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Long term effect of integrated nutrient management on crop productivity, soil fertility and nutrient balance in vertisols under cotton + greengram (1:1) intercropping system

Ajay Shelke, VV Gabhane, Jaipal Yadav, MM Ganvir, Arti Rathod and Ashwini Chandel

Abstract
A field study was conducted during *kharif* 2018 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 results indicated that the application of 50% RDN through FYM/gliricidia in combination with 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} through inorganics resulted in higher crop productivity, improvement in soil fertility with higher nutrient balance in Vertisols under cotton+greengram (1:1) intercropping system.

Keywords: Integrated nutrient management, soil fertility and vertisols

Introduction
Cotton (*Gossypium 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.
Greengram (*Vigna radiata*) is an important pulse crop believed to be originated from India. Greengram commonly known as mung, is also known as "golden gram" and it contains 20-25% protein, 1.3% fat, 3.5% minerals, 4.1% fiber and 56.7% carbohydrate. 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.
Integrated plant nutrient management enhances the crop productivity and improves the soil physical, chemical as well as biological properties. The chemical properties namely organic carbon content and available nutrients enhances with the application of crop residues supplemented with chemical fertilizers. Long term fertilizer experiments have shown that the integrated use of organic manures and chemical fertilizers can maintain high productivity and sustainable crop production. The application of FYM, compost and crop residues effectively maintain the soil organic matter.
The present study was carried out to study the long term effect of FYM/gliricidia green leaf manuring and inorganic fertilizer application on soil fertility and productivity of cotton+greengram (1:1) intercropping system in Vertisols.

Materials and Methods
A field experiment conducted on Vertisols was initiated on the research field of AICRP for Dryland Agriculture, Dr. PDKV, Akola since 1987-1988. The present study was undertaken during 2018-19 (32^{nd} 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

Yield of cotton

The data on yield of cotton in cotton+greengram (1:1) intercropping system is presented in Table 1 and depicted in Fig 1. The mean seed cotton yield ranged from 601.2 to 968.9 kg ha^{-1}. Long term application of 50% RDN through organic source *i.e.* FYM in combination with 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} through inorganics (T_7) recorded higher seed cotton yield (968.9 kg ha^{-1}) and was on par with the application of 50% N through gliricidia + 50% N +100% P_2O_5 + 100% K_2O ha^{-1} through fertilizers (T_6) and application of 100% RDF (T_2). The increase in seed cotton yield with long term application of 50% RDN through organic source *i.e.* FYM in combination with 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} through inorganics (T_7) was 61% and 15% higher as compared to control (T_1) and 100% RDF (T_2) treatments respectively. The lowest seed cotton yield (601 kg ha^{-1}) was recorded in treatment T_1 *i.e.* control.

Table 1: Effect of long term INM treatments on cotton and greengram yield

Treatments		Cotton yield (kg ha^{-1})		Greengram yield (kg ha^{-1})		SCEY (kg ha^{-1})
		Seed cotton	Stalk	Grain	Straw	
T_1	Control	601.2	1301.0	361.0	176.4	882.0
T_2	100% RDF	841.7	1794.0	465.8	213.0	1204.0
T_3	50% RDF	691.7	1553.5	392.8	192.6	997.2
T_4	50% N ha^{-1}gliricidia	634.8	1413.3	369.6	182.7	922.3
T_5	50% N ha^{-1} FYM	686.5	1441.6	357.3	186.5	964.4
T_6	50% N fertilizers + 50% N ha^{-1} gliricidia +100% P_2O_5+ 100% K_2O ha^{-1} fertilizers	904.2	1902.4	503.2	211.3	1295.6
T_7	50% N fertilizers + 50% N ha^{-1} FYM + 100% P_2O_5+ 100% K_2O ha^{-1} fertilizers	968.9	2034.7	536.8	217.7	1386.5
T_8	100% N ha^{-1}gliricidia + 100% P_2O_5+ 100% K_2O ha^{-1} fertilizers	770.6	1641.7	402.2	194.0	1083.4
SE (m) ±		48.8	91.3	36.2	7.6	53.9
CD at 5%		145.1	271.2	107.5	22.7	160.3

