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RESEARCH ARTICLE

EFFECT OF TILLAGE AND NUTRIENT MANAGEMENT ON SEED COTTON YIELD AND AVAILABLE MICRONUTRIENTS

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ABSTRACT

The field experiment was conducted to study the "Effect of Integrated Nutrient Management on Soil Quality and Cotton Productivity under Different Tillage Practices in Vertisol" at the Research farm, Department of Soil Science and Agricultural Chemistry, Dr.PanjabraoDeshmukhKrishiVidyapeeth, Akola.The treatments thus involved two main treatments and eight sub treatments. The experiment main plot comprises of two treatments i.e. conservation tillage (CNS) and (CNV). The seed cotton yield was slightly higher under conservation tillage as compared to conventional tillage Highest seed cotton yield was recorded in the treatment receiving 100 % RDF (60:30:30 NPK kg ha^{-1}(15.57 q ha^{-1}) followed by 50% RDF + 50% N (FYM) (14.84 q ha^{-1}).The higher available zinc (0.44 mg kg^{-1}) and iron (6.70 mg kg^{-1}) were recorded under conservation tillage as compared to conventional tillage (0.43 mg kg^{-1}) and (6.65 mg kg^{-1}) in conventional tillage. The highest available zinc and iron (0.46 mg kg^{-1}) (6.92 mg kg^{-1}) in 50 % RDF + 50 % N (FYM) while lowest (0.39 mg kg^{-1}) (5.94 mg kg^{-1}) in 100 % RDF (60:30:30 NPK kg ha^{-1}) respectively.The available manganese (8.87 mg kg^{-1}) in CNS and (8.83 mg kg^{-1}) in CNV, copper (1.96 mg kg^{-1}) in CNS and (1.85 mg kg^{-1}) in CNV.The highest available manganese ranged from (9.11 mg kg^{-1}) in 50 % RDF + 50 % N (FYM) and lowest (8.34 mg kg^{-1}) in 100 % RDF (60:30:30 NPK kg ha^{-1}). The highest available copper ranged from (2.15 mg kg^{-1}) in 50 % RDF + 50 % N (FYM) and lowest (1.48 mg kg^{-1}) in 100 % RDF (60:30:30 NPK kg ha^{-1}).The highest available boron was recorded in 50 % RDF + 50 % N (FYM) (0.47 mg kg^{-1}) followed by 100 % RDF (60:30:30 NPK kg ha^{-1}, 0.36 mg kg^{-1}).

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INTRODUCTION

Cotton is one of the important cash as well as fibre crop and play vital role in the history and civilization of mankind, with enormous potential in textile industries and is a means of livelihood for millions of farmers and those concerned with its trade, processing, manufacturing and other allied industries. Cotton seed contains about 15-20 per cent oil and is used as vegetable oil and soap industries.No agricultural commodity in the world exercised a profound influence on economy as cotton had done from the time immemorial. Therefore, it is popularly known as white gold. Area under cotton across the world has been sluggish for the past few year; however, production has been increased due to sharp rise in yield. China, India, USA and Pakistan are the major cotton producing countries in the world with share of 70 per cent each of the world cotton production and area, respectively.

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India is the largest cotton growing country in the world with an area under cotton around 34 per cent (12.20 m ha) followed by China (5.5 m ha). China and India are the major cotton consuming countries in the world (around 58 per cent of the world cotton consumption).

MATERIALS AND METHODS

The field experiment was carried out to study the "Effect of integrated nutrient management on soil quality and cotton productivity under different tillage practices in Vertisol" on the Research Farm of Department of Soil Science and Agricultural Chemistry, Dr.PanjabraoDeshmukhKrishiVidyapeeth, Akola during 2011-12 and 2012-13.Akola is situated in between 220 41' N latitude and 770 02' longitudes at an altitude of 307.4 m above mean sea level and has a subtropical climate. The climate is characterized by three distinct seasonsviz., summer becoming hot and dry from March to May.The twoseperateexperimenteach in conservation and conventional tillage wereconducted on same site and hencerandomization with similar set of nutrient management treatments.In conservation tillage one harrowing and two weeding operations were carried every year. In conventional tillage one ploughing, one harrowing, two hoeing and two hand weeding operations were carried out every year.

