Int.J.Curr.Microbiol.App.Sci (2018) Special Issue-6: 1780-1788

EXCELLENT PUBLISHERS

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 Special Issue-6 pp. 1780-1788
Journal homepage: http://www.ijcmas.com

Original Research Article

Long Term Effect of INM on Soil Health and Productivity of Cotton + Greengram Intercropping System in Vertisols

Ashwini Chandel*, V.V. Gabhane, V.H. Jadhao and K. Rajesh Naik

AICRP for Dryland Agriculture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola-444 104, Maharashtra, India
**Corresponding author*

Keywords

Cotton + greengram intercropping, INM, Soil health

A B S T R A C T

The study was undertaken during 2015-16 to assess the effect of long-term fertilization and manuring on soil health and productivity of cotton+greengram intercropping system in Vertisol under rainfed condition. The dynamics of soil characteristics was studied in the on-going long term fertilizer experiment initiated during 1987-88 at Akola, Maharashtra. The experiment comprised of eight treatments viz., no manure no fertilizers, 100% RDF (50:25:00NPK kg ha^{-1}), 50% RDF and substitution of 50% N through FYM and 50% & 100% N through gliricidia, in combination with chemical fertilizers. The experiment was replicated three times in randomised block design. The manure and mineral fertilizers were given to cotton + greengram crop every year. Soil samples from all the treatments were collected from 0-20 cm depth and analyzed as per standard procedures and plot wise yield of the crops was also recorded. The results indicate that significantly higher increase in soil organic carbon, available N, P, K in soil, soil microbial biomass carbon, dehydrogenase assay, CO_2 evolution, alkaline phosphatase activity and productivity of cotton + greengram was recorded with the integrated application of 50% N through fertilizers + 50% N through FYM/gliricidia +100% P_2O_5 ha^{-1} through fertilizers over control and other fertilizer treatments after 29 years of experimentation. Hence, it can be concluded that the long-term conjunctive use of 50% N through FYM/gliricidia + 50% N through inorganics + 100% P_2O_5 ha^{-1} through inorganics to cotton + greengram (1:1) intercropping system resulted in improvement in soil health and higher productivity of cotton+greengram intercropping system in Vertisol under rainfed condition.

Introduction

Cotton (G*ossypium spp*.) is an important cash crop globally known as "king of fiber" and play vital role in the economy of farmers as well as the country and is popularly known as "white gold". It is a fiber crop originated in India and belongs to *Malvaceae* family. Among different species of cotton *Gossypium hirsutum* and *Gossypium arboreum* are commonly grown in Maharashtra and used in textile industries for manufacture of cloth. Besides this, it is also used for several other purposes like making threads and for mixing in other fibers.

It plays a key role in Indian economy. India ranks first in the world having an area of 109.57 lakh ha with the production of 339.17 lakh bales. Maharashtra is one of the leading cotton growing states in India having 38.06 lakh ha area under cotton cultivation which is one third of country's area of cotton cultivation with the production of 80.59 lakh bales. The productivity of cotton in Maharashtra is 360 kg per ha (Anonymous, 2016a). It is one of the important commercial crops and is grown predominantly under rainfed condition in Vidarbha region. Cotton seed contain 15-20 per cent oil and used as vegetable oil in soap industries. After extraction of oil, the left over cake, a byproduct of cotton mill is very important feed for livestock. It can also be used as manure as it contains 6.4% N, 2.9% P and 2.2% K.

Greengram (*vigna radiata*) is an important pulse crop believed to be originated from India. It is short duration legume crop grown mostly as a crop in rotation with different crops. Greengram commonly known as mung, is also known as "golden gram" and it contains 20-25% protein. It is cultivated in variety of soils from red lateritic to black cotton soil. More than 70 % of world's greengram production comes from India.

In India, the area under greengram is about 3.55 Mha with production of 1.80 MT and productivity of 512 kg ha^{-1} whereas, Maharashtra has about 5.11 lakh ha area and production is 2.89 lakh tones with productivity of 566 kg ha^{-1}.The area under greengram in Vidarbha is 1.13 lakh ha and production of 0.78 lakh tones with productivity of 547 kg ha^{-1} (Anonymous, 2016).

