Sustaining cotton productivity and soil health under long term tillage and nutrient management in vertisols of Maharashtra

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ABSTRACT

A field experiment was conducted to study the effect of tillage and nutrient management on soil health and productivity of rainfed cotton in Vertisols at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India. The experiment was carried out during 2005-06 and 2009-10 in Factorial Randomised Block Design (FRBD) with twelve treatment combinations and three replications. The treatments consisted of tillage (conventional and minimum), nutrient management viz., 100% recommended dose of fertilizers (RDF) (50:25:00 NPK kg ha^{-1}), 50% RDF with graded doses of farmyard manure (FYM) (5,10 and 15 t ha^{-1}) and *in-situ* green manuring with *Sesbania aculeata*. The pooled results revealed that numerically higher seed cotton yield and sustainable yield index (SYI) was recorded in minimum tillage as compared to conventional tillage. The application of 50% RDF + FYM @ 15 t ha^{-1} recorded significantly highest seed cotton yield and SYI. The results further revealed that incorporation of FYM @ 15 t ha^{-1} along with 50% RDF recorded significant improvement in chemical properties and fertility of Vertisols. However, this treatment was found to be at par with the application of FYM @ 10 t ha^{-1} along with 50% RDF. Hence, it is recommended that the conjunctive application of FYM @ 10 t ha^{-1} along with 50% RDF was beneficial in improving soil health and sustaining the cotton productivity in Vertisols of Maharashtra, India.

Keywords: cotton productivity, nutrient management, soil health, sustainable yield index, tillage

INTRODUCTION

Cotton is one of the most important cash crops of India. Maharashtra is one of the leading cotton growing states in India having 3.12 million ha area under cotton cultivation which is one third of country's area of cotton cultivation with the production of 5.50 million bales. Vidarbha is a major cotton and cotton-based cropping system growing region in central India where it is grown predominantly as rainfed crop on medium to deep Vertisol [1]. When cotton is grown continuously, there is soil structural degradation, particularly due to shearing and compaction during tillage operations and fertility decline because of the wider nutrient removal use gap [2]. The cotton productivity in Vidarbha region is low compared to National average. The reasons for low productivity includes erratic distribution of rainfall, improper use of chemical fertilizers, poor quality seed, low adoption of improved agrotechniques and decline in physical, chemical and biological properties of the soil. Among the various production constraints, unbalanced and inadequate nutrition to cotton crop is considered to be one of the important factors.

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Now a days, use of chemical fertilizers in higher and balanced quantity is essential for sustaining the crop productivity in intensive cropping areas. Therefore, to maintain crop productivity, the use of chemical fertilizers in balanced quantity is important. But looking into the continuous increasing prices of fertilizers, it becomes necessary to minimize the expenses on fertilizers by using alternative sources like farmyard manure, crop residues, green manuring along with reduced tillage practices for sustaining the crop yields and soil fertility. These practices not only increase the crop yield but also improve the physical, chemical and biological properties of soil. The long term integrated application of chemical fertilizers with organic manures improves soil physical, biological properties and soil fertility and crop yields. When integrated nutrient management through chemical fertilizers and different organic sources are applied on long term basis, they show beneficial impact on soil quality. Therefore, the present study was carried out to assess the effect of tillage and integrated nutrient management on soil health and cotton productivity on Vertisols under semi arid climatic conditions in Vidarbha region of Maharashtra, India.

MATERIALS AND METHODS

The soil of the experimental site is deep black with clay texture and classified as Typic Haplustert of Vertisols. The initial soil properties indicate that the site is moderately alkaline in pH (8.1), low in available nitrogen (180 kg/ ha) and moderate phosphorus (12.10 kg/ha) and high in available potassium (365.5 kg/ ha). The experiment was laid out in factorial randomized block design with twelve treatment combinations and three replications. The treatments consisted of tillage (conventional and minimum) and integrated nutrient management as N_1-100% RDF, N_2-50% RDF, N_3-50% RDF+FYM @ 5 t ha^{-1}, N_4-50% RDF+FYM @ 10 t ha^{-1}, N_5-50% RDF+FYM @15 t ha^{-1} and N_6-50% RDF + *in situ* green manure of *Sesbania aculeata*.