Seed cotton yield

Nutrient management treatments	
T1	: 100% RDF (60:30:30 NPK kg ha-1)
T2	: 50% RDF + In situ green manuring (sunhemp)
T3	: 50% RDF + 50% N (FYM)
T4	: 50% RDF + 50% N (wheatstraw)
T5	: 50% RDF + 50% N (GLM)
T6	: 50% RDF + 25% N (FYM) + 25%N (wheat straw)
T7	: 50% RDF + 25% N (FYM) + 25%N (GLM)
T8	: 50% RDF + 25% N (wheat straw) + 25%N (GLM)

Different treatments consists balance use of chemical fertilizer along with organic source of nutrient in which 50 per cent N applied through chemical fertilizer and remaining N was applied through various sources like FYM, crop residues (wheat straw) and green manuring (sunhemp). The quantity of P and K supplied through different organics, green manuring and crop residues, the compensation remaining P and K compensated through chemical fertilizers. Data in respect of the effect of crop residues application in combination of with inorganic fertilizers on seed cotton yield are presented.

a. Effect of tillage

Seed cotton yield was influenced significantly during both the seasons. The effect of tillage on seed cotton yield was found to be significant. However, in the first year slightly higher values of seed cotton yield (14.25 q ha-1) were observed in conservation tillage as compared to conventional tillage (12.39 q ha-1). In the second year higher values of seed cotton yield (15.00 q ha-1) were observed in conservation tillage as compared to conventional tillage (13.07 q ha-1). In pooled mean analysis higher values of seed cotton yield (14.63 q ha-1) were observed in conservation tillage as compared to conventional tillage (12.73 q ha-1). In Vertisols, the RT systems have been reported to yield equal to or better than the CT systems (Blaiseet al., 2005; Constable et al., 1992).The findings are in conformity with the results reported by Kochetkov (1976), Moursiet al. (1978), Patil et al. (1977), Selvaraj and Palaniappan (1977), Sethi (1988), Deshmukh and Dahatonde (1999), Sarode et al. (2003), Ogunwoleet al. (2003), Deshmukh et al. (2004), Patilet al. (2004a),.

Table 1. Effect of tillage and nutrient management on seed cotton yield

Treatments	Seed cotton yield (q ha-1)		
	2011-12	2012-13	Mean
a.Tillage			
Set I :Conservation tillage	14.25	15.00	14.63
Set II :Conventional tillage	12.39	13.07	12.73
SE (m) ±	0.31	0.34	0.32
CD at 5 %	0.90	1.01	0.95
b.Nutrient management			
T1:100% RDF (60:30:30 NPK kg ha-1)	14.82	15.57	15.20
T2:50% RDF + In situ GM (sunhemp)	11.45	11.93	11.69
T3:50% RDF + 50% N (FYM)	14.09	14.84	14.47
T4:50% RDF + 50% N (WS)	13.30	14.25	13.78
T5:50% RDF + 50% N (GLM)	11.94	12.69	12.32
T6 :50% RDF + 25%N (FYM) + 25% N (WS)	13.85	14.36	14.11
T7 : 50% RDF + 25% N (FYM) + 25% N (GLM)	13.61	14.6	14.10
T8 : 50% RDF + 25% N (WS) + 25% N (GLM)	13.50	14.05	13.79
SE (m) ±	0.62	0.68	0.65
CD at 5 %	1.85	2.02	1.92
c.Interaction effect	Sig	Sig	Sig

b. Effect of nutrient management

The seed cotton yield content varied from 11.45 to 14.82, 11.93 to 15.57 and 11.69 to 15.20 q ha-1 during first year, second year and pooled mean respectively. Seed cotton yield was influenced significantly due to integrated nutrient management. In the first year seed cotton yield (14.82 q ha-1) was found significantly higher in the treatment of 100% RDF (60:30:30 NPK kg ha-1) followed by, 50% N through FYM + 50% RDF(14.09 q ha-1) and 50%RDF+25%N (FYM)+ 25% N (WS) (13.85 q ha-1) which were found to be at par with each other. In the second year seed cotton yield (15.57 q ha-1) was found significantly higher in the treatment of 100% RDF (60:30:30 NPK kg ha-1) followed by, 50% N through FYM + 50% RDF(14.84 q ha-1), 50% RDF + 25% N (WS) + 25% N (GLM) (14.60 q ha-1), which were found to be at par with each others. The lowest seed cotton yield (11.93 q ha-1) was recorded in treatment 50% RDF + In situ GM (sunhemp). In the pooled mean data seed cotton yield (15.20 q ha-1) was found significantly higher in the treatment of 100% RDF (60:30:30 NPK kg ha-1) followed by, 50% N through FYM + 50% RDF(14.47 q ha-1) and 50%RDF+25%N (FYM)+ 25% N (WS) (14.11 q ha-1) these treatment were found to be at par with each others. The lowest Seed cotton yield (11.69 q ha-1) was recorded in treatment 50% RDF + In situ GM (sunhemp). This could be ascribed to the effect of applied fertilizer and mineralization of organic sources or through solublization of the nutrients from the native sources during the process of decomposition.