Long-term fertilizer experiments have shown that the integrated use of organic manures and chemical fertilizers can maintain high productivity and sustainable crop production. Recent studies have indicated that a periodic addition of large quantities of green mauring to the soil maintain the nitrogen and organic matter at adequate level**.** The application of FYM, compost and crop residues effectively maintain the soil organic matter. The FYM contains all the nutrients needed for crop growth including trace elements. By using organic matter in soil, a balanced nutrition is made available to the plants.

Gliricidia sepium is a leguminous multipurpose tree and adopts very well in a wide range of soils. The leaves decompose relatively fast, providing nitrogen and potassium. Gliricidia as green leaf manure plays important role in increasing the fertility status of soils and helps in conserving soil through reduced soil erosion also.

Materials and Methods

The experiment is the part of long term experiment that was taken on same site since 1987-88 without changing randomization under rainfed condition on farm of AICRP for Dryland Agriculture, Dr. PDKV, Akola (Maharashtra). The experimental site is located 22°42´ N and 77°02´E, 307.42 m above mean sea level in a semi-arid tropical zone. Rainfall during *kharif* 2015 (June-September) amounted 644.6 mm which was 98.2% of the corresponding normal rainfall (656.2 mm).

The eight treatments comprising organic and inorganic sources of fertilizer were : T_1-Control; T_2 -100% N + 100% P_2O_5 ha^{-1} fertilizers ;T_3- 50% N + 50% P_2O_5 ha^{-1} fertilizers; T_4 -50% N ha^{-1}gliricidia ; T_5 -50% N ha^{-1} FYM ; T_6 -50% N fertilizers + 50% N gliricidia+100% P_2O_5 ha^{-1} fertilizers ; T_7 -50% N fertilizers + 50% N ha^{-1} FYM +100% P_2O_5 ha^{-1} fertilizers;T_8 -100% N ha^{-1} gliricidia + 100% P_2O_5 ha^{-1} fertilizers. The soil samples were collected after harvest of cotton crop and were analyzed as per standard methods. The season of 2015-16 represents 29^{th} year of the experimentation.

Results and Discussion

Soil organic carbon

Soil organic carbon content showed significant increase, on an average from 4.50 g kg^{-1} (T_1 control) to 6.90 g kg^{-1} (T_7) under the study (Table 1). The highest organic carbon content (6.90 g kg^{-1}) was recorded with the conjoint use of chemical fertilizers with 50 per cent N through FYM (T_7) and it was found to be on par with treatments of integration of chemical fertilizers with 50 per cent N and 100 per cent N through gliricidia green leaf mauring (T_6 & T_8) and it was found to be lowest in control (T_1).

The increase in organic carbon content under integrated use of chemical fertilizers and organic manure treatments might have been due to direct incorporation of organic matter, better root growth and more plant residues addition. The subsequent decomposition of these materials might have resulted into enhanced organic carbon content of soil. Addition of leguminous biomass into soil decomposed rapidly upon incorporation into soil under the experimental conditions characterized by high temperature and alternate aerobic and anaerobic condition hasten decomposition. The soil organic carbon showed profound increase under green manuring and FYM indicating potential benefits of addition of organic matter to these soils (Katkar *et al.,* 2006).

Available Nitrogen

The available nitrogen differs significantly in all treatments presented in (Table 2).The available N content after 29th crop cycle was found to increase substantially from 214.0 kg ha^{-1} (initial status) to 257.2 kg ha^{-1} (T_7). The significantly highest available soil N (257.2 kg ha^{-1}) status was recorded by integration with 50% N fertilizers+50%N ha^{-1}FYM + 100% P_2O_5 ha^{-1}fertilizers(T_7) and it was found to be on par with 50% N fertilizers + 50% N gliricidia +100% P_2O_5 ha^{-1} fertilizers (T_6) and100% N ha^{-1} gliricidia + 100% P_2O_5 ha^{-1} (T_8).The lower value (209.1 kg ha^{-1}) of available N was found in treatment T_1 *i.e.* control.