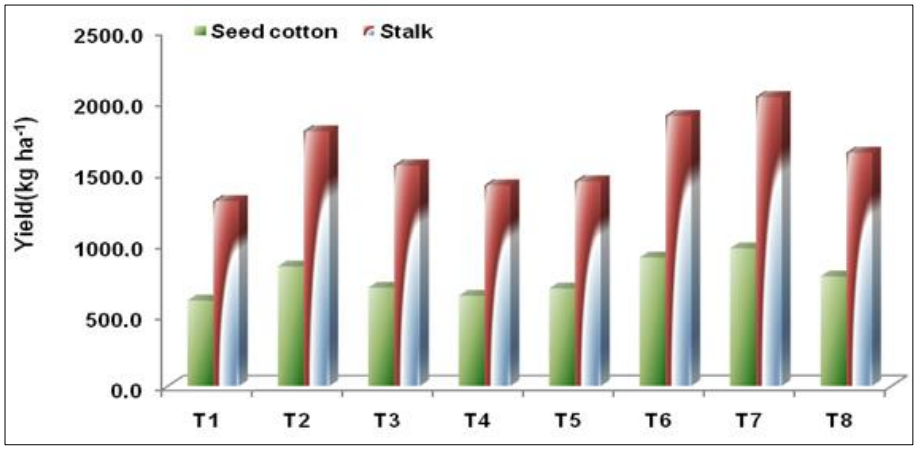

Fig 1: Effect of long term INM treatments on cotton yield

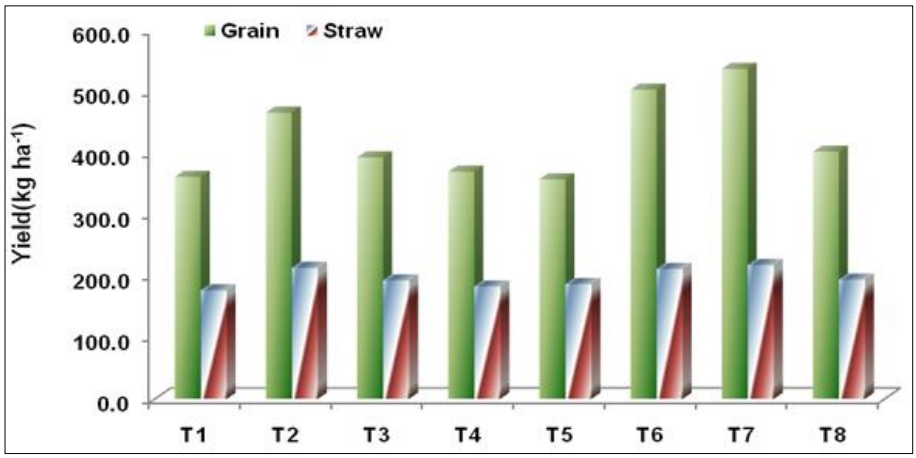

Fig 2: Effect of long term INM treatments on greengram yield

The mean cotton stalk yield ranged from 1301.0 to 2034.7 kg ha^{-1} and significantly higher cotton stalk yield (2034.7 kg ha^{-1}) was recorded with long term application of 50% RDN through organic source *i.e.* FYM in combination with 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} through inorganics (T_7) and was on par with the application of 50% N through gliricidia + 50% N +100% P_2O_5 + 100% K_2O ha^{-1} through fertilizers (T_6) and application of 100% RDF (T_2).The increase in cotton stalk yield with long term application of 50% RDN through organic source *i.e.* FYM in combination with 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} through inorganics (T_7) was 56% and 13% higher as compared to control (T_1) and 100% RDF (T_2)

treatments respectively. The lowest cotton stalk yield (1301.0 kg ha^{-1}) was recorded in treatment T_1 *i.e.* control.