The interaction of conservation tillage with FYM was found most beneficial and recorded highest yield of cotton. This can be attributed to the combined effect of conservation tillage in improving soil properties along with FYM resulting into highest yield of cotton. The conservation tillage along with glyricidia green leaf manuring also recorded yields which whereat par with FYM which also signifies the importance of conservation tillage with organics.This could be attributed to the intercrop competition with the cotton crop for moisture and nutrients availability throughout the crop growing period. Similar results were observed by Sethi (1988). The findings are in conformity with the results reported by Kochetkov (1976), Moursi et al. (1978), Patil et al. (1977), Selvaraj and Palaniappan (1977), Sethi (1988), Deshmukh and Dahatonde (1999), Sarode et al. (2003), Ogunwole et al. (2003), Deshmukh et al. (2004), Patil et al. (2004a). This may be ascribed to the improvement in the soil physical, chemical and biologicalproperties due to the incorporation of organics along with 50 per cent recommended dose of fertilizers which might have hastened the nutrient availability as well as better soil condition for root penetration. The results are in close agreement with the findings reported by Subramanian et al. (2000), Basavanneppa and Biradar (2002), Babalad and Itnal (2004), Hulihalli and Patil (2004), Halemani et al. (2004a), Halemani et al. (2004b), Hongal et al. (2004), Praharajet al. (2004b) and Hulihalli and Patil (2006a). Similar findings were reported by Sethi (1988).

Available micronutrients in the soil

The micronutrient deficiency is emerging in swell-shrink soil due to intensive agriculture, use of high analysis NPK fertilizers and lack of addition of organic manures.

Available zinc

Data pertaining to available zinc as influenced by different treatments are presented.

Table 2. Effect of tillage and nutrient management on available zinc in soil

Treatments	Available Zn (mg kg-1)	
a.Tillage	2011-12	2012-13
Set I :Conservation tillage	0.42	0.44
Set II :Conventional tillage	0.41	0.43
SE (m) ±	0.002	0.003
CD at 5 %	0.004	0.005
b. Nutrient management		
T1:100% RDF (60:30:30 NPK kg ha-1)	0.38	0.39
T2:50% RDF + In situ GM (sunhemp)	0.41	0.45
T3:50% RDF + 50% N (FYM)	0.44	0.46
T4:50% RDF + 50% N (WS)	0.42	0.45
T5:50% RDF + 50% N (GLM)	0.41	0.43
T6 :50% RDF + 25%N (FYM) + 25% N (WS)	0.43	0.46
T7 : 50% RDF + 25% N (FYM) + 25% N (GLM)	0.42	0.45
T8 : 50% RDF + 25% N (WS) + 25% N (GLM)	0.41	0.42
SE (m) ±	0.006	0.007
CD at 5 %	0.018	0.020
c. Interaction effect	NS	NS

a. Effect of tillage

The effect of tillage on available zinc was found to be significant. In first year, slightly higher available zinc was observed in conservation tillage (0.42 mg kg-1) as compared to conventional tillage (0.41 mg kg-1), while during second year higher zinc was recorded in conservation tillage (0.44 mg kg-1) as compared to conventional tillage (0.43 mg kg-1), Similar results about effect of tillage on the distribution of Manganese, Copper, Iron, and Zinc in soil reported by Shuman and Hargrove (1984) and also noticed by Jacinthe and Lal (2009), Liu (2005). In 2011 there is 2.38 per cent and in 2012 (2.27 per cent) increase in Conservation over conventional tillage.