The increase in available N due to incorporation of FYM/gliricidia green leaf manuring may be due to higher amount of nitrogen content and the favourable soil conditions under green leaf manuring might have helped the mineralization of soil N leading to build-up of higher available N. Several earlier studies also showed an increase in available N with the application of FYM + inorganic fertilizers (Katkar *et al.*, 2002 and Surekha and Rao 2009).

Available phosphorus

It is evident from the data in (Table 2) that available P content of soil varied significantly and it ranged from 10.3 to 15.8 kg ha^{-1} indicating that the soil was low to medium in available phosphorus content.

During 29th cycle the highest available P (15.8 kg ha^{-1}) was found with the application of 50% N fertilizers + 50% N ha^{-1} FYM + 100% P_2O_5 ha^{-1} fertilizers(T_7) and it was found to be on par with 50% N fertilizers + 50% N gliricidia +100% P_2O_5 ha^{-1} fertilizers (T_6) and 100% N ha^{-1} gliricidia + 100% P_2O_5 ha^{-1} (T_8). The lower value of available P was found in treatment T_1 *i.e.* control (10.3 kg ha^{-1}). The increase in available phosphorus status was due to application of FYM, gliricidia green leaf manuring being direct source of phosphorus in the soil. During decomposition of green manure, various organic acids are produced which solubilized phosphatase and other phosphate bearing minerals and thereby lowers the phosphate fixation and increase it's availability. Similar findings are in conformity with findings of Sonune *et al.*, (2003) and Verma *et al.*, (2005).

Available Potassium

The significantly higher available K (362.1 kg ha^{-1}) status in 29^{th} cycle of study was recorded with the conjoint use of chemical fertilizers with 50 per cent N through FYM (T_7) and it was found to be on par with treatments of integration of chemical fertilizers with green mauring (T_6 & T_8).

The application of organic and chemical amendments in conjunction increased the K content of the soil. The buildup of soil available K by the application of potassium through FYM/ gliricidia green leaf manuring might be due to the fact that FYM and gliricidia leaves contains higher amount of K and it is deposited in the soil and due to applied K through FYM, gliricidia green leaf manure, the solubilizing action of certain organic acids produced during decomposition and it results in greater capacity to hold K in the available form. The lowest available potassium status (280.0 kg ha^{-1}) was observed in control treatment (No manures, No fertilizers).

Long-term application of chemical fertilizers with organic manures increased the K content of the soil. Similar results were recorded by Malewar and Hasnabade (1995) and Kumar *et al.*, (2008).

Soil microbial biomass carbon

The results pertaining to soil microbial biomass carbon status of soil was significantly influenced by different treatments. The soil microbial biomass carbon in soil varied from 113.27 mg kg^{-1} soil to 171.06 mg kg^{-1} soil after 29^{th}cycle.

The results obtained during 29^{th} cycle indicate that treatment with application of 50% N fertilizers + 50% N ha^{-1} FYM + 100% P_2O_5 ha^{-1} fertilizers (T_7)recorded highest soil microbial biomass carbon(171.06 mg kg^{-1} soil) and it was found to be on par with application of 50%N and 100%N through gliricidia in combination with chemical fertilizer application (T_6 & T_8) and lowest soil microbial biomass carbon was noted in control treatment (T_1) under study for cotton +greengram intercropping system.

Increase in soil microbial biomass carbon might be due to application of FYM/ gliricidia green leaf manuring which adds mineralizable and readily hydrolizable carbon which resulted in higher microbial activity and in turn higher soil microbial biomass carbon.

Moreover, the SMBC acts as the transformation agent of the organic matter in the soil. Similar results were also reported by Chander *et al.*, (1997), Tiwari *et al.*, (2001) and Mali *et al.*, (2015).

CO_2 evolution

The results pertaining to CO_2 evolution in soil was significantly influenced by different treatments. The treatment with application of 50% N fertilizers + 50% N ha^{-1} FYM + 100% P_2O_5 ha^{-1} fertilizers(T_7) recorded significantly highest CO_2 evolution (49.13 CO_2 evolved mg 100 g^{-1}soil) followed by treatment with application of 50% N fertilizers + 50% N ha^{-1} gliricidia + 100% P_2O_5 ha^{-1} fertilizers(T_6). The lowest CO_2 evolution was observed in control treatment (22.0 CO_2 evolved mg 100 g^{-1} soil). The increased metabolically active microbial biomass could have resulted in increased soil respiration rate by the application of gliricidia green leaf manuring.