Higher cotton yield with conjunctive application of FYM and gliricidia green leaf manure along with chemical fertilizers may be due to balanced supply of nutrients to the crop throughout the crop growth period. Green leaf 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.

Yield of greengram

The yield of greengram in cotton+greengram intercropping system is presented in Table 1 and depicted in Fig 2. The greengram grain yield ranged from 361.0 to 536.8 kg ha^{-1}. Long term application of 50% RDN through organic source *i.e.* FYM in combination with 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} through inorganics (T_7) recorded higher greengram grain yield (536.8 kg ha^{-1}) and was on par with the application of 50% N through gliricidia + 50% N +100% P_2O_5 + 100% K_2O ha^{-1} through fertilizers (T_6) and application of 100% RDF (T_2).The increase in greengram grain yield with long term application of 50% RDN through organic source *i.e.* FYM in combination with 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} through inorganics (T_7) was 48% and 15% higher as compared to control (T_1) and 100% RDF (T_2) treatments respectively. The lowest greengram grain yield (361kg ha^{-1}) was recorded in treatment T_1 *i.e.* control.

The greengram straw yield ranged between 176.4 to 217.7 kg ha^{-1}. Long term application of 50% RDN through organic source *i.e.* FYM in combination with 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} through inorganics (T_7) recorded higher greengram straw yield (217.7 kg ha^{-1}) and was on par with the application of 50% N through gliricidia + 50% N +100% P_2O_5 + 100% K_2O ha^{-1} through fertilizers (T_6) and application of 100% RDF (T_2).The increase in greengram straw yield with long term application of 50% RDN through organic source *i.e.* FYM in combination with 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} through inorganics (T_7) was 23% and 2% higher as compared to control (T_1) and 100% RDF (T_2) treatments respectively. The lowest greengram grain yield (176.4 kg ha^{-1}) was recorded in treatment T_1 *i.e.* control.

Higher greengram yield with conjunctive application of FYM and gliricidia green leaf manure along with chemical fertilizers may be due to balanced supply of nutrients to the crop throughout the crop growth period. Green leaf 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.

Seed cotton equivalent yield

The seed cotton equivalent yield (SCEY) ranged between 882.0 to 1386.5 kg ha^{-1} (Table 1). Long term application of 50% RDN through organic source *i.e.* FYM in combination with 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} through inorganics (T_7) recorded higher seed cotton equivalent yield (1386.5 kg ha^{-1}) and was on par with the application of 50% N through gliricidia + 50% N +100% P_2O_5 + 100% K_2O ha^{-1} through fertilizers (T_6).The increase in seed cotton equivalent yield with long term application of 50% RDN through organic source *i.e.* FYM in combination with 50% N + 100% P_2O_5 + 100% K_2O ha^{-1} through inorganics (T_7) was 57% and 15% higher as compared to control (T_1) and 100% RDF (T_2) treatments respectively. The lowest seed cotton equivalent yield (882 kg ha^{-1}) was recorded in treatment T_1 *i.e.* control.

Higher seed cotton equivalent yield with conjunctive application of FYM and gliricidia green leaf manure along with chemical fertilizers may be due to balanced supply of nutrients to the crop throughout the crop growth period. Green leaf 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.

In general, the increase in yield of cotton and greengram was recorded with conjunctive application of FYM and gliricidia green leaf manure along with chemical fertilizers. Similar observations were recorded by Deshpande and Patil (2007) [1], Rao and Janawade (2009) [6] and Simon *et al.* (2016) [10].

Organic carbon

The experimental results presented in (Table 2 and Fig 3) indicate 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%).

