The Pharma Innovation Journal 2021; 10(11): 1113-1118

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(11): 1113-1118

www.thepharmajournal.com
Received: 14-08-2021
Accepted: 24-10-2021

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Effect of crop residue recycling and nutrient management on soil properties under cotton based intercropping systems in Vertisol

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Abstract
The integrated use of organic along with chemical fertilizers and also only use of organic is a promising approach in preserving soil biological activities, which will ultimately show positive impacts on different soil physicochemical properties. With view of enhancing soil health, the present investigation was conducted at Research Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, during year 2017-18 and 2018-19. The experiment was laid out in split plot design with three replications. The main plot treatments comprised of nutrient management *viz*., INM (75% RDF + compensation through NPS compost) and Organic (100% NPK dose through NPS compost). Sub plot treatments consisted of cotton based intercropping systems *viz*., Cotton + dhaincha (1:1), Cotton + sunhemp (1:1), Cotton + greengram (1:1), Cotton + blackgram (1:1) and Sole cotton.
Application of 75% recommended dose of fertilizers with substitution of 25% dose through enriched compost (NPS) was found to be improved the soil properties. The 100% recommended dose of fertilizers through enriched NPS compost also showed improvement. Thus the results revealed that, the chemical fertilizers of cotton can be reduced by 25% when compensated with enriched compost.

Keywords: INM, Organic, intercropping and Nitrophosposulpho compost

Introduction
The word cotton is derived from Arabic word "Qutun". It is an important commercial crop in India and plays a very vital role in our economy. Cotton (*Gossypium spp*.) is the world's leading natural textile fibre crop and a significant contributor of oilseed. India is leading cotton grower in the world, China leading in terms of cotton production. Cotton is cultivated in 77 countries in world, China, India, United States, Brazil and Pakistan, these five countries produces 78% of the total world production from 72% of the world gross cotton area. On the productivity front Australia leading with yield of 1814 kg ha^{-1}, followed by China 1726 kg ha^{-1}, Brazil 1636 kg ha^{-1} and India way behind at 507 kg ha^{-1} (Anonymous, 2018) [1].
In India cotton is grown on 122.38 lakh ha with production of 361 lakh bales and productivity 501 kg ha^{-1}. In Maharashtra, cotton is grown on 41.19 lakh ha with production 81 lakh bales and productivity 334 kg lint ha^{-1} (Anonymous, 2018) [1]. In Vidarbha region, area under cultivation of cotton is 16.18 lakh ha with production of about 30.50 lakh bales and 320 kg lint ha^{-1}. Crop residue should not be considered as waste but should be treated as tremendous natural resources available with the farmers at their own field because it acts as a storehouse of soil fertility improvements besides its role in improving the soil physicochemical and biological properties. Its retention from agricultural point of view is pivotal in sustaining soil fertility in light of scarcity of alternative sources of organic amendments, which in turn, save the cost on purchase of fertilizers and other chemical amendments. Besides, it has dynamic role to play in securing the environmental as well as soil health by reducing soil erosion, soil moisture retention and nutrient recycling. It improves the soil and environmental quality because it acts as a source of organic matter and carbon storage. *In-situ* incorporation of crop residues is one of the options to incorporate residues into fields to improve soil organic matter levels and return to the soils with the nutrients contained in straw. Long term incorporation of crop residues increase the availability of macro and micro nutrients and also build up the level of soil organic matter. Crop residues provide energy for growth and activities of microbes and substrate for microbial biomass, and provide conditions for source-sink of nutrients. Intercropping, which breaks down the monoculture structure, can provide pest control benefits, weed control advantages, reduced wind erosion, and improved water infiltration (Turkhede *et*

al. 2017) [3]. Nitrogen fixation by legumes helps to reduce the use of nitrogen fertilizers for next crop (Ladha *et al*. 2004) [22]. Green manures application to soil helps to improve organic matter, fertility status (Doran and Smith, 1987) [11] and raise nutrient holding ability of soil (Drinkwater *et al.* 1998) [12]. After green revolution natural fertility of the soil has been degraded due to intensive cultivation, use of high doses of chemical fertilizers and insufficient use of organics i.e. farm yard manure, compost, crop residue, green manure, biofertilizers etc. (Bahadur *et al.* 2015) [4]. Most of the soils of the cotton growing areas are low in organic carbon, nitrogen and available phosphorus. Considering soil as a only and finite source of crop production, increase in production and productivity can be achieved only through enhanced soil fertility by replenishment of removed nutrients by use of compost, crop residue and *in-situ* residue recycling through intercropping.