Table 1. Long-term effect of INM on Soil organic carbon under cotton + greengram intercropping system

Treatments		Organic carbon (g kg^{-1})
T_1	Control	4.50
T_2	100% N + 100% P_2O_5 ha^{-1} fertilizers	5.95
T_3	50% N + 50% P_2O_5 ha^{-1} fertilizers	5.80
T_4	50% N ha^{-1} gliricidia	6.35
T_5	50% N ha^{-1} FYM	6.30
T_6	50% N fertilizers + 50% N gliricidia +100% P_2O_5 ha^{-1} fertilizers	6.78
T_7	50% N fertilizers + 50% N ha^{-1} FYM + 100% P_2O_5 ha^{-1} fertilizers	6.90
T_8	100% N ha^{-1} gliricidia + 100% P_2O_5 ha^{-1} fertilizers	6.48
	SE (m) ±	0.14
	CD at 5%	0.41

Table.2 Long- term effect of INM on available nutrients status in soil under cotton + greengram intercropping system

Treatments		Available Nutrients (kg ha^{-1})		
		N	P	K
T_1	Control	209.1	10.3	280.0
T_2	100% N + 100% P_2O_5 ha^{-1} fertilizers	240.4	13.3	317.3
T_3	50% N + 50% P_2O_5 ha^{-1} fertilizers	236.2	12.5	313.6
T_4	50% N ha^{-1} gliricidia	234.2	11.3	324.8
T_5	50% N ha^{-1} FYM	238.3	12.2	326.7
T_6	50% N fertilizers + 50% N gliricidia +100% P_2O_5 ha^{-1} fertilizers	250.9	15.1	358.4
T_7	50% N fertilizers +50% N ha^{-1} FYM +100% P_2O_5 ha^{-1} fertilizers	257.2	15.8	362.1
T_8	100% N ha^{-1} gliricidia + 100% P_2O_5 ha^{-1} fertilizers	242.5	14.9	339.7
	SE (m) ±	6.4	0.6	11.7
	CD at 5%	19.0	1.9	34.6

Table.3 Long term effect of INM on Soil microbial biomass carbon and CO_2evolution under cotton + greengram intercropping system

Treatments		Soil microbial biomass carbon (mg kg^{-1} soil)	CO_2 evolution (mg 100 g^{-1} soil)
T_1	Control	113.27	22.00
T_2	100% N + 100% P_2O_5 ha^{-1} fertilizers	145.24	33.00
T_3	50% N + 50% P_2O_5 ha^{-1} fertilizers	137.59	26.03
T_4	50% N ha^{-1} gliricidia	136.13	30.54
T_5	50% N ha^{-1} FYM	135.42	33.73
T_6	50% N fertilizers + 50% N gliricidia +100% P_2O_5 ha^{-1} fertilizers	163.21	43.63
T_7	5 0% N fertilizers + 50% N ha^{-1} FYM + 100% P_2O_5 ha^{-1} fertilizers	171.06	49.13
T_8	100% N ha^{-1} gliricidia + 100% P_2O_5 ha^{-1} fertilizers	163.88	42.53
	SE (m) ±	8.32	1.86
	CD at 5%	24.73	5.54

Table.4 Long-term effect of INM on Dehydrogenase activity and Alkaline phosphatase under cotton + greengram intercropping system