The treatments which received organic matter through FYM and gliricidia green leaf manuring recorded improvement in the organic carbon content of the soil over control. However, highest 0.70% soil organic carbon was recorded in treatment 50% N fertilizers + 50% N ha^{-1} FYM + 100% P_2O_5+ 100% K_2O ha^{-1} fertilizers (T_7) followed by 0.69% organic carbon content in 50% N fertilizers + 50% N gliricidia +100% P_2O_5+ 100% K_2O ha^{-1} fertilizers (T_6) 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 increase in organic carbon content was 0.24% and 0.08% higher with application of 50% N fertilizers +

Table 2: Effect of long term INM treatments on organic carbon content in soil

Treatments		OC (%)	OC balance (%)
T_1	Control	0.46	0.00
T_2	100% RDF	0.62	0.16
T_3	50% RDF	0.55	0.09
T_4	50% N ha^{-1}gliricidia	0.60	0.14
T_5	50% N ha^{-1} FYM	0.60	0.14
T_6	50% N fertilizers + 50% N ha^{-1}gliricidia +100% P_2O_5+ 100% K_2O ha^{-1} fertilizers	0.69	0.23
T_7	50% N fertilizers + 50% N ha^{-1} FYM + 100% P_2O_5+ 100% K_2O ha^{-1} fertilizers	0.70	0.24
T_8	100% N ha^{-1}gliricidia + 100% P_2O_5+ 100% K_2O ha^{-1} fertilizers	0.68	0.22
SE (m) ±		0.02	-
CD at 5%		0.07	-

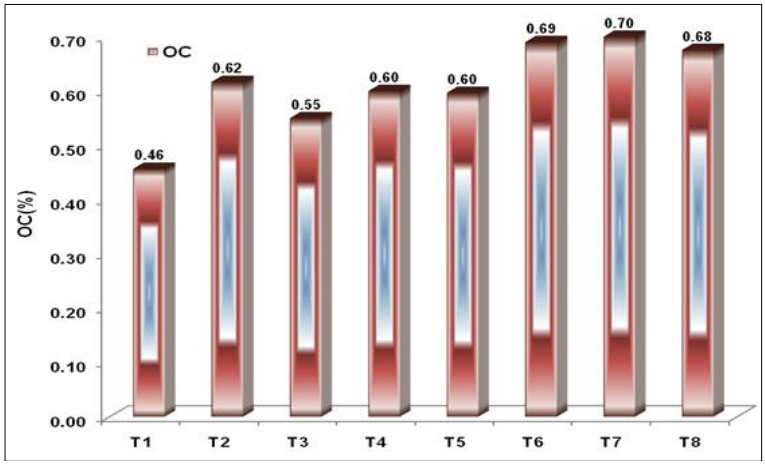

Fig 3: Effect of long term INM treatments on organic carbon in soil

50% N ha^{-1} FYM + 100% P_2O_5+ 100% K_2O ha^{-1} fertilizers (T_7) as compared to control (T_1) and 100% RDF (T_2) treatments respectively. The lower value (0.46%) of organic carbon was found in treatment T_1 *i.e.* control.

The higher values of organic carbon content with application of FYM and gliricidia 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. Similar results were also reported by Regar *et al.* (2009) [7], Verma and Mathur (2009) [13], Porpavai *et al.* (2011) [4], Sharma *et al.* (2011) [8] and Tamboli *et al.* (2013) [11].

Organic carbon balance

The data in respect of organic carbon balance (Table 2 and Fig 4) indicate the higher gain of 0.24% in treatment 50% N fertilizers + 50% N ha^{-1} FYM + 100% P_2O_5+ 100% K_2O ha^{-1} fertilizers (T_7) followed by treatments 50% N fertilizers + 50% N ha^{-1} gliricidia +100% P_2O_5+ 100% K_2O ha^{-1} fertilizers (T_6) and 100% N ha^{-1}gliricidia + 100% P_2O_5+ 100% K_2O ha^{-1} fertilizers (T_8).

