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Long term effect of integrated nutrient management on soil fertility and nutrient balance in cotton + greengram (1:1) intercropping system on Vertisols

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Abstract
A field study was conducted during *kharif* 2019-20 at Research field of AICRP for Dryland Agriculture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra to assess the long term effect of integrated nutrient management on soil fertility and yield of cotton+greengram intercropping system in Vertisols. The soil of the experimental site was Vertisol which was moderately alkaline in reaction, low in available nitrogen, medium in available phosphorus and high in available potassium. The eight treatments replicated three times in randomized block design comprised of control, 50% and 100% RDF, 50% N ha^{-1} through gliricidia/FYM, 50% N fertilizers + 50% N ha^{-1} through gliricidia / FYM + 100% P_2O_5+ 100% K_2O ha^{-1} fertilizers, 100% N ha^{-1} through gliricidia + 100% P_2O_5+ 100% K_2O ha^{-1} fertilizers. The significant improvement in soil fertility with higher nutrient balance was recorded with application of 50% N through gliricidia + 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} through fertilizers and was on par with 50% RDN through FYM in combination with 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} through fertilizers in Vertisols under cotton+greengram(1:1) intercropping system.

Keywords: Integrated nutrient management, soil fertility and vertisols

Introduction
Cotton is a soft, fluffy staple fiber that grows in a boll, or protective case, around the seeds of the cotton plants of the genus *Gossypium* in the mallow family Malvaceae. The fiber is almost pure cellulose. Among different species of cotton *Gossypium hirsutum* and *Gossypium arboreum* are commonly grown in Maharashtra and used in textile industries for manufacture of cloth. India is the largest cotton growing country in the world and occupies 37.5% world cotton area and produces around 24.3% of world cotton production. In 2019-20 area, production and productivity under cotton in India is estimated as 125.84 lakh ha, 360.0 lakh bales of 170 kg and 486 kg ha^{-1} respectively. In India, Maharashtra rank first in acreages with 43.69 lakh ha and 82.0 lakh bales production with average productivity of 319 kg lint/ha (Anonymous, 2020a) [1]. In Maharashtra state, Vidarbha is the largest cotton growing region accounting for 15.81 lakh ha^{-1} acreage with production of 35.5 lakh bales and productivity of 388.0 kg lint ha^{-1} (Anonymous, 2020b) [2].
Greengram also known as 'moong' is one of the main pulse crop of India. It is a rich source of protein along with fibre and iron. It can be cultivated as *kharif* as well as summer crop. Greengram is also known as "golden gram" and it contains 20-25% protein, 1.3% fat, 3.5% minerals, 4.1% fiber and 56.7% carbohydrates. In India, the area under greengram is about 34.4 lakh ha with production of 14.00 lakh tonnes and productivity of 406.98 kg ha^{-1} whereas; Maharashtra has about 4.8 lakh ha area with production of 2.0 lakh tonnes and productivity of 423.6 kg ha^{-1}. The area under greengram in Vidarbha is 0.83 lakh ha and production of 0.44 lakh tones with productivity of 333.0 kg ha^{-1} (Anonymous, 2020b) [2].
Integrated nutrient management is the process to maintain the soil fertility and plant nutrient supply at an optimum level through optimization by the benefits of all possible sources of nutrients like inorganic, organic, bio-fertilizers and through green manure. It enhances the availability of applied as well as native soil nutrients, synchronizes the nutrient demand of the

crop with nutrient supply from native and applied sources and improves the physical, chemical and biological functioning of soil. There is now tremendous pressure on growers to use integrated nutrient management approach to increase productivity and sustain soil health. Organic amendment offers an alternative or supplementing control tactic to increase production (Meena *et al*., 2015) [6].

Materials and Methods

With the aim of maintenance of soil fertility and nutrient balance through optimization of benefit from organic plant nutrient sources available at farm level in the region, a fixed frame plot experiment with the combinations of organic and inorganic nutrient sources is being conducted in cotton+greengram intercropping system on Vertisols since 1987-88. The present study was carried out during 2019-20 (33rd cycle). The eight treatments replicated three times in randomized block design comprised of control, 50% and 100% RDF, 50% N ha^{-1} through gliricidia/FYM, 50% N fertilizers + 50% N ha^{-1} gliricidia/FYM + 100% P_2O_5+ 100% K_2O ha^{-1} fertilizers and 100% N ha^{-1} gliricidia + 100% P_2O_5+ 100% K_2O ha^{-1} fertilizers. The plotwise surface soil samples were collected and analysed for available nutrients as per standard methods.

Results and Discussion

Organic carbon

The experimental results presented in Table 1 indicates that, there was a build up of organic carbon status of soil under cotton + greengram intercropping system in all treatments excluding control over the initial status (0.46%).