b. Effect of nutrient management

Available zinc was influenced significantly due to integrated nutrient management. In the first year available zinc (0.44 mg kg-1) was found significantly highest in the treatment of 50% N through FYM + 50% RDF followed by, 50%RDF+25%N (FYM)+ 25% N (WS) (0.43 mg kg-1) and 50%RDF + 25% N (FYM) + 25% N (GLM) (0.42 mg kg-1) and these treatments were found to be at par with each others. The lowest available zinc (0.38 mg kg-1) was recorded in treatment 100% RDF (60:30:30 NPK kg ha-1). During second year available zinc (0.46mg kg-1) was found significantly higher in the treatment of 50% N through FYM + 50% RDF which was at par with 50 % RDF+ 25% N (FYM)+ 25% N (WS) (0.46 mg kg-1) and 50%RDF + 25% N (FYM) + 25% N (GLM) (0.45 mg kg-1). The lowest available zinc (0.39 mg kg-1) was recorded in treatment 100% RDF (60:30:30 NPK kg ha-1). Available zinc was influenced significantly due to integrated nutrient management. However, higher content of available Zn in the treatments that received combined application of crop residues and inorganic fertilizers (T4 to T8) as compared to inorganic treatments alone. This might be due to the mineralization of organically bound forms of Zn in the organic materials, which encouraged the formation of organic chelates of higher stability, because zinc is known to form relatively stable chelates with organic ligands which decrease their susceptibility to absorption, fixation and/or precipitation (Bellakki et al., 1998). The other possible reason for increased zinc availability could be an enhanced microbial activity in the soil and consequent release of complex organic substances (chelating agents), which could have prevented micronutrients from precipitation, fixation, oxidation and leaching. The results are in conformity with Guled et al. (2002) and Ismail et al. (1998). The available zinc in soil was maintained in treatment supplied with FYM. The identical results were observed by Babhulkar et al. (2000), Poongothai and Chideshwari (2003) and Chitdeshwari and Duraisami (2005). The available zinc increased from initial status by combined application of urea and FYM noticed by Katkar (2008). Thus, the results indicated that due to continuous cropping with only chemical fertilizers without addition of organics there is considerable depletion of zinc in soils which indicates immense necessity of regular application of organics either through FYM, green manures or crop residues to maintain the zinc status of soils. The increased zinc content maintained under integrated nutrient management for a long period might be due to the addition of organics. The organic materials form chelates and increase the availability of zinc. The similar findings were reported by Verma et al. (2005) and Masto et al. (2007). Improved Zn availability in soil by application of inorganic fertilizers over initial could be due to the possible addition of Zn as impurity through fertilizer. Considerable improvement in available Zn content was reported with the application of inorganic fertilizers (Prasad et al., 1979), crop residues + inorganic fertilizers (Bellakkiet al. 1998; Sharma et al., 2000). While, Hegde (1996) reported that available Zn content remained unaffected with integrated nutrient supply, which included inorganic fertilizers, FYM, wheat straw and green manuring. Overall results showed that incorporation of crop residues in combination with fertilizers were highly effective in increasing soil available Zn over the treatments of inorganic fertilizers alone. The application of FYM appreciably increased the availability of applied and native micronutrient cations in the order of their increase Fe > Cu >Mn> Zn. As these elements are known to form stable complexes of different stability with organic ligands which decreases their susceptibility to adsorption or fixation or precipitation reactions in soil. The highest magnitude of response of cotton to zinc alone might be due to marginal value of DTPA extractable Zn (0.60 to 1.20 ppm) in soil. Zinc deficiency is more frequently noticed in calcareous soil and also in soils that are excessively high in phosphorus. The phosphorus fertilization high clay and $CaCO_3$ content immobilised the applied phosphorus and resulted in increase zinc adsorption to form soluble $Zn\text{-}PO_4$ complex (Malewar, 1980). The results thus clearly indicated that without addition of organics there is considerable depletion of zinc and soils show depletion of zinc which indicate immense necessity of regular application of organics either FYM or crop residues and /or green manures to maintain the zinc status of soils. Although there is presence of available zinc as compare to initial, but it takes time to reach sufficiency level, so addition of organics is necessary.

In 2012, per cent increase recorded in 50% RDF + 50% N (FYM) and 50% RDF + 25% N (FYM) + 25 % N (WS) (19.56 %) over initial value and 50% RDF + 25% N (FYM) + 25 % N (GLM) (17.77 %) respectively. In 2012, per cent increase recorded in 50% RDF + 50% N (FYM) and 50% RDF + 25% N (FYM) + 25 % N (WS) (15.21 %) over initial value and 50% RDF + 25% N (FYM) + 25 % N (GLM) (13.33 %) respectively. During 2012, the increase in the available zinc was found to be 19.56, 15.21, 19.56 and 9.30 percent in the FYM, sunnhemp Green manuring, wheat straw and glyricidia green leaf manure along with 50 % RDF as compared to 100% RDF (60:30:30 NPK kg ha-1) respectively.

Available iron

Data in respect of available iron as influenced by different treatments are presented.

a. Effect of tillage

During first year numerically higher available iron was observed in conservation tillage (6.24 mg kg-1) as compared to conventional tillage (6.20 mg kg-1). In second year numerically higher iron was observed in conservation tillage (6.70 mg kg-1) as compared to conventional tillage (6.65 mg kg-1). Similar results about effect of tillage on the distribution of Manganese, Copper, Iron, and Zinc in soil reported by Shuman and Hargrove (1984) and also noticed by Jacinthe and Lal (2009), Liu (2005) and also reported by Mohantyet al.2007. In 2011 there is 0.64 per cent and in 2012 (0.74 per cent) increase in Conservation over conventional tillage.

b. Effect of nutrient management

Available iron was influenced significantly due to integrated nutrient management. In the first year available iron (6.39 mg kg-1) was found significantly higher in the treatment of 50% N through FYM + 50% RDF followed by, 50% RDF+25% N (FYM)+ 25% N (WS) (6.38 mg kg-1) and 50% RDF + 25% N (FYM) + 25% N (GLM) (6.38 mg kg-1) and these treatment were found to be at par with each others. The lowest available iron (5.94 mg kg-1) was recorded in treatment 100% RDF (60:30:30 NPK kg ha-1). In the second year, available iron (6.92 mg kg-1) was found significantly higher in the treatment of 50% N through FYM + 50% RDF found at par with 50% RDF+25% N (FYM)+ 25% N (WS) (6.85 mg kg-1) and 50% RDF + 25% N (FYM) + 25% N (GLM) (6.78 mg kg-1). The lowest available iron (6.42 mg kg-1) was recorded in treatment 100% RDF (60:30:30 NPK kg ha-1).