	Treatments	Dehydrogenase activity (µg TPF g^{-1}24 hr^{-1})	Alkaline phosphatase (µg p-nitrophenol g^{-1}24hr^{-1})
T_1	Control	25.38	197.65
T_2	100% N + 100% P_2O_5 ha^{-1} fertilizers	32.06	220.60
T_3	50% N + 50% P_2O_5 ha^{-1} fertilizers	26.81	214.32
T_4	50% N ha^{-1} gliricidia	29.60	236.60
T_5	50% N ha^{-1} FYM	30.74	239.07
T_6	50% N fertilizers + 50% N gliricidia +100% P_2O_5 ha^{-1} fertilizers	33.42	256.75
T_7	50% N fertilizers + 50% N ha^{-1} FYM + 100% P_2O_5 ha^{-1} fertilizers	35.18	261.13
T_8	100% N ha^{-1} gliricidia + 100% P_2O_5 ha^{-1} fertilizers	32.11	255.74
	SE (m) ±	0.97	4.42
	CD at 5%	2.87	13.14

Table.5 Long- term effect of INM on Yield of crops under cotton + greengram intercropping system

	Treatment	Yield (kg ha^{-1})			
		Cotton		Greengram	
		Seed cotton	Stalk	Grain	Straw
T_1	Control	648.0	1608.7	245.4	179.0
T_2	100% N + 100% P_2O_5 ha^{-1} fertilizers	968.9	2132.4	344.8	247.2
T_3	50% N + 50% P_2O_5 ha^{-1} fertilizers	895.2	1833.1	325.6	209.1
T_4	50% N ha^{-1} gliricidia	810.7	1683.5	309.8	194.0
T_5	50% N ha^{-1} FYM	827.5	1646.1	321.0	198.7
T_6	50% N fertilizers + 50% N gliricidia +100% P_2O_5 ha^{-1} fertilizers	1017.6	2169.8	413.4	260.3
T_7	50% N fertilizers +50% N ha^{-1} FYM +100% P_2O_5 ha^{-1} fertilizers	1179.9	207.3	448.4	264.0
T_8	100% N ha^{-1} gliricidia + 100% P_2O_5 ha^{-1} fertilizers	987.7	1795.7	357.5	231.2
	SE (m) ±	63.1	112.6	23.4	13.3
	CD at 5%	187.4	334.5	69.6	39.5
	CV	11.9	10.3	11.7	10.3

The treatments having fertilizers alone recorded comparatively lower rate of microbial respiration. Similar results were also reported by Chander *et al.,* (1997), Tejada *et al.,* (2008) and Mali *et al., (*2015).

Dehydrogenase activity

The data pertaining to the dehydrogenase activity presented in Table 4 revealed that the results after 29th cycle showed that treatment with application of 50% N fertilizers + 50% N ha^{-1} FYM + 100% P_2O_5 ha^{-1} fertilizers (T_7) recorded highest dehydrogenase activity (35.18 µgTPF g^{-1} 24 h^{-1}) and it was found to be on par with application with of 50% N fertilizers + 50% N ha^{-1} gliricidia + 100% P_2O_5 ha^{-1} fertilizers(T_6) and lowest dehydrogenase activity in soil was recorded in control treatment (T_1). The stronger effects of FYM/ gliricidia green leaf manuring on dehydrogenase activity might be due to the more easily decomposable components of crop residues on the metabolism of soil microorganisms and due to the increase in microbial growth with addition of carbon substrate. The FYM application was superior in improving DHA as it stratified microbial population. Similar results were also reported by Surucu *et al.,* (2014) and Mali *et al., (*2015).

Alkaline phosphatase

The result pertaining to alkaline phosphatase in soil (Table 4) was significantly influenced by different treatments. The alkaline phosphatase activity showed statistically significant improvement under the treatment with application of 50% N fertilizers + 50% N ha^{-1} FYM + 100% P_2O_5 ha^{-1} fertilizers(T_7) which recorded significantly highest alkaline phosphatase (261.13 µg p- nitriphenol g^{-1} 24 h^{-1}) followed by treatment with application of 50% N fertilizers + 50% N ha^{-1} gliricidia + 100% P_2O_5 ha^{-1} fertilizers(T_6),treatment with 100% N ha^{-1} gliricidia + 100% P_2O_5 ha^{-1} fertilizers(T_8), and these treatments were found to be at par with each other over the chemical fertilizers only. The lowest alkaline phosphatase was observed in control treatment. Significantly higher activities of alkaline phosphatase in soil treated with FYM may be due to enhanced microbial activity and diversity of phosphate solubilizing bacteria during years of experimental study. Similar results were also reported by Chander *et al.,* (1997), Abdallahi and N'Dayegamiye (2000) and Tejada *et al.,* (2008).