Table 1: Effect of long term INM treatments on organic carbon in soil

Treatments		OC (%)	OC balance (%)
T_1	Control	0.45	-0.01
T_2	100% RDF	0.61	0.15
T_3	50% RDF	0.53	0.07
T_4	50% N ha^{-1}gliricidia	0.60	0.14
T_5	50% N ha^{-1} FYM	0.61	0.15
T_6	50% N fertilizers + 50% N ha^{-1}gliricidia + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers	0.73	0.27
T_7	50% N fertilizers + 50% N ha^{-1} FYM + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers	0.72	0.26
T_8	100% N ha^{-1}gliricidia + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers	0.69	0.23
SE (m) ±		0.02	-
CD at 5%		0.07	-

The treatments which received organic matter through FYM and green leaf manuring of gliricidia lopping recorded improvement in the organic carbon content of the soil over control. However, highest 0.73% soil organic carbon was recorded in treatment 50% N ha^{-1} gliricidia + 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers (T_6) followed by 0.72% organic carbon content in 50% N ha^{-1} FYM + 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers (T_7) and 100% N ha^{-1} gliricidia + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers (T_8) which were found to be on par with each other. The lower value (0.45%) of organic carbon was found in treatment T_1 *i.e.* control.

The higher values of organic carbon content with application of gliricidia and FYM green leaf manuring may be attributed to addition of organic materials and greater root biomass with their addition as evidenced from the higher yields obtained in these treatments. Application of organic sources and/ or combination with chemical fertilizer helped for building up of organic carbon. Similar results were also reported by Regar *et al.* (2009) [9], Sharma *et al*. (2011) [11] and Tamboli *et al*. (2013) [13].

Organic carbon balance

The data in respect of organic carbon balance (Table 1) indicates the higher gain of 0.27% in treatment 50% N ha^{-1} gliricidia + 50% + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers (T_6) followed by treatments 50% N ha^{-1} FYM + 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers (T_7) and 100% N ha^{-1} gliricidia + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers (T_8).

Soil, water and temperature are the limiting factors of the dryland agriculture and have direct influence on the soil organic carbon. Natural incorporation of the crop residues in to the soil after harvest of the crop is common phenomenon, but year after year, continuous addition of the crop residues or green manuring or even FYM has a very little effect on soil organic carbon in dryland condition. The data of long-term experimentation showed the improvement and maintenance of the soil organic carbon content in dryland agriculture as a result of judicious use of gliricidia green leaf manure and well decomposed FYM in combination with the inorganic fertilizers. Use of organic or inorganic plant nutrient sources alone was not helpful in significant build up of organic carbon in soils under dryland condition.

Available Nitrogen

The data (Table 2) on available nitrogen status of the experimental soil, indicated that significantly higher available nitrogen (261.33 kg ha^{-1}) was observed in treatment T_6 (50% N ha^{-1} gliricidia + 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers) which was on par (259.24 kg ha^{-1}) with application of 50% N ha^{-1} FYM + 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers (T_7) and treatment (T_8) application of 100% N ha^{-1}gliricidia + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers (252.97 kg ha^{-1}). It was also noted that 28.7% and 10.6% increase in available N content was recorded with application of 50% N ha^{-1} gliricidia + 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers (T_6) as compared to control (T_1) and 100% RDF (T_2), respectively. The lowest available nitrogen (202.79 kg ha^{-1}) was observed in absolute control (T_1).

The higher value of available N over the initial value might be due to nitrogen fixation by greengram crop. The favorable soil conditions under gliricidia/FYM addition might have helped in mineralization of soil N leading to build up of higher available N. Similar results were also reported by Shirale and Khating (2009) [12], Deshmukh *et al.* (2011) [4], Gabhane *et al*. (2013) [5], Naik (2016) [7] and Chandel *et al*. (2017) [3].

Available Phosphorus

The data indicates that the treatments (T_6 & T_7) which received 50% N fertilizers + 100% P_2O_5 + 100% K_2O ha^{-1}

fertilizers with 50% N either through gliricidia lopping or FYM recorded higher content of available phosphorus over all other treatments. The maximum 18.59 kg ha^{-1} available phosphorus was recorded in treatment 50% N ha^{-1} gliricidia + 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers (T_6) and was on par (17.25 kg ha^{-1}) with treatment application of 50% N ha^{-1} FYM + 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers (T_7).

It was also noted that 72.9% and 11% increase in available phosphorus content was recorded with application of 50% N ha^{-1} gliricidia + 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers (T_6) as compared to control (T_1) and 100% RDF (T_2), respectively. The lowest 10.75 kg ha^{-1} available P was observed in control treatment.

The increase in available phosphorus status is due to use of gliricidia/FYM, being direct source of phosphorus and it might have also solubilized the native phosphorus in the soil through release of various organic acids which had chelating effect, that reduced phosphorus fixation. The higher values of available phosphorus in treatment T_6 and T_7 may be due to addition of phosphorus through FYM/ gliricidia in soil. Similar results were recorded by Vaiyapuri *et al.* (2008) [14], Regar *et al*. (2009) [9], Shirale and Khating (2009) [12], Vidyavathi *et al*. (2011) [15] and Naik (2016) [7].