The farmyard manure was applied one month before sowing on oven dry basis. Sesbania was sown in between two rows of cotton and buried 40 days after sowing. The recommended fertilizer dose 50:25:00 kg N, P_2O_5 and K_2O per hectare was applied to cotton. Full quantity of the phosphorus was applied as a basal dose through single super phosphate. Nitrogen was applied through urea in two splits, half at the time of sowing and half at 30 DAS to cotton. The soil samples (0- 30 cm depth) were collected before the start of experiment (2005-06) and after five years of the crop cycles (2009-10). These samples were analysed for various parameters as per standard methods [3]. The sustainable yield index was computed on the basis of the yield obtained from 2005-06 to 2009-10 and annual rainfall [4]. The regression of mean yield with annual rainfall was derived, then the estimate of error (σ) was computed. Based on the following equation SYI was calculated

$$SYI = \frac{Y - \sigma}{Y_{max}}$$

where, Y is the estimated average yield of a practice across the years. σ is its estimated standard error based on average rainfall of five years, and Y_{max} is the observed maximum yield in the experiment during the years of cultivation.

RESULTS AND DISCUSSION

The higher seed cotton yield was observed in minimum tillage compared to conventional tillage (Table 1). However, results are statistically non significant. Similarly, Tennakoon and Hulugalle [5] also observed non significant differences in cotton yield due to minimum tillage in a Vertisol. The seed cotton yield was significantly affected due to the various nutrient management treatments (Table 1). The pooled results indicated that the application of 50% RDF+FYM @ 15 tha^{-1} recorded

significantly highest seed cotton yield (16.04 qha^{-1}) which was at par with the application of 50% RDF+FYM @ 10 tha^{-1} (14.89 qha^{-1}). The seed cotton yield obtained in treatment 100% RDF (13.58 qha^{-1}) and 50% RDF+green manuring (12.60 qha^{-1}) were statistically at par with each other and superior over only 50% RDF. The increase in the yield due to 50% RDF+FYM @ 15 tha^{-1} was 7.7 and 18.1% higher over 50% RDF+FYM @ 10 tonnes/ha and 100% RDF, respectively. In other treatments the yield trend was as follows FYM @ 10 tonnes/ha + 50% RDF ≥ 100% RDF ≥ green manuring + 50% RDF. The increase in seed cotton yield due to integrated use of FYM and chemical fertilizers (50% RDF) attributed to efficient utilization of nutrient from soil [6] besides direct addition of nutrients from FYM into the soil [7].

Application of FYM @ 10 tha^{-1} along with 50% RDF not only helped in saving the RDF of NPK but also in realizing the higher productivity of cotton. These findings indicated that integrated use of chemical fertilizers with farmyard manure @ 10 tha^{-1} facilitates to curtail the use of chemical fertilizers up to 50% and is a better alternative to use of full dose of recommended fertilizers. Yadav and Kumar [8] also reported that substitution of 50% N through farmyard manure and Sesbania green manuring to rice gave equal or more yields than 100% NPK fertilizers alone.

The lowest seed cotton yield (8.70 q ha^{-1}) was recorded in 50% RDF. The decline in the yield of cotton in a treatment of 50% RDF only through chemical fertilizers clearly indicated that imbalanced fertilization could not sustain the yield. Better response of FYM @ 10 tha^{-1} compared with *in situ* green manuring is attributed to slow decomposition and N mineralization of sesbania due to rainfed conditions compared to FYM. The interaction effect between tillage and integrated nutrient management with respect to seed cotton and stalk yield were found to be non-significant.

The data in respect of sustainable yield index (SYI) as influenced by tillage and nutrient management is presented in Table 1. The slightly higher SYI (0.32) was obtained in minimum tillage as compared to conventional tillage (0.30). Among the nutrient management treatments highest SYI (0.56) was recorded with 50% RDF + FYM @ 15 tonnes/ha followed by 50% RDF+ FYM @ 10 tonnes/ha (0.50). The application of FYM @ 10 tonnes/ha along with 50% RDF recorded 16.3% higher SYI over 100% RDF. While, application of FYM @ 15 tonnes/ha along with 50% RDF recorded 30.2% SYI over 100% RDF. Nayak et al. [9] also observed highest SYI of rice-wheat system with NPK + FYM over NPK alone or NPK + crop residue. Comparatively lower values of SYI among the treatments having only chemical fertilizers (50 and 100% RDF) than the integrated use of FYM and fertilizers suggests that combined use of both inorganic and organic manures brings more sustainability of yield on long-term basis.

The soil pH, EC and organic carbon were not significantly influenced by tillage methods (Table 2). However, slight improvement in organic carbon (5.72 g kg^{-1}) was observed in minimum tillage compared to conventional tillage. Lower organic C with intensive tillage is frequently reported in the literature and appears to be due to rapid microbial decomposition by incorporation of crop residues during tillage [10]. The integrated nutrient management also did not influence the pH of soil indicating high buffering capacity of Vertisol having smectic minerals. The pH of soil ranged from 7.96 to 8.05. The application of FYM and *in situ* green manuring of dhaincha significantly lowered the EC of soil over 100% RDF through chemical fertilizers. The highest OC (6.33 g/kg) was observed in 50% RDF + FYM @ 15 tonnes/ha followed by 50% RDF + FYM @ 10 tonnes/ha (6.03 g/kg) which were found to be on par with each other. Organic carbon content of soil is an indication of organic fraction in soil from the microbial decomposition of organic residues and its amount depend upon the type and quality of organic matter and also stage of decomposition. Sharma et al. [11] also observed improvement in organic carbon status of soil in farmyard manure/green manure applied plots after continuous 31 cropping cycles.