The hypothesis of this study is use of integrated nutrient management and organics with cotton based intercropping systems is a way to build-up soil organic matter and thereby augmenting the soil fertility and soil quality as well as conserve soil moisture, reduce soil erosion and nutrient losses there by sustaining the crop yields as well as soil health.

Materials and Methods

A field experiment was carried out during year 2017-18 and 2018-19 at Research Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra). It was two years study being conducted on the same site with same randomization. The topography of the field was fairly uniform and leveled. The soil of the experimental area was Vertisol (black and clayey in texture) belonging to fine, smectitic, hyperthermic, Typic Haplusterts and slightly alkaline in reaction (pH 7.76), medium calcareous and moderate in soil organic carbon (4.96 g kg^{-1}). Soil fertility status indicated low in available nitrogen (195.17 kg ha^{-1}), medium in available phosphorous (12.90 kg ha^{-1}), high in available potassium (368.42 kg ha^{-1}) and deficient in available sulphur (8.27 mg kg^{-1}).

The experiment comprised of two main plots i.e. INM (75% RDF + Compensation through NPS compost) and Organic (100% NPK dose through NPS compost) and five subplot treatments with cotton based intercropping systems *viz*.T1: Control (Sole cotton), T2: Cotton + dhaincha (1:1), T3: Cotton + sunhump (1:1), T4: Cotton + greengram (1:1) and T5: Cotton + blackgram (1:1) which were executed in split plot design with three replications. Sowing of intercrops *viz.* dhaincha, sunhemp, green gram and black gram were done in between two rows of cotton crops. *In situ* incorporation of dhaincha and sunhemp was done forty days after sowing and covered it with the soil. The incorporation of greengram and blackgram residues was done after pod picking. The weight of biomass of intercrops on green basis and oven dry basis were recorded. The cotton variety Ajit-199 BG-II was sown with 120 x 30 cm spacing. Recommended dose of fertilizers in INM plots were 90 kg N ha^{-1}, 45 kg ha^{-1} P_2O_5 and 45 kg ha^{-1} K_2O applied from Urea, SSP and MOP. For organic plots RDF was compensated through Nitrophosposulpho compost which was applied before sowing of crops on the basis of actual NPK content present in compost and incorporated well in the soil.

The treatment wise initial surface soil samples (0-20 cm) before sowing from experimental site and after harvest of crop was collected. The air dried samples were carefully and gently ground with the wooden pestle to break soil lumps (clods) and passed through different sieves for analysis of soil parameters with standard analytical methods.

Results and Discussion

Physical properties of soil

Soil bulk density

The effect of crop residue and nutrient management on soil bulk density was found to be non significant (Table 1). Numerically, the lower bulk density was recorded with application of organic (100% NPK dose through NPS compost) (1.39 Mg m^{-3}) than the integrated nutrient management. The numerical reduction in bulk density also recorded in INM (75% RDF + compen. through NPS compost) (1.41 Mg m^{-3}) over initial. As these indicated an enrichment of fine fractions i.e. silt and clay a part from the retention of dissolved organic matter leading to change in physical properties of soil. The lower values of bulk density in these treatments might be due to higher organic matter in soil, better aggregation and increased root growth in INM and organic treated plots. Similar results were also reported by Gayatri *et al.* (2010), Sharma *et al.* (2011), Sonune *et al.* (2012) and Mitran *et al.* (2018) [14, 40, 43, 29].

The effect of different intercropping systems on bulk density was also found non significant (Table 1). It reduced from 1.42 to 1.38 Mg m^{-3} under various intercropping systems. But higher reduction in bulk density up to 1.38 Mg m^{-3} was recorded in cotton + dhaincha and cotton + sunhemp. Similar findings were reported by Katkar (2008) [20] and Nazmus Salahin *et al*. (2013) [32]. The reduction in bulk density may be attributed to better aggregation, increased porosity and improvement in soil structure caused due to increase in soil organic matter under the treatments of integrated use of chemical fertilizers and organic manures.