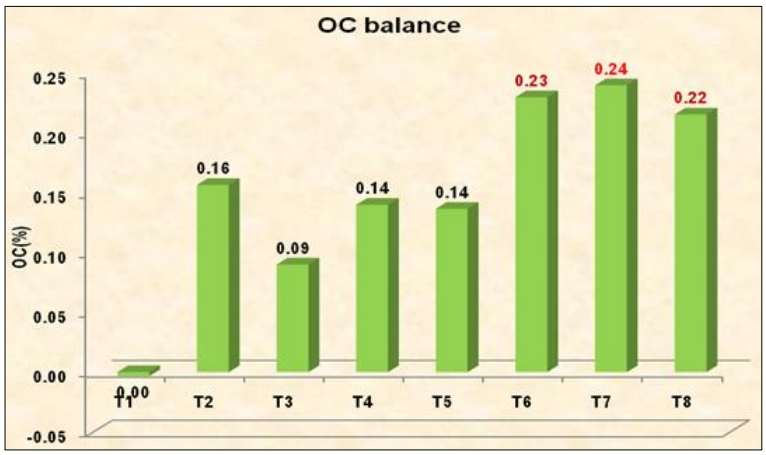

Fig 4: Organic carbon balance

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 3 and Fig 5) on available nitrogen status of the experimental soil, indicated that significantly higher available nitrogen (257.15 kg ha^{-1}) was observed in T_7 (50% N fertilizers + 50% N ha^{-1} FYM + 100% P_2O_5+ 100% K_2O ha^{-1} fertilizers) which was on par with treatment (T_6) application of 50% N fertilizers + 50% N gliricidia +100% P_2O_5+ 100% K_2O ha^{-1} fertilizers (252.97 kg ha^{-1}) and application of 100% N ha^{-1}gliricidia + 100% P_2O_5+ 100% K_2O ha^{-1} fertilizers (T_8). It was also noted that 28% and 10% increase in available N content was recorded with application of 50% N fertilizers + 50% N ha^{-1} FYM + 100% P_2O_5+ 100% K_2O ha^{-1} fertilizers (T_7) as compared to control (T_1) and 100% RDF (T_2) respectively. The lowest available nitrogen (200.70 kg ha^{1}) was observed in absolute control (T_1).

Available Phosphorus

In general, the data indicate that the treatments (T_7 & T_6) which received 50% N fertilizers + 100% P_2O_5 + 100% K_2O ha^{-1} fertilizers with 50% N either through FYM or gliricidia lopping recorded higher content of available phosphorus over all other treatments. The maximum 17.85 kg ha^{-1} available phosphorus was recorded in treatment 50% N fertilizers +

50% N ha^{-1} FYM + 100% P_2O_5+ 100% K_2O ha^{-1} fertilizers (T_7) and was on par with treatment application of 50% N fertilizers + 50% N gliricidia +100% P_2O_5+ 100% K_2O ha^{-1} fertilizers (T_6) (17.77 kg ha^{-1}).

It was also noted that 62% and 7% increase in available phosphorus content was recorded with application of 50% N fertilizers + 50% N ha^{-1} FYM + 100% P_2O_5+ 100% K_2O ha^{-1} fertilizers (T_7) as compared to control (T_1) and 100% RDF (T_2) respectively. The lowest 10.98 kg ha^{-1} available P was observed in control treatment. Hence to minimize the conversion of plant available phosphate to unavailable form due to the calcareous nature of black soil as well as about 21% calcium content in the SSP fertilizer, the addition of FYM in combination with fertilizers is necessary which not only contain about 0.2% phosphorus but also increases the availability to crops in dryland condition.