Available Potassium

The black soils developed from basalt have the major quantity of the mineral feldspar which is rich in K, Na and Ca, hence potash fertilizers are not recommended for the crops grown on black soils. The swelling and shrinkage property of black clayey soils trap the K ions in crystal lattice. The data on available potassium status of the experimental soil, indicated that significantly

Table 2: Effect of long term INM treatments on soil fertility

Treatments		Available Nutrients (kg ha^{-1})		
		N	P	K
T_1	Control	202.79	10.75	306.13
T_2	100% RDF	236.25	16.73	339.73
T_3	50% RDF	225.79	13.81	324.80
T_4	50% N ha^{-1}gliricidia	229.97	14.86	328.53
T_5	50% N ha^{-1} FYM	232.06	14.78	336.00
T_6	50% N fertilizers + 50% N ha^{-1}gliricidia + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers	261.33	18.59	399.47
T_7	50% N fertilizers + 50% N ha^{-1} FYM + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers	259.24	17.25	395.73
T_8	100% N ha^{-1}gliricidia + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers	252.97	17.02	392.00
SE (m) ±		5.47	0.60	18.94
CD at 5%		16.27	1.79	56.27
Initial(1987-88)		214	12.97	316.8

higher available potassium (399.47 kg ha^{-1}) was observed in treatment T_6 (50% N ha^{-1} gliricidia + 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers), followed by treatment (T_7) application of 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} through Urea, SSP & MOP in combination with 50% N ha^{-1} through FYM (395.73 kg ha^{-1}) and 100% N ha^{-1} gliricidia + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers (392.00 kg ha^{-1}). It was also noted that 30.5% and 17.6% increase in available K content was recorded with application of 50% N ha^{-1} gliricidia + 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers (T_6) as compared to control (T_1) and 100% RDF (T_2), respectively. The lowest available potassium (306.13 kg ha^{-1}) was observed in absolute control (T_1).

In general, the treatments (T_6 & T_7) which received gliricidia lopping/FYM in combination with fertilizers showed better performance in respect of available potassium over all other treatments. Thus, the results indicate that to exploit the inherent potential available potash supplying capacity of black soil, application of the FYM/gliricidia in combination with the inorganic fertilizers is necessary.

Thus, from the data, it is revealed that, application 50% N + 100% P_2O_5 ha^{-1} + 100% K_2O ha^{-1} through urea, SSP and MOP + 50% N ha^{-1} through gliricidia/FYM resulted in build up of soil fertility. The build up of soil available K by the application of potassium through gliricidia green leaf manuring and FYM might be due to the fact that gliricidia leaves contains higher amount of K and it is deposited in the soil and due to applied K through gliricidia green leaf manure, the solubilizing action of certain organic acids produced during decomposition results in greater capacity to hold K in the available form. Similar results were observed by Shirale and Khating (2009) [12], Wagh *et al.* (2016) [16], Naik *et al.* (2018) [8] and Satpute *et al.* (2019) [10].

Nutrient balance: The data on nutrient (N, P & K) balance as influenced by various treatments are presented in Table 3

Table 3: Effect of long term INM treatments on nutrient balance in cotton+ greengram intercropping system

Treatment	Nutrient status at the end (2019-20) (kg ha^{-1})			Net gain (+)/Loss (-) (kg ha^{-1})		
	N	P	K	N	P	K
T_1	202.79	10.75	306.13	-11.2	-2.2	-10.7
T_2	236.25	16.73	339.73	22.2	3.8	22.9
T_3	225.79	13.81	324.80	11.8	0.8	8.0
T_4	229.97	14.86	328.53	16.0	1.9	11.7
T_5	232.06	14.78	336.00	18.1	1.8	19.2
T_6	261.33	18.59	399.47	47.3	5.6	82.7
T_7	259.24	17.25	395.73	45.2	4.3	78.9
T_8	252.97	17.02	392.00	39.0	4.1	75.2
Initial	214	12.97	316.8	-	-	-

The data in respect of nitrogen balance indicate the gain of nitrogen in all the treatments except control. However, the higher gain of nitrogen (47.3 kg ha^{-1}) was recorded with application of 50% N ha^{-1} gliricidia +50% N + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers (T_6) followed by 45.2 kg ha^{-1} with application of 50% N ha^{-1} FYM + 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers (T_7). The results revealed that, the combined use of nitrogen sources *i.e.* fertilizer and organic matter is essential for improvement in available N content of soil.

The data in respect of phosphorus balance indicate the gain of phosphorus in the treatments where gliricidia and FYM were used as organic sources in combination with inorganic fertilizers. However, the higher gain of phosphorus (5.6 kg ha^{-1}) was recorded in treatment T_6 followed by T_7 (4.3 kg ha^{-1}).

The data in respect of potassium balance indicate the gain of potassium in all the treatments except control. However higher gain of potassium (82.7 kg ha^{-1}) was recorded with application of 50% N ha^{-1} gliricidia + 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers (T_6) followed by 78.9 kg ha^{-1} with application of 50% N ha^{-1} FYM + 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers (T_7). The higher gain was noticed where gliricidia and FYM were used as organic sources in combination with inorganic fertilizers.

Conclusion

The integrated application of 50% N through gliricidia / FYM+ 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} through fertilizers resulted in improvement in soil fertility with higher nutrient balance in cotton + greengram (1:1) intercropping system in Vertisols under rainfed conditions.

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