Table 3. Effect of tillage and nutrient management on available iron in soil

Treatments	Available iron (mg kg-1)	
a.Tillage	2011-12	2012-13
Set I :Conservation tillage	6.24	6.70
Set II :Conventional tillage	6.20	6.65
SE (m) ±	0.02	0.03
CD at 5 %	NS	NS
b. Nutrient management		
T1:100% RDF (60:30:30 NPK kg ha-1)	5.94	6.42
T2:50% RDF + In situ GM (sunhemp)	6.02	6.58
T3:50% RDF + 50% N (FYM)	6.39	6.92
T4:50% RDF + 50% N (WS)	6.20	6.62
T5:50% RDF + 50% N (GLM)	6.18	6.58
T6 :50% RDF + 25%N (FYM) + 25% N (WS)	6.38	6.85
T7 : 50% RDF + 25% N (FYM) + 25% N (GLM)	6.38	6.78
T8 : 50% RDF + 25% N (WS) + 25% N (GLM)	6.24	6.65
SE (m) ±	0.04	0.06
CD at 5 %	0.14	0.17
c. Interaction effect	NS	NS

Incorporation of crop residues in combination with 50 per cent chemical fertilizers increased available iron content in the soil over control. Further, it was observed that the available iron content in the soil increased during second year of experimentation. Further, it could be noted that the combined use of manures and crop residues with inorganic fertilizers improved available status of soil as compared to that of application of inorganic treatments alone. Similar findings were also reported by Patil and Patil (1982). They reported that addition of higher quantity of organic matter favoured increase in iron accompanied by a decrease in soil pH.The enhancement in available iron due to the addition of organic substances may be ascribed to the presence of appreciable quantity of iron in the organics and due to their ability to form stable water soluble complexes preventing the reaction of soil constituents and also increasing the Fe content through release from the native sources (Gupta et al., 1988). Appreciable quantity of Fe as a contaminant through super phosphate might also added to such an increase in available Fe in the treatments involving inorganic fertilizers application. Increased availability of Fe with combined application of vermicompost, inorganic fertilizer, green manures were earlier reported by Shinde and Ghosh (1973), Hegde (1996) and Prakash et al. (2002). The available iron shows emerging deficiencies in alkaline calcareous soils due to intensive cropping and the INM is therefore imperative to maintain the Fe status of soils.Also organic matter in the form of green manure, in addition to affecting the oxidation-reduction condition of soil, also functions as a chelating agent for water soluble Fe^{2+}. Similar results were reported by Vipin Kumar and Singh (2010) and also noticed by Katkar (2008).

In 2011, the per cent increase recorded in 50% RDF + 50% N (FYM) (24.88 %) over initial value, followed by 50% RDF + 25% N (FYM) + 25 % N (WS) (24.76 %)and 50% RDF + 25% N (FYM) + 25 % N (GLM) (24.76 %), while during 2012, per cent increase recorded in 50% RDF + 50% N (FYM) (30.63 %) over initial value, followed by 50% RDF + 25% N (FYM) + 25 % N (WS) (29.92 %)and 50% RDF + 25% N (FYM) + 25 % N (GLM) (29.20 %) respectively. In 2011, the per cent increase recorded in 50% RDF + 50% N (FYM) (7.04 %) over 100% RDF (60:30:30 NPK kg ha-1), followed by 50% RDF + 25% N (FYM) + 25 % N (WS) (6.89 %)and 50% RDF + 25% N (FYM) + 25 % N (GLM) (6.89 %), while during 2012, per cent increase recorded in 50% RDF + 50% N (FYM) (7.22 %) over 100% RDF (60:30:30 NPK kg ha-1), followed by 50% RDF + 25% N (FYM) + 25 % N (WS) (6.27 %)and 50% RDF + 25% N (FYM) + 25 % N (GLM) (5.30 %).

During 2011, the increase in the available iron was found to be 7.04, 1.32, 4.19 and 3.88 percent in the FYM, sunnhemp Green manuring, wheat straw and glyricidia green leaf manure along with 50 % RDF as compared to 100% RDF (60:30:30 NPK kg ha-1). During 2012, the increase in the available iron was found to be 7.22, 10.63, 3.02 and 6.27 percent in the FYM, sunnhemp Green manuring, wheat straw and glyricidia green leaf manure along with 50 % RDF as compared to 100% RDF (60:30:30 NPK kg ha-1) respectively.

Available manganese

Data with respect to available manganese as influenced by different treatments are presented.

Effect of tillage

In first year slightly higher available manganese was observed in conservation tillage (8.64 mg kg-1) as compared to conventional tillage (8.60 mg kg-1) and during second year higher manganese was observed in conservation tillage (8.87 mg kg-1) as compared to conventional tillage (8.83 mg kg-1). Similar results about effect of tillage on the distribution of Manganese, Copper, Iron, and Zinc in soil reported byShuman and Hargrove (1984) and also noticed by Simon et al., 2009, Liu (2005) and also reported by Mohanty et al. (2007). In 2011 there is 0.46 per cent and in 2012 (0.45 per cent) increase in Conservation over conventional tillage.

b. Effect of nutrient management

The results of the present investigation showed that available manganese was non-significantly influenced during both the years of experimentation. Available manganese was influenced significantly due to integrated nutrient management. In the first year, available manganese (8.79 mg kg-1) was found slightly higher in the treatment of 50% N through FYM + 50% RDF followed by, 50%RDF+25%N (FYM)+ 25% N (WS) (8.78 mg kg-1) and 50% RDF + 25% N (FYM) + 25% N (GLM) (8.77 mg kg-1).