Table 3: Effect of long term INM treatments on soil fertility

Treatments		Available Nutrients (kg ha^{-1})		
		N	P	K
T_1	Control	200.70	10.98	303.33
T_2	100% RDF	232.06	16.58	336.80
T_3	50% RDF	223.70	13.07	321.07
T_4	50% N ha^{-1}gliricidia	227.88	13.89	321.47
T_5	50% N ha^{-1} FYM	225.79	13.07	330.27
T_6	50% N fertilizers + 50% N ha^{-1}gliricidia +100% P_2O_5+ 100% K_2O ha^{-1} fertilizers	252.97	17.77	389.87
T_7	50% N fertilizers + 50% N ha^{-1} FYM + 100% P_2O_5+ 100% K_2O ha^{-1} fertilizers	257.15	17.85	396.27
T_8	100% N ha^{-1}gliricidia + 100% P_2O_5+ 100% K_2O ha^{-1} fertilizers	242.52	16.87	378.40
SE (m) ±		5.0	0.30	13.95
CD at 5%		14.9	0.90	41.44
Initial(1987-88)		214	12.97	316.8

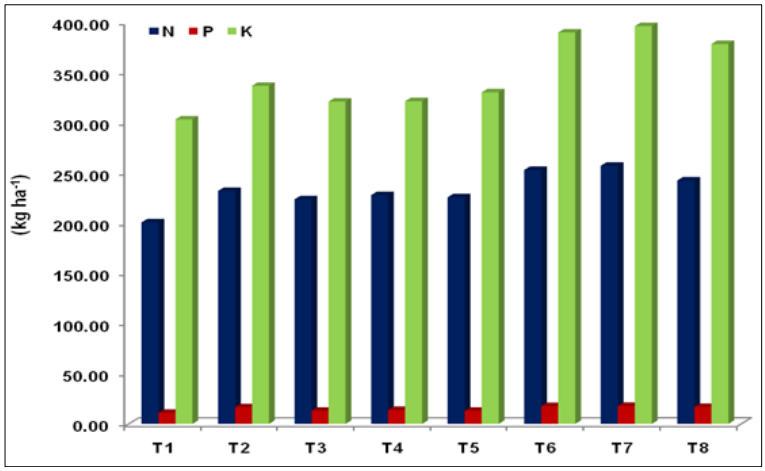

Fig 5: Effect of long term INM treatments on available nutrients in soil

The increase in available N due to incorporation of FYM and gliricidia green leaf manuring may be due to higher amount of nitrogen content in leaves 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. Similar results were also given by Vaiyapuri *et al.* (2008) [12], Garrido *et al.* (2009) [3], Vidyavathi *et al*. (2011) [14] and Rajashekarappa *et al.* (2013) [5].

The higher content of available P may be due to the application of potassium through gliricidia green leaf manuring which increases the availability of phosphorus in the soil. During decomposition of green manure, various organic acids are produced which solubilize phosphatase and other phosphate bearing minerals and thereby lowers the phosphate fixation and increase its availability. Similar results were recorded by Vaiyapuri *et al.* (2008) [12], Regar *et al.* (2009) [7], Shirale and Khating (2009) [9] and Vidyavathi *et al.* (2011) [14].

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 higher (396.27 kg ha^{-1}) available potassium was observed in treatment T_7 (50% N fertilizers + 50% N ha^{-1} FYM + 100% P_2O_5+ 100% K_2O ha^{-1} fertilizers, followed by treatment (T_6) 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 gliricidia lopping (389.87kg ha^{-1}) and 100% N ha^{-1}gliricidia + 100% P_2O_5 + 100% K_2O ha^{-1}fertilizers (378.40 kg ha^{-1}).It was also noted that 30% and 17% increase in available K content was recorded with application of 50% N fertilizers + 50% N ha^{-1} FYM + 100% P_2O_5+ 100% K_2O ha^{-1} fertilizers (T_7) as compared to control (T_1) and 100% RDF (T_2) respectively. The lowest available potassium (303.33 kg ha^{-1}) was observed in absolute control (T_1).

In general, the treatments (T_7 & T_6) which received FYM/ gliricidia lopping 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 FYM / gliricidia resulted in build up of soil fertility. The build up of soil available K by the application of potassium through FYM and gliricidia green leaf manuring 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 Dhonde and Bhakare (2008) [2], Vaiyapuri *et al.* (2008) [12], Regar *et al.* (2009) [7] and Porpavai *et al.* (2011) [4].

