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Long term effect of integrated nutrient management on soil biological properties and productivity of cotton + greengram intercropping system in vertisols

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Abstract
A study was conducted during 2016-17 on the long term experiment initiated during 1987 on Vertisols at Research field of AICRP for Dryland Agriculture, Dr. PDKV, Akola, Maharashtra. The study was conducted with the objective to assess the long term impact of integrated nutrient management on biological properties of soil and yield sustainability under cotton+greengram (1:1) intercropping system in Vertisols The eight treatments comprised of control,100% RDF(50:25:00 NPK kg ha^{-1}) through chemical fertilizer,50% RDF through chemical fertilizer, 50% N through FYM/gliricidia, 50% N through fertilizers + 50% N through FYM/gliricidia +100% P_2O_5 ha^{-1} fertilizers and 100% N ha^{-1} gliricidia + 100% P_2O_5 ha^{-1} fertilizers in randomised block design with three replications.
The results after 30^{th} cycle(2016-17) indicated the significant improvement in soil biological properties and enhanced productivity of crops under integrated nutrient management comprising of 50% N through FYM/gliricidia + 50% N through inorganics + 100% P_2O_5 ha^{-1}, while the lowest improvement was observed in control, indicating considerable enhancement in soil quality due to integrated nutrient management. Hence, it is concluded that long term integrated use of 50% N through FYM/gliricidia + 50% N through fertilizers + 100% P_2O_5 ha^{-1} not only significantly improved biological properties of soil but it was found as the most promising approach from the view point of yield sustainability of cotton+greengram (1:1) intercropping system in Vertisols under rainfed condition.

Keywords: Integrated nutrient management, soil biological properties, Vertisols

Introduction
Cotton “white gold” the king of fibers is premier cash crop of central and western part of country with enormous potential in employment generation and economic trade activity. India ranks first in area under cotton in the world however, stands third in production. Among different species of cotton, *Gossypium hirsutum* and *Gossypium arborium* 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.
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) [2].
Greengram (*Vigna radiata*) is an excellent source of high (25%) quality protein. The whole or split grains are used as ‘dal’ or made into flour. The straw and husk are a fodder for cattle. Grains are also used in many Indian dishes. It belongs to leguminosae family and is believed to be native of central Asia. It can be raised on wide array of soil ranging from red lateritic soils of south India to black cotton soils of Maharashtra. It is one of the thirteen food legumes grown in India and third most important pulse crop of India after chickpea and pigeonpea.
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, 2016b) [3].

In Vidarbha region of Maharashtra, cotton is grown predominantly as a rainfed crop. As such in Vidarbha region about 89 per cent cultivable land is under rainfed farming and rainfed cotton crop production has direct bearing on the agrarian economy of the region. The cotton productivity of Vidarbha region is low due to imbalanced use of fertilizers, erratic distribution of rainfall, low adoption of improved agro-techniques and decline in soil health.

Integrated plant nutrient management is an intelligent use of optimum combination of organic, inorganic and biological nutrient sources in specific crop, cropping system and climatic situation so as to achieve and sustain optimum yield and to improve or maintain soil properties. Integrated plant nutrient management is beneficial to maintain soil fertility, sustainable agricultural production and increase availability of nutrients from all resources and minimizing loss of nutrients.

Materials and Methods

The experiment is the part of long term experiment that was taken on same land since 1987-88 without changing randomization under rainfed condition on farm of AICRP for Dryland Agriculture, Dr. PDKV, Akola (Maharashtra) in randomised block design replicated thrice. 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 2016-17 represents 30^{th} year of the experimentation.