Table 4. Effect of tillage and nutrient management on available manganese in soil

Treatments	Available Manganese (mg kg-1)	
a.Tillage	2011-12	2012-13
Set I :Conservation tillage	8.64	8.87
Set II :Conventional tillage	8.60	8.83
SE (m) ±	0.16	0.18
CD at 5 %	NS	NS
b.Nutrient management		
T1:100% RDF (60:30:30 NPK kg ha-1)	8.34	8.63
T2:50% RDF + In situ GM (sunhemp)	8.42	8.72
T3:50% RDF + 50% N (FYM)	8.79	9.11
T4:50% RDF + 50% N (WS)	8.60	8.86
T5:50% RDF + 50% N (GLM)	8.58	8.77
T6 :50% RDF + 25%N (FYM) + 25% N (WS)	8.78	8.94
T7 : 50% RDF + 25% N (FYM) + 25% N (GLM)	8.77	8.91
T8 : 50% RDF + 25% N (WS) + 25% N (GLM)	8.64	8.87
SE (m) ±	0.32	0.36
CD at 5 %	NS	NS
c. Interaction effect	NS	NS

The lowest available manganese (8.34 mg kg-1) was recorded in treatment 100% RDF (60:30:30 NPK kg ha-1). In the second year, available manganese (9.11 mg kg-1) was found significantly higher in the treatment of 50% N through FYM + 50% RDF followed by, 50%RDF+25%N (FYM)+ 25% N (WS) (8.94 mg kg-1) and 50% RDF + 25% N (FYM) + 25% N (GLM) (8.91 mg kg-1) whereas lowest available manganese (8.63 mg kg-1) was recorded in treatment 100% RDF (60:30:30 NPK kg ha-1). Available manganese was not influenced significantly due to integrated nutrient management. The lowest available manganese (8.49 mg kg-1) was recorded in treatment 100% RDF (60:30:30 NPK kg ha-1).The availability of micronutrients increased with increase in organic carbon and clay content due to formation of chelate complexes in the soil (Yadav and Meena, 2009). Further, it could be observed that the higher content of available manganese in the treatments which received combined application of crop residues and inorganic fertilizers than that of inorganic treatments alone. This could be attributed to the fact that organic matter releases Mn2+ bound with organic ligands and accelerates the reduction of Mn4+ to Mn2+ and extended period of composting of organic manures, readily liberated the Mn into labile pool (Selvi and Selvaseelan, 1997). Increase in available Mn was reported by many other workers with the crop residues + inorganic fertilizers (Bellakki et al., 1998; Sharma et al., 2000), chemical fertilizers (Prasad et al., 1979) and FYM + chemical fertilizers (Prasad and Singh, 1980) and also noticed by Katkar (2008). In 2011, the per cent increase recorded in 50% RDF + 50% N (FYM) (4.20 %) over initial value, followed by 50% RDF + 25% N (FYM) + 25 % N (WS) (4.10 %)and 50% RDF + 25% N (FYM) + 25 % N (GLM) (3.99 %), while during 2012, per cent increase recorded in 50% RDF + 50% N (FYM) (7.57 %) over initial value, followed by 50% RDF + 25% N (FYM) + 25 % N (WS) (5.81 %)and 50% RDF + 25% N (FYM) + 25 % N (GLM) (5.49 %) respectively. In 2011, the per cent increase recorded in 50% RDF + 50% N (FYM) (5.11 %) over 100% RDF (60:30:30 NPK kg ha-1), followed by 50% RDF + 25% N (FYM) + 25 % N (WS) (5.01 %)and 50% RDF + 25% N (FYM) + 25 % N (GLM) (4.90 %), while during 2012, per cent increase recorded in 50% RDF + 50% N (FYM) (5.26 %) over 100% RDF (60:30:30 NPK kg ha-1), followed by 50% RDF + 25% N (FYM) + 25 % N (WS) (3.46 %)and 50% RDF + 25% N (FYM) + 25 % N (GLM) (3.14 %) respectively. During 2011, the increase in the available manganese was found to be 5.11, 0.95, 3.02 and 2.79 percent in the FYM, sunnhemp Green manuring, wheat straw and glyricidia green leaf manure along with 50 % RDF as compared to 100% RDF (60:30:30 NPK kg ha-1). During 2012, the increase in the available manganese was found to be 5.26, 1.03, 2.59 and 1.59 percent in the FYM, sunnhemp Green manuring, wheat straw and glyricidia green leaf manure along with 50 % RDF as compared to 100% RDF (60:30:30 NPK kg ha-1) respectively.