Hydraulic conductivity

The data in respect of hydraulic conductivity as influenced by integrated nutrient management (75% RDF + compen. through NPS compost) and organic (100% NPK dose through NPS compost) reported in Table 1. Significantly highest improvement in hydraulic conductivity was recorded in 100% NPK dose through NPS compost (0.73 cm hr^{-1}) as compared with INM (75% RDF + compen. through NPS compost) 0.69 cm hr^{-1}. Better aggregation and increased porosity due to addition of organic manure which directly influenced hydraulic conductivity and ultimately soil water dynamics. Hydraulic conductivity was enhanced due to continuous addition of organics solely or in combination with inorganic fertilizers as compared to inorganics alone (Saha *et al*. 2010). Jayshree *et al.* (2018) [37, 18] also reported an improvement of hydraulic conductivity with the application of organics. The data pertaining to the hydraulic conductivity of soil as influenced by different intercropping systems found statistically non significant (Table 1) and numerically it ranged from 0.69 cm hr^{-1} to 0.75 cm hr^{-1} indicating that the highest (0.75 cm hr^{-1}) hydraulic conductivity was recorded in cotton + dhaincha (1:1) and lowest in sole cotton (0.69 cm hr^{-1}). In all the intercropping systems the slight improvement in hydraulic conductivity was recorded. The improvement in soil physical conditions due to organic matter buildup by the incorporation of green manure or crop residue is associated with a decrease in bulk density, and increases in total pore space, water stable aggregates, and hydraulic conductivity of the soil (Tejada *et al*. 2008) [46]. These results are in accordance with the findings of Manchala *et al.* (2017) [25].

Table 1: Soil physical properties of soil as influenced by different treatments

Tr. No	Treatments	BD (Mg m^{-3})	HC (cm hr^{-1})
		2018	2018
A.	Main Plot (Nutrient Management)		
M1	INM (75% RDF + Compen. through NPS compost)	1.41	0.69
M2	Organic (100% NPK dose through NPS compost)	1.39	0.73
	SE (m)±	0.006	0.01
	CD at 5%	NS	0.03
B.	Sub plot (Cotton based intercropping systems)		
S1	Control (Sole cotton)	1.42	0.69
S2	Cotton + Dhaincha (1:1)	1.38	0.75
S3	Cotton + Sunhemp (1:1)	1.38	0.72
S4	Cotton + Greengram (1:1)	1.40	0.71
S5	Cotton + Blackgram (1:1)	1.41	0.70
	SE (m)±	0.01	0.01
	CD at 5%	NS	NS
	Interaction (M X S)	NS	NS
	Initial	1.43	0.65

Chemical properties of soil

Organic carbon

Significantly maximum organic carbon (5.44 g kg^{-1}) recorded with application of 100% NPK dose through NPS compost (Table 2). Slightly higher values of organic carbon 5.35 g kg^{-1} were also observed with 75% RDF + compen. through NPS compost as compared to initial organic carbon (4.96 g kg^{-1}). Crop residue and nutrient management helps in leaving crop residues to accumulate on the soil surface and increase carbon sequestration by reducing oxidation of SOC in soil. 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. These results are in agreement with the findings of Ramesh *et al.* (2009), Panwar *et al.* (2010), Singh *et al.* (2014) and Mali *et al.* (2015) [35, 33, 41, 23].

The soil organic carbon content significantly influenced under different intercropping systems varied from 5.20 to 5.64 g kg^{-1} (Table 2). Further, it was observed that highest organic carbon was recorded with cotton + dhaincha (1:1) intercropping system (5.64 g kg^{-1}) and it was found statistically at par with cotton + sunhump (1:1) intercropping (5.50 g kg^{-1}). In respect of grain legume crops highest organic carbon (5.34 g kg^{-1}) recorded with cotton + greengram (1:1) intercropping and it was found at par with cotton + blackgram (1:1) intercropping system (5.28 g kg^{-1}). Increase in organic carbon content in the soil depends on the quantity of organic matter added to the soil. Dhaincha accumulated maximum green biomass which was incorporated into the soil. Increased age of green manures helps in accumulation of higher biomass which might be the reason for increase in organic carbon content due to incorporation of aged green manures. The findings are in conformity with the findings of Khokle (2016), Parmar *et al*. (2016) and Meshram *et al*. 2018 [21, 34, 28].

Available nitrogen (N)

The data pertaining to the available nitrogen as influenced by INM (75% RDF + compen. through NPS compost and Organic (100% NPK dose through NPS compost) presented in Table 2. The significant difference recorded with INM and organic after harvest of cotton. Available nitrogen was recorded significantly higher in INM (75% RDF + compen. through NPS compost (218.18 kg ha^{-1}) as compared to (100% NPK dose through NPS compost) (212.79 kg ha^{-1}).This increase in available N might be due to the direct addition of the N through compost and green manuring to the available pool of soil. The results are in conformity to those obtained by Boggs *et al.,* (2000), Melero *et al.* (2008), Surekha and Rao (2009), Sonune *et al*. (2012), Sankar *et al*. (2014), Singh *et al*. (2014) and Gudadhe *et al*. (2015) [8, 27, 45, 43, 38, 41, 15].