Results and Discussion

Long term effect of integrated nutrient management on soil biological properties

The biological activity of a soil is the function of number of organisms present in soil and their physiological efficiency. The rate of respiration can be used as an index of the biological activity in soil as it reflects physiological efficiency of the organisms. All biological reactions in soils are catalyzed by enzymes. Soil enzyme activities are believed to indicate the extent of specific processes in soil and in some cases act as indicators of soil fertility. Microorganism population is influenced by intercropping systems as well as application of organic materials which in turn favourably augmented beneficial population and their activities such as organic matter decomposition, mineralization of organic residues and availability of plant nutrients. The nutrition of plant certainly depends upon the composition of soil flora in the rhizosphere. All the chemical processes related to nutrient availability are by and large dependent on microorganisms. The physical and chemical properties of soil determine the nature of soil environment in which microorganisms are developed. The type and nature of crop residue with their composition, soil porosity and moisture content, soil temperature, cultivation practices and cropping systems are responsible for survival of microbes in the soil. The microbial biomass, which is the total sum of all microorganisms present in soil, serve as a temporary sink for nutrient including N and can be used as an index of soil fertility. Soil enzymes play a major role in nutrient availability; it may be associated with viable cell, dead cell, cell debris and immobilized enzymes in the soil matrix. In the soil, enzyme can be stabilized either being adsorbed to internal or external clay surfaces or complexed with humic colloids by adsorption and cross linked, microcapsulation, ion exchange, entrapment or co-polymerization. Soil biological attributes and the changes due to management practices observed are very much useful for maintaining soil quality.

Soil microbial biomass carbon

The soil microbial biomass carbon acts as the transformation agent of the organic matter in the soil and it helps in the cycling of nutrients in the soils. As such, the biomass is a both source and sink relationship of the carbon, nitrogen and phosphorus contained in the organic matter. It is the centre of majority of biological activity in soil. SMBC is an important component of soil organic matter and comprises 1-3 per cent of total organic carbon in soil, but it has a rapid turnover rate and represents a labile reservoir of nutrients. Due to its dynamic character, microbial biomass responds to agricultural management practices.

Data pertaining to soil microbial biomass carbon (SMBC) as influenced by different treatments are presented in Table 1 indicating considerable variation in population of microorganisms under the influence of different treatments. The results pertaining to soil microbial biomass carbon status of soil was significantly influenced by different treatments during 30 years of experiment. The soil microbial biomass carbon in soil varied from 104.52 µg g^{-1} soil to 173.17 µg g^{-1} soil in 30^{th} cycle.

The results specified during 30^{th} cycle indicate that 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 (173.17 µg g^{-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 cotton +greengram intercropping system. It was observed that during 30^{th} cycle the SMBC was found quite low in control; however, it was considerably improved due to INM indicating the need of addition of organic matter to the soil along with chemical fertilizers for achieving good soil biological activity.

The sources of organics under study have recorded on par results in respect of SMBC. It was interesting to note that the substitution of 50% recommended nitrogen fertilizer dose by using FYM has recorded significant increase in SMBC which was also on par with 50% substitution of N through gliricidia indicating that over a long run 50% N substitution through gliricidia green leaf manuring is also a soil restorative practice causing considerable improvement in soil health. These results are in conformity with Manna *et al.* (2005) [5] and Mishra *et al.* (2008) [11] Chakraborty *et al.* (2011) [4].

Table 1: Soil microbial biomass carbon and CO_2 evolution as influenced by the long term effect of INM under cotton + greengram intercropping system

Treatments		Soil microbial biomass carbon (μg g^{-1} soil)	CO_2 evolution (mg 100 g^{-1} soil)
T_1	Control	104.52	19.25
T_2	100% N + 100% P_2O_5 ha^{-1} fertilizers	148.85	26.95
T_3	50% N + 50% P_2O_5 ha^{-1} fertilizers	133.05	24.20
T_4	50% N ha^{-1} gliricidia	141.72	35.20
T_5	50% N ha^{-1} FYM	146.67	34.65
T_6	50% N fertilizers + 50% N gliricidia +100% P_2O_5 ha^{-1} fertilizers	170.20	46.93
T_7	5 0% N fertilizers + 50% N ha^{-1} FYM + 100% P_2O_5 ha^{-1} fertilizers	173.17	50.05
T_8	100% N ha^{-1} gliricidia + 100% P_2O_5 ha^{-1} fertilizers	168.10	43.08
	SE (m) ±	2.75	1.09
	CD at 5%	8.18	3.24

CO_2 Evolution

Soil respiration is an evaluation of soil biological activity and extent of organic matter decomposition. Profound influence of integrated nutrient management treatments comprising 50% recommended dose of nitrogen through FYM and gliricidia (green manure) in combination with fertilizers was found on soil respiration over chemical fertilizer treatments during 30th cycle (2016-17) under study (Table 1).

