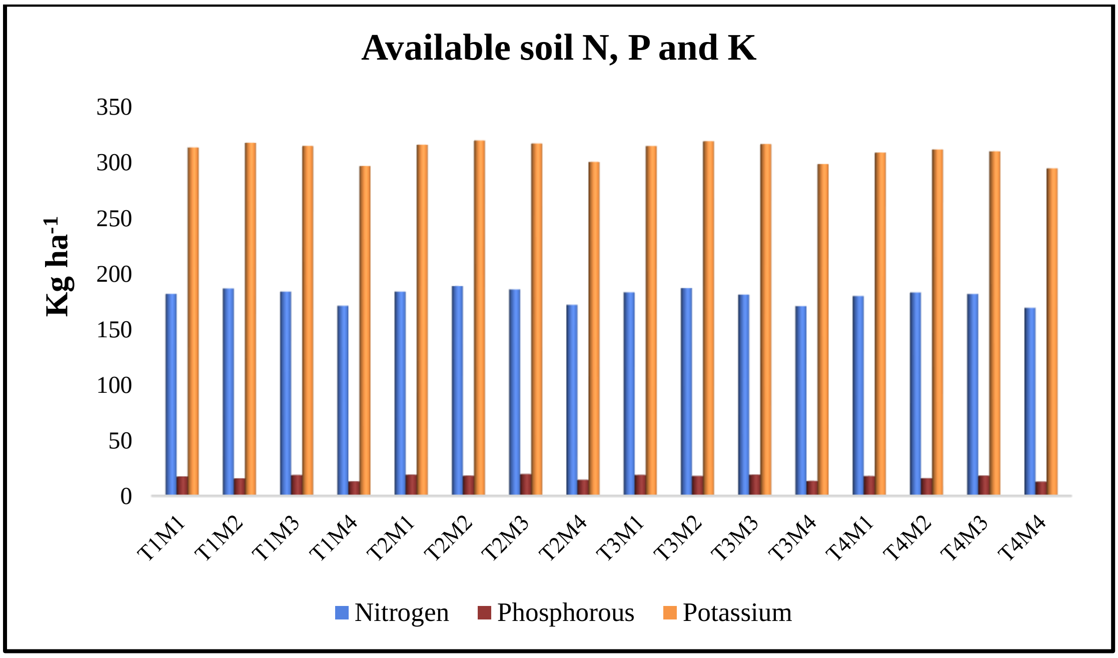

Fig. 3. Available soil nitrogen, phosphorus and potassium (N, P and K) as influenced by interaction effect of tillage and organic manures

3.3.3 Interaction effect of tillage and organic manures

Data with respect to the interaction of tillage and organic inputs on available soil nitrogen, phosphorous and potassium is presented in Tables 7, 8 and 9, respectively and depicted in Fig. 3. Reduced tillage with vermicompost resulted in the highest levels of soil available nitrogen (186.20 kg ha^{-1}) and potassium (317.30 kg ha^{-1}), showing that less soil disturbance, when combined with organic inputs, improves nutrient retention. While reduced tillage with phospho-compost increased phosphorus (18.04 kg ha^{-1}) availability. In contrast, zero tillage and no-manure treatments consistently resulted in the lowest nutrient levels.

4. CONCLUSION

On the basis of the present investigation on the effect of different tillage and organic inputs on soil properties and yield of cotton on *Vertisols*, it can be deducted that the conventional tillage in combination with the phospho-compost, was effective on improving the crop yield and nutrient uptake relative to zero tillage and no-manure treatments. The residual fertility of the soil with respect to available soil macronutrients (N, P and K) was enhanced by reduced tillage along-with the application of vermicompost and phospho-compost. In general, these practices improved the soil nutrient content and fertility status as compared to zero tillage and no-manure treatments, which resulted in lower nutrient levels. Therefore, the combination of reduced tillage with organic inputs *viz.* farmyard manure (FYM), vermicompost and phospho-compost proved to be beneficial for enhancing soil nutrient availability, higher yield and promoting sustainable soil health.

Based on the present results, it is suggested to promote reduced tillage combined with organic inputs like farmyard manure, vermicompost and phospho-compost to enhance soil fertility, nutrient availability and cotton yield on *Vertisols*. Conventional tillage with organic inputs can be used for short-term yield improvements. Future research should focus on long-term impacts of these practices on soil health, their effectiveness on other soil types (e.g., *Inceptisols, Aridisols*), optimization of organic input combinations, assessing their economic feasibility for farmers and to examine their environmental effects, particularly on greenhouse gas emissions.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology.

Details of the AI usage are given below

1. From Google

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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