The data in respect of available nitrogen as influenced by different intercropping systems was found to be significant. Available nitrogen was recorded significantly higher in cotton + dhaincha (1:1) (222.83 kg ha^{-1}) and it was found on par with cotton + sunhump (1:1) (218.93 kg ha^{-1}). In respect of grain legume intercropping maximum available nitrogen recorded in cotton + greengram (1:1) (213.80 kg ha^{-1}) and it was at par with cotton + blackgram (1:1) (212.25 kg ha^{-1}) intercropping systems (Table 2). It was observed that considerable improvement in available N status was observed in all the treatments which involve combined application of crop residues and intercropping over initial status. This might be attributed to improved microbial activity increased due to availability of organic matter along with readily available N from inorganic fertilizers. The increase in available nitrogen due to organic material application can be attributed to greater multiplication of soil microbes, which could convert organic nitrogen in to inorganic form (Reddy *et al.* 2002) [36]. Intercropping of cotton with greengram and blackgram having 1:1 row proportion also found to be increased the available N content at harvest of cotton or at the end of cropping systems also reported by Chand *et al*. (2018) [9]. Legumes are advantageous for soils due to their symbiotic relationship with nitrogen-fixing bacteria; thus, legume intercrops can self-regulate soil nitrogen levels to optimize soil nutrient (Araujo *et al.,* 2019) [2]. The findings are in conformity with the results reported by Gabhane *et al*. (2013) [13], Wagh *et al. (*2016) [50] and Ashwini *et al*. (2017) [3].

Available phosphorous (P)

It is evident from the data (Table 2) that available P content of soil varied significantly and it ranged from 16.07 to 17.80 kg ha^{-1} indicating that the soil was low in available phosphorus. Maximum availability of available phosphorus recorded with INM (75% RDF + compen. through NPS compost) i.e. 17.80 kg ha^{-1} as compared to organic (100% NPK dose through NPS compost) i.e 16.07 kg ha^{-1}. Available phosphorus was found maintained under balanced fertilizer use where organic manures and fertilizer was applied in combination. Application of organics in combination with fertilizers increased the available phosphorus status of soil; this could be attributed to the effect of applied fertilizer and mineralization of organic sources or through solubilization of the nutrients from the native sources during the process of decomposition. Similar findings also recorded by Reddy *et al.* (2002) [36], More and Hangare (2003) [30], Katkar *et al*. (2002) [19] and Tiwari *et al.* (2002) [47].

In respect of intercropping systems, significantly higher available phosphorous was recorded in the treatment of cotton + dhaincha (1:1) intercropping system (18.46 kg ha^{-1}) which was observed at par with cotton + sunhemp (1:1) intercropping system (17.68 kg ha^{-1}). Cumulative increase in available phosphorous was also recorded in remaining intercropping system. The lowest availability of phosphorus was found in sole cotton. The black soils which have high phosphorus fixation problems are specifically becoming deficient under the intensive cropping systems. Under these circumstances the crops having potential of adding considerable biomass through intercropping to the soil have special significance in black soils. The increase in available phosphorus due to legume crop cultivation can be ascribed to the development of phosphorus solubilizing organisms in the root zone of legumes (Sharma *et al.* 1986) [39].

The results are in conformity with the findings reported by Gabhane *et al. (*2013) [13], Megha *et al.* (2017) [26] and Naik *et al*. (2018) [31].

Available potassium (K)

The significantly highest availability of potassium was recorded with INM (75% RDF + compen. through NPS compost) (401 kg ha^{-1}), only organic (100% NPK dose through NPS compost) also recorded higher availability of potassium (392 kg ha^{-1}) as compared with initial (368 kg ha^{-1}) (Table 2). The buildup of soil available K by the application of INM and organics might be due to the compost contains higher amount of K and it is deposited in the soil and due to applied K through compost solubilizing action of certain organic acids produced during decomposition and it results in greater capacity to hold K in the available form. Venkateswarlu *et al*. (2007) [49] observed that the annual incorporation of legume improved the soil properties and fertility status of the soil. Similar results were also recorded by Jayakumar and Surendran (2017) [17].