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 (50.05 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 (19.25 mg 100 g^{-1} soil).

It is indicative of the nutrient turn over at higher carbon expenses met through added organic carbon. Similar results were also reported by Mishra *et al.* (2008) [11] on the basis of long term fertilizer experiment continued since 1956 on acid soil (Alfisol) at Ranchi. The lowest values were recorded under control while, the substitution of 50% N through other organic sources i.e. FYM (T_7) was on par with the application of 50% N through gliricidia (T_6). Thus, the increased metabolically active microbial biomass could have resulted in increased soil respiration rate. Similar findings were reported by Mali *et al.* (2015) [8] and Surekha and Rao (2009) [13].

Dehydrogenase Activity

The data pertaining to the dehydrogenase activity presented in Table 2 revealed that the dehydrogenase activity in soil increased with increase in addition of increased dose of well decomposed organic manure i.e. FYM. The data in respect of dehydrogenase activity showed significant influence of various organic sources i.e FYM and gliricidia green leaf manuring.

Table 2: Dehydrogenase activity and Alkaline phosphatase as influenced by the long-term effect of INM 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	21.69	191.62
T_2	100% N + 100% P_2O_5 ha^{-1} fertilizers	31.25	222.57
T_3	50% N + 50% P_2O_5 ha^{-1} fertilizers	24.18	213.08
T_4	50% N ha^{-1} gliricidia	32.64	237.95
T_5	50% N ha^{-1} FYM	33.97	239.27
T_6	50% N fertilizers + 50% N gliricidia +100% P_2O_5 ha^{-1} fertilizers	38.82	262.36
T_7	50% N fertilizers + 50% N ha^{-1} FYM + 100% P_2O_5 ha^{-1} fertilizers	39.52	265.64
T_8	100% N ha^{-1} gliricidia + 100% P_2O_5 ha^{-1} fertilizers	36.75	256.92
	SE (m) ±	0.68	3.93
	CD at 5%	2.03	11.67

The results after 30th 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 (39.52 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 Chander *et al.* (1997) [5], Tejada *et al.* (2008) [15], Surucu *et al.* (2014) [14] and Mali *et al.* (2015) [8].

Alkaline Phosphatase

The general name phosphatase has been used to describe a broad group of enzymes that catalyze the hydrolysis of both esters and anhydrides of H_3PO_4 involving five major groups. Due to relative importance of phosphomonoesterases in soil organic P mineralization and plant nutrition, their assay in soil assumes more importance. The enzymes are classified as acid and alkaline phosphomonoesterases because they show optimum activities in acid and alkaline ranges. Alkaline phosphomonoesterases activity is derived from microorganisms only.

The result pertaining to alkaline phosphatase in soil (Table 2) 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 (265.64 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 (191.62 µg p- nitriphenol g^{-1} 24 h^{-1}). 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 experimental study. Similar results were also reported by Chander *et al.* (1997) [5], Abdallahi and N Dayegamiye (2000) [1], Tejada *et al.* (2008) [15] and Mali *et al.* (2015) [8].

Long term effect of integrated nutrient management on yield of crops

The data pertaining to seed cotton and stalk yield and greengram grain and straw yield in intercropping system under long term effect of organics and fertilizers is presented in Table 3. The seed cotton yield as well as greengram yield was found statistically significant under different treatments during the year 2016-17.

Yield of Cotton

The significantly highest seed cotton yield (1545.1 kg ha^{-1}) was recorded with the application of 50% N through FYM +50% N through inorganics+100% P_2O_5 ha^{-1} fertilizers (T_7)followed by application of 50% N through gliricidia+50% N through inorganics+ 100% P_2O_5 ha^{-1} fertilizers (T_6)which were found to be on par with each other. The lower seed cotton yield (648.0 kg ha^{-1}) was recorded in control (T_1) treatment.