Crop yield

The yield of cotton and greengram during 2015-16 showed considerable increase due to integrated nutrient management in comparison to only chemical fertilizers (Table 5). The substitution of 50% N by FYM/gliricidia along with chemical fertilizers was found superior among all the treatments. However, inclusion of organics was found beneficial in increasing the yield of both the crops.

The seed cotton and stalk yield of cotton under the treatments of integrated nutrient management involving 50 per cent N through organics i.e. FYM/gliricidia followed by 50 per cent recommended N fertilizer dose to cotton showed superior yields as compared to other treatments because of residual effect of organics.The increase in yield in the treatments of organics might be due to reclamation besides addition of nutrients and overall improvement. After the 29th year of study, the significantly highest seed cotton (1179.9kg ha^{-1}) and stalk (207.3 kg ha^{-1}) yield of cotton was obtained under 50% N fertilizers + 50% N ha^{-1} FYM + 100% P_2O_5 ha^{-1} fertilizers and which was on par with

50% N fertilizers + 50% N ha^{-1}gliricidia + 100% P_2O_5 ha^{-1} fertilizers(T_6) and 100% N ha^{-1} gliricidia + 100% P_2O_5 ha^{-1} fertilizers(T_8) and lowest yield was obtained in control (T_1), no manure no fertilizer application. The residual effect of previous year treatments and incorporation of residues of greengram after harvest, augment the yield in treatments of organics by adding more nutrients which help more subsequently in cotton yield.

The greengram grain yield was significantly highest under 50% N fertilizers + 50% N ha^{-1} FYM + 100% P_2O_5 ha^{-1} fertilizers (T_7) which was on par with 50% N and 100% N through gliricidia in combination with chemical fertilizer application (T_6 & T_8). The straw yield of greengram was significantly influenced under all the treatments. The treatment 50% N fertilizers + 50% N ha^{-1} FYM + 100% P_2O_5 ha^{-1} fertilizers (T_7) recorded significantly highest straw yield over control and on par with T_6&$T_{8.}$ Although the grain and straw yield of greengram under 50% N through FYM and chemical fertilizers were on par with 50% N through gliricidia and chemical fertilizers (T_6) and 100% N through gliricidia and chemical fertilizers (T_8); the numerically higher yields under integrated nutrient management indicate the continuous mining of nutrients under intensive cropping system. The intensification and exhaustion of soil nutrients is so severe that in spite of use of organics the readily available chemical fertilizers have recorded the on par yields.

The significantly lower yields under control and RDF as compared with gliricidia green leaf mauring and FYM + chemical fertilizers indicated the soil fertility depletion.

Higher yield of crops with conjunctive application of organic manure along with inorganic fertilizers may be due to INM treatment which might have matched the crop demand at different physiological stages and reduced the losses through denitrification and volatilization as reflected in recording of higher dry matter yield. Organic manure undergo decomposition during which series of nutrient transformation takes place which helps in their higher availability to the crops and higher uptake of nutrients by the crops will result in higher yield. Thus, it can be concluded that there is scope for reduction in fertilizer dose at certain level when combined with organic sources like FYM or gliricidia green leaf manuring. The results are in conformity with the findings Kamble *et al.*, (2009), Shirale and khating (2009), Doli *et al.*, (2015) and Simon *et al.*, (2016). Hence, it can be concluded that the long-term conjunctive use of 50% N through FYM/gliricidia + 50% N through inorganics + 100% P_2O_5 ha^{-1} through fertilizers to cotton + greengram (1:1) intercropping system resulted in improvement in soil health and higher productivity of cotton + greengram intercropping system in Vertisol under rainfed condition.

References

Abdallahi, M. M. and N'Dayegamiye, A 2000. Effects of two incorporations of green manures on soil physical and biological properties and on wheat (*Triticum aestivum* L.) yields and N uptake. *Can.J.Soil Sci.* 80(1):81-89.

Anonymous, 2016. Research review committee (Pulses), held at Dr.PDKV, Akola (M.S).