Nutrient balance

The data in respect of nitrogen balance (Table 4 and Fig 6) indicate the gain of nitrogen in all the treatments except control. However, the higher gain of nitrogen was recorded in treatment T_7 (43.2 kg ha^{-1}) followed by T_6 (39.0 kg ha^{-1}). 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 (Table 4) indicate the gain of phosphorus in the treatments where gliricidia and FYM were used as organic sources in combination with inorganic fertilizers.

Table 4: Effect of long term INM treatments on nutrient balance in cotton+ greengram intercropping system

Treatment	Nutrient status at the end (2018-19) (kg ha^{-1})			Net gain(+) / Loss(-) (kg ha^{-1})		
	N	P	K	N	P	K
T_1	200.70	10.98	303.33	-13.3	-1.99	-13.5
T_2	232.06	16.58	336.80	18.1	3.61	20.0
T_3	223.70	13.07	321.07	9.7	0.10	4.30
T_4	227.88	13.89	321.47	13.9	0.92	4.70
T_5	225.79	13.07	330.27	11.8	0.10	13.5
T_6	252.97	17.77	389.87	39.0	4.80	73.1
T_7	257.15	17.85	396.27	43.2	4.88	79.5
T_8	242.52	16.87	378.40	28.5	3.90	61.6
Initial	214	12.97	316.8	-	-	-

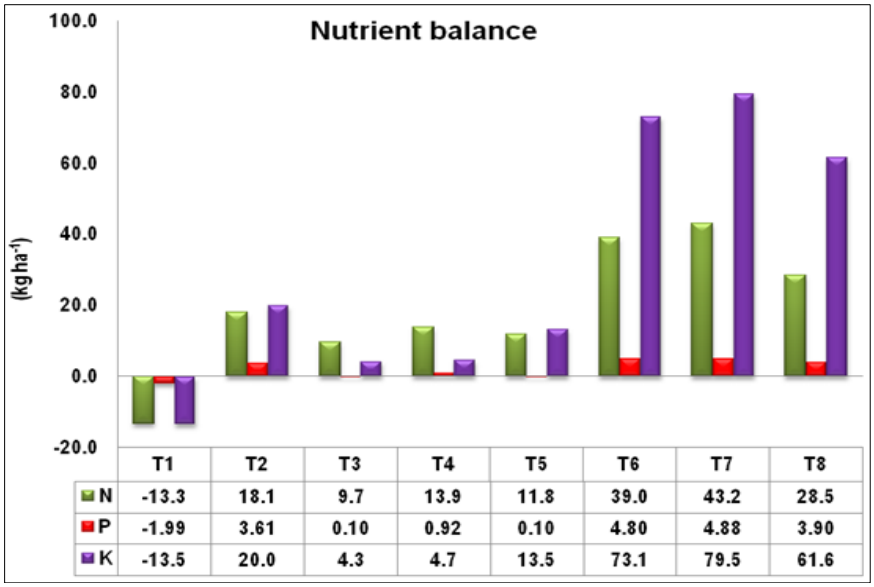

Fig 6: Effect of long term INM treatments on nutrient balance in soil

However, the higher gain of phosphorus was recorded in treatment T_7 (4.88 kg ha^{-1}) followed by T_6 (4.80 kg ha^{-1}).

The data in respect of potassium balance (Table 4) indicate the gain of potassium in all the treatments except control. However the higher gain was noticed where gliricidia and FYM were used as organic sources in combination with inorganic fertilizers.

Conclusion

The long term effect of integrated nutrient management to substitute 50% RDN through FYM /gliricidia resulted in improvement in fertility status of soil with higher nutrient balance and crop productivity in Vertisols under cotton + greengram (1:1) intercropping system.

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