Available copper

The data related to effect of various treatment of crop residues combination with inorganic fertilizers on available copper reported.

a. Effect of tillage

In first year numerically higher available copper was recorded in conservation tillage (1.74 mg kg-1) as compared to conventional tillage (1.64 mg kg-1). In second year numerically higher copper was recorded in conservation tillage (1.96 mg kg-1) as compared to conventional tillage (1.85 mg kg-1), but the 5.61 per cent increase in Cu content under conservation tillage was found compared to conventional tillage Similar results about effect of tillage on the distribution of Manganese, Copper, Iron, and Zinc in soil reported by Shuman and Hargrove (1984) and also noticed by Simonet al. 2009, Liu (2005) and also reported by Mohanty et al. (2007). In 2011 there is 5.74 per cent and in 2012 (5.61 per cent) increase in Conservation over conventional tillage.

b. Effect of nutrient management

Available copper was influenced significantly due to integrated nutrient management. In the first year, available copper (1.93 mg kg-1) was found significantly highest in the treatment of 50% N through FYM + 50% RDF followed by, 50% RDF+25%N (FYM)+ 25% N (WS) (1.85 mg kg-1) and 50% RDF + 25% N (FYM) + 25% N (GLM) (1.79 mg kg-1). These treatment were found to be at par with each others and T8 and T4. The lowest available copper (1.48 mg kg-1) was recorded in treatment 100% RDF (60:30:30 NPK kg ha-1) and T8 and T4. During second year available copper (2.15 mg kg-1) was found significantly highest in the treatment of 50% N through

FYM + 50% RDF and found to be at par with all other treatment except T1 and T2. The lowest available copper (1.70 mg kg-1) was recorded in treatment 100% RDF (60:30:30 NPK kg ha-1). It could be observed that the higher content of available copper in the treatments of combined application of crop residues and inorganic fertilizers as compared to inorganic treatments alone. The findings are in line with the results reported by Bellakki et al. (1998). It was thus apparent that the FYM, green manures and crop residues have the potential in maintaining micronutrient status in soils which can overcome the emerging deficiency problems and their regular use in conjunction with chemical fertilizers is more beneficial over only chemical fertilizers.This increase in available copper may be due to addition of organic manures along with inorganic fertilizers which enhance the microbial activity and consequent release of complex organic substance would have prevented copper from precipitation, fixation, oxidation and leaching. Thus, the findings of present investigation suggest that the use of FYM, wheat straw, glyricidia, along with chemical fertilizers help in maintaining available micronutrient status of soil over a long period. There was a considerable increase in available micronutrients with continuous use of chemical fertilizer and FYM (Prasad and Singh, 1980). Lal and Mathur (1989) also reported removal of micronutrients by the crop for 30 years did not bring their level below critical limit, though

Table 5. Effect of tillage and nutrient management on available copper in soil

Treatments	Available copper (mg kg-1)	
a. Tillage	2011-12	2012-13
Set I :Conservation tillage	1.74	1.96
Set II :Conventional tillage	1.64	1.85
SE (m) ±	0.12	0.18
CD at 5 %	NS	NS
b. Nutrient management		
T1:100% RDF (60:30:30 NPK kg ha-1)	1.48	1.70
T2:50% RDF + In situ GM (sunhemp)	1.52	1.74
T3:50% RDF + 50% N (FYM)	1.93	2.15
T4:50% RDF + 50% N (WS)	1.68	1.90
T5:50% RDF + 50% N (GLM)	1.56	1.78
T6 :50% RDF + 25%N (FYM) + 25% N (WS)	1.85	2.07
T7 : 50% RDF + 25% N (FYM) + 25% N (GLM)	1.79	2.01
T8 : 50% RDF + 25% N (WS) + 25% N (GLM)	1.69	1.91
SE (m) ±	0.09	0.11
CD at 5 %	0.27	0.33
c. Interaction effect	NS	NS