Anonymous, 2016a. Annual Progress Report, Central Institute for Cotton Research, Nagpur.

Chander, K., Goyal, S., Mundra, M.C.and Kapoor, K.K.1997.Organic matter, microbial biomass and enzyme activity of soils under different crop rotations in the tropics. *Biol Fertil Soils*., 24.306–310.

Doli, A.N., Pathrikar, D.T. and Gourkhede, P.H. 2015. Effect of fertility levels and green manuring on Bt cotton. *Int. J. Trop. Agric.*, 33(2):1805-1808.

Kamble, Anand S., Palled, Y.B. and Channagoudar, R.F. 2009. Response of hybrid cotton (DHH-11) to *in situ* green manuring and nitrogen levels in northern transitional tract of *Karnataka. Int.J.Agri.Sci*. 5(2):543-546.

Katkar, R.N., Turkhede, A.B. and Wankhede, S.T. 2006. Residual effect of manures and inorganic fertilizer on soil properties and yield of cotton. *PKV Res. J.* 30 (1):36-41.

Katkar, R.N., Turkhede, A.B., Solanke, V.M., Wankhede, S.T. and Patil, M.R. 2002. Effect of organic manures and fertilizers on soil properties and yield of cotton, *J. Cotton Res. Dev*. 16(1):89-92.

Kumar Balwindar, Gupta, R.K. and Bhandari, A.L. 2008. Soil fertility changes after long-term application of organic manures and crop residues under rice-wheat system. *J. Indian Soc. Soil Sci.* 56(1):80-85.

Malewar, G.U. and Hasnabade, A.R. 1995. Effects of long-term application of fertilizers and organic sources on some properties of Vertisol. *J. Mah. agric. Univ.* 20 (2):285-286.

Mali, D.V., Kharche, V.K., Jadhao, S.D., Jadhao, S.M., Saoji, B.V., Gite, P.A. and Age, A.B. 2015. Soil biological health under long-term fertilization in sorghum- wheat sequence on swell-shrink soils of central India. *J. Indian Soc. Sci.* 63(4):423-428.

Shirale, S. T. and Khating, L.E. 2009. Effect of organic and inorganic nutrients on yield, nutrient uptake and balance in different cropping systems in Vertisol. *Ann. Plant Physiol*. 23(1):83-85.

Simon A. Mngomba, Akinnifesi, Festus K. Amber Kerr, Salipira, K. and Muchugi, Alice. 2016. Growth and yield responses of cotton (*Gossypium hirsutum*) to inorganic and organic fertilizers in southern Malawi. Springer Science + Business Media Dordrecht, Published Online March 24, 2016.

Sonune, B.A., Tayade, K.B., Gabhane, V.V. and Puranik, R.B. 2003. Long- term effect of manuring and fertilization on fertility and crop productivity of Vertisols under sorghum-wheat sequence. *Crop Res.* 25(3):460-467.

Surekha K. and Rao, K.V. 2009. Direct and residual effects of organic sources on rice productivity and soil quality of Vertisols. *J. Indian Soc. Soil Sci.* 57(1): 53-57.

Surucu, A., Ozyazici, M.A., Bayrakli, B. and Kizilkaya, R. 2014. Effects of green manuring on soil enzyme activity. Fresenius Environmental Bulletin, 23(9): 2126-2132.

Tejada. M, Gonzalez, J.L., Garcia-Martinez, A.M. and Parrado, J. 2008. Application of a green manure and green manure composted with beet vinasse on soil restoration effects on soil properties. *Bio resource Technology*, 99(11):4949-4957.

Tiwari, V.N., Benri, I.K., Tiwari, K.N. and Upadhyay, R.M. 2001. Integrated nitrogen management throughout natural green manuring under wheat-mungbean cropping sequence. *J. Indian Soc. Soil Sci.* 49:271-275.

Verma Arvind, V. Nepalia, and P.C. Kanthaliya, 2005. Effect of continuous cropping and fertilization on crop yields and nutrient status of a Typic Haplustept. *J. Indian Soc. Soil Sci.* 53(3): 365-368.