Table 1. Sustainability of cotton as influenced by various treatments.

Treatments	Cotton Yield(q ha^{-1}) (Pooled mean of 5 years)	Sustainable Yield Index (SYI)
Tillage		
Conventional Tillage	12.85	0.30
Minimum Tillage	13.13	0.32
SE (m)±	0.229	-
CD (p=0.05)	NS	-
Nutrient Management		
100 % RDF	13.58	0.43
50 % RDF	8.70	0.18
50 % RDF+ 5 t FYM ha^{-1}	12.13	0.36
50 % RDF+ 10 t FYM ha^{-1}	14.89	0.50
50 % RDF+ 15 t FYM ha^{-1}	16.04	0.56
50 % RDF+ GM (Sesbania)	12.60	0.38
SE (m) ±	0.40	-
CD (p=0.05)	1.17	-
Interaction effect	NS	

Table 2. Chemical properties of soil after harvest of cotton as influenced by various treatments.

Treatments	pH (1:2.5)	EC (dS m^{-1})	Org. C (g kg^{-1})
(a) Tillage			
Conventional tillage	8.00	0.32	5.58
Minimum tillage	8.00	0.31	5.72
SE (m) ±	0.013	0.008	0.07
CD at 5 %	NS	NS	NS
(b) Nutrient Management			
100 % RDF	8.04	0.35	5.76
50 % RDF	8.05	0.36	4.28
50 % RDF+ FYM @ 5 t ha^{-1}	8.02	0.31	5.68
50 % RDF+ FYM @ 10 t ha^{-1}	7.99	0.29	6.03
50 % RDF+ FYM @ 15 t ha^{-1}	7.96	0.28	6.33
50 % RDF+ GM (Dhaincha)	7.97	0.31	5.83
SE (m)±	0.023	0.013	0.121
CD at 5 %	NS	0.039	0. 35
Interaction effect	NS	NS	NS
Initial value	8.07	0.31	5.40

The residual soil fertility (available N, P and K) was slightly enhanced in minimum tillage (Table 3). However, the improvement was not significant over conventional tillage. Significantly highest availability of N (260.5 kg/ha) and P (14.69 kg/ha) was observed with the application of 50% RDF + FYM @ 15 tonnes/ha followed by application of 50% RDF + FYM @ 10 tonnes/ha which were on par with each other. The increase in available N might be due to direct addition of N

through FYM and green manure to the available pool of soil [12]. The favourable soil conditions under farmyard manure and green manure addition might have helped in the mineralization of soil N leading to build up of higher available N. Among the inorganic fertilizer treatments, 100% RDF have also improved the available N status of soil. The availability of phosphorus in conjunctive use of organics and inorganics might be due to minimization of P fixation in soil and direct addition of P in soil.

Table 3. Fertility status of soil after harvest of cotton as influenced by various treatments.

Treatments	Available nutrients (kg ha^{-1})		
	N	P	K
(a) Tillage			
Conventional tillage	223.11	13.08	378.9
Minimum tillage	228.12	13.31	381.7
SE (m) ±	2.214	0.29	2.74
CD at 5 %	NS	NS	NS
(b) Nutrient Management			
100 % RDF	235.4	13.46	363.43
50 % RDF	159.5	11.43	349.17
50 % RDF+ FYM @ 5 t ha^{-1}	205.6	12.89	382.35
50 % RDF+ FYM @ 10 t ha^{-1}	250.2	13.72	396.10
50 % RDF+ FYM @ 15 t ha^{-1}	260.5	14.69	402.5
50 % RDF+ GM (Dhaincha)	242.5	12.98	388.55
SE (m)±	3.84	0.50	4.74
CD at 5%	11.25	1.47	13.91
Interaction	NS	NS	NS
Initial value	180.2	12.10	365.50

While, in case of availability of K, the application of FYM @ 10 tonnes/ha and *in situ* green manuring of sesbania was on par with FYM @ 15 tonnes/ha + 50 % RDF. Sharma et al. [13] explained that significant increase in available K content has been due to either FYM or green manure along with fertilizers N, suggesting that FYM and green manure helped to maintain the supply of K by releasing the K from reserve source. Hence, this study recommended that the conjunctive application of FYM @ 10 tha^{-1} along with 50% RDF is beneficial in improving soil health and sustaining the cotton productivity in Vertisols of Maharashtra.

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