they were not supplied from outside sources. Constant supply through native minerals (feldspar, hornblende, biotite, tourmaline, etc.) and fertilizer carrying these nutrients as impurities was the probable reason for the same. They further observed higher amount of available Zn, Cu and Mn in plots supplied with only organics than those in inorganic or half organic + inorganic applied plots. Addition of organic materials might have enhanced the microbial activity in the soil and consequently the release of complex organic substances like humic and fulvic acids acting as chelating agents during the decomposition of organic manure and crop residue. This could have prevented micronutrients from precipitation, fixation, oxidation, leaching and augmented the solubility, mobility, availability of insoluble micronutrients. Prasad and Sinha (2000) in their studies on long term effect of fertilizers and organic manures on soil properties in rice – wheat cropping systems in calcareous soils of Pusa (Bihar) also reported available Zn, Fe, Cu and Mn increased in soil when different levels of fertilizers were applied along with crop residues and organic manure in calcareous soil. Application of FYM significantly increased availability of micronutrients over rest of the treatments probably due to the decomposition of FYM and consequent release of micronutrients (Swarup, 1991) and also noticed by Katkar (2008). In 2011, the per cent increase recorded in 50% RDF + 50% N (FYM) (15.02 %) over initial value, followed by 50% RDF + 25% N (FYM) + 25 % N (WS) (11.35 %)and 50% RDF + 25% N (FYM) + 25 % N (GLM) (8.37 %), while during 2012, per cent increase recorded in 50% RDF + 50% N (FYM) (23.72 %) over initial value, followed by 50% RDF + 25% N (FYM) + 25 % N (WS) (20.77 %)and 50% RDF + 25% N (FYM) + 25 % N (GLM) (18.40 %) respectively. During 2012, per cent increase recorded in 50% RDF + 50% N (FYM) (20.93 %) over 100% RDF (60:30:30 NPK kg ha-1), followed by 50% RDF + 25% N (FYM) + 25 % N (WS) (17.87 %) and 50% RDF + 25% N (FYM) + 25 % N (GLM) (15.42 %) respectively. During 2012, the increase in the available copper was found to be 20.93, 2.29, 10.52 and 4.49 percent in the FYM, sunnhemp Green manuring, wheat straw and glyricidia green leaf manure along with 50 % RDF as compared to 100% RDF (60:30:30 NPK kg ha-1) respectively.

Available boron

The data pertaining to effect of various treatments of organics combination with inorganic fertilizers on available boron reported.

a. Effect of tillage

Slightly higher available boron was observed in conservation tillage (0.41 mg kg-1) as compared to conventional tillage (0.40 mg kg-1) and in conservation tillage (0.43 mg kg-1) as compared to conventional tillage (0.42 mg kg-1) during first and second year respectively. Similar results were recorded by Bellakki et al. (1998). Similar results about effect of tillage on the distribution of Manganese, Copper, Iron, and Zinc in soil reported byShuman and Hargrove (1984) and also noticed by Simon et al. (2009), Liu (2005) and also reported by Mohanty et al. (2007).

b. Effect of nutrient management

Available boron was influenced significantly due to integrated nutrient management. Significantly highest available boron (0.45 mg kg-1) was recorded in the treatment of 50% N through FYM + 50% RDF which was followed by, 50%RDF+25%N (FYM)+ 25% N (WS) (0.43 mg kg-1) and 50%RDF + 25% N (FYM) + 25% N (GLM) (0.42 mg kg-1) while lowest available boron (0.36 mg kg-1) was recorded in treatment 100% RDF (60:30:30 NPK kg ha-1). During second year, available boron (0.47mg kg-1) significantly highest in the treatment of 50% N through FYM + 50% RDF and followed by, 50% RDF+25% N (FYM)+ 25% N (WS) (0.45 mg kg-1) and 50% RDF + 25% N (FYM) + 25% N (GLM) (0.44 mg kg-1). The lowest available boron (0.38 mg kg-1) was recorded in treatment 100% RDF (60:30:30 NPK kg ha-1). Further, it could be observed that the higher content of available boron in the treatments of combined application of crop residues and inorganic fertilizers as compared to inorganic treatments alone. This may be due to formation of sodium borate at higher pH, which is highly soluble, available boron was positively correlated with organic matter. This in aggrement with general observation that boron deficiency is less prevalent in soils with high organic matter content as most of the soil boron is retained by soil organic matter and become available later on the decomposition. The findings are in line with the results reported by Bellakki et al. (1998) and also noticed by Katkar (2008). It was thus apparent that the FYM, green manures and crop residues have the potential in maintaining micronutrient status in soils which can overcome the emerging deficiency problems and their regular use in conjunction with chemical fertilizers is more beneficial over only chemical fertilizers.

Table 6. Effect of tillage and nutrient management on available boron in soil

Treatments	Available boron (mg kg-1)	
a.Tillage	2011-12	2012-13
Set I :Conservation tillage	0.41	0.43
Set II :Conventional tillage	0.40	0.42
SE (m) ±	0.001	0.001
CD at 5 %	0.003	0.004
b.Nutrient management		
T1:100% RDF (60:30:30 NPK kg ha-1)	0.36	0.38
T2:50% RDF + In situ GM (sunhemp)	0.41	0.42
T3:50% RDF + 50% N (FYM)	0.45	0.47
T4:50% RDF + 50% N (WS)	0.40	0.41
T5:50% RDF + 50% N (GLM)	0.39	0.41
T6 :50% RDF + 25%N (FYM) + 25% N (WS)	0.43	0.45
T7 : 50% RDF + 25% N (FYM) + 25% N (GLM)	0.42	0.44
T8 : 50% RDF + 25% N (WS) + 25% N (GLM)	0.41	0.42
SE (m) ±	0.001	0.002
CD at 5 %	0.003	0.006
c.Interaction effect	NS	NS

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