The significantly highest cotton stalk yield (2469.1 kg ha^{-1}) was recorded with the application of 50% N through FYM +50% N through inorganics+100% P_2O_5 ha^{-1} fertilizers (T_7)followed by application of 50% N through gliricidia+50% N through inorganics+ 100% P_2O_5 ha^{-1} fertilizers (T_6)which were found to be on par with each other. The lowest stalk yield (1496.4kg ha^{-1}) was recorded in the treatment T_1 control. Higher cotton yield with conjunctive application of FYM, 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. Similar results were also reported by Kamble *et al.* (2009) [7], Mankar and Nawlakhe (2009) [9] and Sonune *et al*. (2012) [12].

Yield of Greengram

The significantly highest grain yield (1243.4 kg ha^{-1}) of greengram was recorded by the treatment T_7 receiving 50% N through fertilizers + 50% N ha^{-1} through FYM + 100% P_2O_5 ha^{-1} through fertilizers and was found to be on par with application of 50% N fertilizers + 50% N gliricidia +100% P_2O_5 ha^{-1} fertilizers(T_6).

The highest straw yield (624.7kg ha^{-1}) of greengram was recorded by the treatment T_7 receiving 50% N through fertilizers + 50% N ha^{-1} through FYM + 100% P_2O_5 ha^{-1} through fertilizers and was found to be on par with application 50% N fertilizers + 50% N gliricidia +100% P_2O_5 ha^{-1} fertilizers(T_6). Similar results were also reported by Mankar and Nawlakhe (2009) [9] and Choudhari *et al*. (2011) [6].

Table 3: Yield of cotton+greengram under (1:1) intercropping system

Treatment		Yield (kg ha^{-1})				SCEY (q ha^{-1})
		Cotton		Greengram		
		Seed	Stalk	Grain	Straw	
T_1	Control	835.0	1496.4	936.1	413.1	19.63
T_2	100% N + 100% P_2O_5 ha^{-1} fertilizers	1267.1	2169.8	1105.0	531.1	25.98
T_3	50% N + 50% P_2O_5 ha^{-1} fertilizers	1018.3	1870.6	1100.9	492.1	23.45
T_4	50% N ha^{-1} gliricidia	901.6	1739.6	1080.6	470.1	22.03
T_5	50% N ha^{-1} FYM	941.2	1720.9	1194.5	464.0	23.80
T_6	50% N fertilizers + 50% N gliricidia +100% P_2O_5 ha^{-1} fertilizers	1515.2	2450.4	1229.1	618.6	29.96
T_7	50% N fertilizers +50% N ha^{-1} FYM +100% P_2O_5 ha^{-1} fertilizers	1545.1	2469.1	1243.4	624.7	30.43
T_8	100% N ha^{-1} gliricidia + 100% P_2O_5 ha^{-1} fertilizers	1340.1	2169.8	1202.7	584.0	27.89
	SE (m) ±	68.2	134.3	48.7	38.9	0.79
	CD at 5%	202.5	398.9	144.8	115.4	2.35

The average seed cotton equivalent yield was higher at integrated use of FYM / Gliricidia along with chemical fertilizers (Table 3). It was drastically reduced at control, under only chemical fertilizers and although not revealed very prominently in crop yields the integrated nutrient management using organics recorded improvement in cotton seed equivalent.

Conclusion

The results after 30th cycle indicated that the use of FYM followed by gliricidia green leaf manuring in conjunction with chemical fertilizers improved the soil biological properties and productivity of cotton +greengram intercropping system. Hence, it is concluded that long term application of 50% N through FYM/gliricidia + 50% N through fertilizers + 100% P_2O_5 ha^{-1} to cotton+greengram (1:1) intercropping system resulted in sustaining crop productivity and build up biological properties of Vertisols under rainfed condition.

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