Available potassium content as affected by different intercropping cropping systems reveled that available potassium significantly varied from 387 to 410 kg ha^{-1} indicating that the soil was very high in available potassium content. Table 2 indicated that significantly higher available potassium (410 kg ha^{-1}) was recorded in cotton + dhaincha (1:1) intercropping system was statically on par with cotton + sunhump (1:1) (403 kg ha^{-1}) intercropping system. In grain legume intercropping system available potassium content was recorded more (393 kg ha^{-1}) in cotton + greengram (1:1) intercropping system and which was found at par with cotton + blackgram (1:1) (390 kg ha^{-1}) intercropping system. However, the lowest available potassium content recorded with sole cotton (387 kg ha^{-1}). The crop residues having considerable concentration of potassium have enough potential for enhancing the potassium availability in black soils which can partially reduce the chemical fertilizers to some extent**.** Singh *et al.* (2001) [42] reported that significant increase in available K content has been due to green manure which helps to maintain the supply of K by releasing the K from reserve source. The results are in the line with the findings of Bharambe *et al*. (1999) [7], Chandramohan, (2002) [10] and Katkar *et al.* (2002) [19].

Available sulphur

The available sulphur (S) content in soil (Table 2) was found significantly higher with the application of INM (75% RDF + compen. through NPS compost (9.02 mg kg^{-1}). Application of organic (100% NPK dose through NPS compost) also influence available sulphur content in soil in some extent (8.70 mg kg^{-1}) as the NPS compost having sulphur content above 1%. The increase in available sulphur under main plots might be due to solubilization of the nutrients from native sources during the process of decomposition, which in turn the conservation of organics to more available sulphate forms. The results are in close agreements with the findings of Bharadwaj and Owmanvar, (1994), Sonune *et al.* (2005) and Mali *et al.* (2014) [5, 44, 24].

The data as regards the effect of different intercropping systems, available sulphur indicated that the available sulphur in different intercropping systems varied significantly from 8.71 to 9.02 mg kg^{-1}. Further, it was noted that the higher available sulphur was noticed in cotton + dhaincha (1:1) (9.02 mg kg $^{-1}$) and was found on par with cotton + sunhump (1:1) intercropping system (8.92 mg kg $^{-1}$). The available sulphur content also increased in cotton + greengram (1:1) and cotton + blackgram (1:1). However, available sulphur content in soil was found lowest in sole cotton.

Improvement in soil available sulphur status under crop residues and green manuring due to its ameliorative effect on improvement of physical and chemical properties which helps to improve the availability of native sulphur in the soil. The results corroborates with the findings reported by Bharambe *et al*. (2002) [6] and Halemani *et al.* (2004) [16].

Table 2: Soil chemical properties as influenced by different treatments

Tr. No	Treatments	OC (g kg^{-1})	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Available S (mg kg^{-1})
A.	**Main Plot (Nutrient Management)**					
M1	INM (75% RDF + Compen. through NPS compost)	5.35	218.10	17.80	401	9.02
M2	Organic (100% NPK dose through NPS compost)	5.44	212.79	16.07	392	8.70
	SE (m)±	0.010	0.73	0.07	1.54	0.024
	CD at 5%	0.063	4.44	0.40	9.4	0.148
B.	**Sub plot (Cotton based intercropping systems)**					
S1	Control (Sole cotton)	5.20	209.43	15.51	387	8.71
S2	Cotton + Dhaincha (1:1)	5.64	222.83	18.46	410	9.02
S3	Cotton + Sunhemp (1:1)	5.50	218.93	17.68	403	8.92
S4	Cotton + Green gram (1:1)	5.34	213.80	16.62	393	8.86
S5	Cotton + Black gram (1:1)	5.28	212.25	16.40	390	8.80
	SE (m)±	0.05	1.33	0.36	2.94	0.047
	CD at 5%	0.14	3.99	1.07	8.81	0.139

	Interaction (M X S)	NS	NS	NS	NS	NS
	Initial	4.96	195.17	12.90	368.42	8.27

Conclusion
Inclusion of legumes to the cotton based intercropping system coupled with residue recycling and addition of green biomass was found effective in enhancing the soil health by augmenting the soil physical and chemical properties as against sole cropping system.

Acknowledgment
It is my pleasure to give my heartfelt gratitude to Head, Department of Soil Science and Agricultural Chemistry, Post Graduate Institute, Dr. PDKV, Akola (M.S) and Dr. V.K. Kharche, Professor and chairman of my advisory committee and all advisory committee members, Dept. of Soil Science and Agricultural Chemistry, Dr. PDKV, Akola (M.S)

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