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Impact of potash management through gliricidia green leaf manuring on carbon pools and yield of rainfed cotton in vertisols

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Abstract
A field study entitled, "Effect of potash management through gliricidia green leaf manuring on carbon pools and yield of rainfed cotton in Vertisols" was conducted during *kharif* 2019-20 at Research field of AICRP for Dryland Agriculture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra. 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 nine treatments replicated three times in randomized block design comprised of control, 100% RDF (60:30:30 NPK kg ha^{-1}), 100%, 75% and 50% N and 100% P through chemical fertilizers and the combinations of 15, 20 and 30 kg K ha^{-1} through gliricidia green leaf manure at 30 DAS and remaining recommended dose of potassium as basal dose through inorganic fertilizers. The results indicated that application of 100% NP + 10 kg K (inorganic) + 20 kg K ha^{-1} through gliricidia green leaf manure at 30 DAS recorded significantly higher cotton yield with improvement in various carbon pools, and it was found to be on par with application of 100% NP + 15 kg K (inorganic) + 15 kg K ha^{-1} through gliricidia green leaf manure. Among the various carbon pools, the very labile and labile carbon pool was highly correlated with yield of cotton. Hence, it is concluded that conjunctive application of 100% NP + 10 kg K (inorganic) + 20 kg K ha^{-1} through gliricidia green leaf manuring at 30 DAS resulted in higher organic carbon pools and yield of cotton grown in Vertisols under rainfed conditions.

Keywords: Carbon pools, gliricidia green leaf manuring, potash management, vertisols

Introduction

Cotton (*Gossypium* spp.) is an important cash crop globally known as "king of fibre" and play vital role in the economy of farmers as well as the country and is popularly known as "white gold". It is a fibre crop originated in India and belongs to Malvaceae family, accounting for around 25% of the total global fibre production. Among different species of cotton *Gossypium hirsutum* and *Gossypium arboreum* are commonly grown in Maharashtra and used in textile industries for manufacture of cloth. World cotton area and production in 2019-20 is estimated at 33.4 million hectares and 118.6 million bales. 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, 2019 -20a) [1, 2].

India accounts for about one-third of global cotton area. Within India, two-thirds of cotton is produced in the central cotton growing zone; including, the states of Maharashtra, Madhya Pradesh, Gujarat and Odisha. Approximately 62% of India's cotton is produced on rainfed areas and 38% on irrigated lands. 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, 2019-20b) [1, 2]. In Vidarbha region about 89% cultivable land is under rainfed farming and rainfed cotton crop production has direct bearing on the agrarian economy of the region. The influence of soil organic pools on yield is both indirect and direct as the soil organic carbon plays multifunctional role such as buffering, restoring and supplying of plant nutrients etc. It is a storehouse of all soil microorganisms inhabiting in soil; improve physical, chemical and biological properties of soil. Soil organic carbon is the fraction of carbon associated with organic matter in plant and soil. The organic carbon is present in different fractions or pools in soil such as active pool, passive pool and slow pool etc. The active pool of C consists of labile or easily decomposed material and half-life of this pool is only a few days to one year. Organic matter in this pool has relatively high average C/N ratio (about 15-30) and included such organic matter fractions as living biomass, tiny pieces of detritus (POM), most of the polysaccharides and other non-humic substances. Active pool provides most of the readily accessible food for microbes and most of the readily mineralizable nitrogen. It can be readily increased by addition of fresh plant and animal residues into the soil and readily loss occurs if such additions are reduced or tillage is intensified. This pool rarely comprises > 10-20% of total soil organic matter.

The slow pool of soil organic carbon has intermediate properties between the active and passive pools. Probably includes the finest fraction of particulate organic matter that are high in lignin and other slowly decomposable and chemically resistant components, half-life is typically measured in decades. This pool is an important source of mineralizable N and other plant nutrients as well as also responsible for structure stability, lead to enhance infiltration, resistance to erosion and ease of tillage practices. It also probably makes some contribution to the effects associated primarily with active and passive pools.

*Gliricidia sepium*is a leguminous multipurpose tree and adopts very well in a wide range of soils. The leaves of gliricidia decompose relatively fast with addition of plant nutrients and organic matter to the soil and increases crop productivity. It plays important role in increasing the fertility status of soils and helps in conserving soil through reduced soil erosion also.

Materials and Methods

A field experiment conducted on Vertisols was initiated on the research field of AICRP for Dryland Agriculture, Dr. PDKV, Akola since 2015-16. The present study was undertaken during 2019-20 with nine treatments replicated three times in randomized block design comprised of control, 100% RDF (60:30:30 NPK kg ha^{-1}), 100%, 75% and 50% N and 100% P through chemical fertilizers and the combinations of 15, 20 and 30 kg K ha^{-1} through gliricidia green leaf manure at 30 DAS and remaining recommended dose of potassium as basal dose through inorganic fertilizers.

Soil organic carbon (SOC) was determined by modified Walkley and Black (1934) using 36 N H_2SO_4 implying the recovery factor of 1.298 represents the total SOC pool. This fraction was sub-fractionated into four different pools namely very labile (pool I: C_{VL}), labile (pool II: C_L), less labile (pool III: C_{LL}) and non-labile (pool IV: C_{NL}) using 5, 10 and 20 ml of concentrated (36.0 *N*) H_2SO_4 that resulted in three acid-aqueous solution ratios of 0.5:1, 1:1 and 2:1 (corresponding to 12.0, 18.0 and 24.0 *N* of H_2SO_4, respectively). The amount of C, thus determined allowed the differentiation of total soil organic carbon into the following four different pools, according to their decreasing order of oxidizability.

Pool I (C_{VL} very labile)	:	Organic C oxidizable by 12.0 *N* H_2SO_4
Pool II (C_L labile)	:	The difference in C oxidizable by 18.0 *N* and that by 12.0 *N* H_2SO_4
Pool III (C_{LL} less labile)	:	The difference in C_{tot} oxidizable by 24.0 *N* and that by 18.0 *N* H_2SO_4
Pool IV (C_{NL} non labile)	:	The difference between C and oxidizable by 24.0 *N* H_2SO_4.

The pool I and II together represent the active pool [active pool = Σ (pool I + pool II)] while pool III and pool IV together constitute the passive pool [Passive pool = Σ (pool III + pool IV)] of organic C in soils (Chan *et al*. 2001) [3].

Results and Discussion

Yield of cotton

The data on seed cotton and stalk yield of cotton (Table 1) was significantly influenced by various treatments. The significantly higher seed cotton yield (1087.10 kg ha^{-1}) was observed with application of 100% NP + 10 kg K ha^{-1} (inorganic) + 20 kg K ha^{-1} through gliricidia (T_4) and it was on par with the application of 100% NP + 15 kg K (inorganic) +15 kg K ha^{-1} through gliricidia (T_3), application of 100% RDF (60:30:30 NPK kg ha^{-1}) (T_2) and treatment receiving 100% NP + 30 kg K ha^{-1} through gliricidia (T_5). It was also observed that 102.4% and 18.3% increase in yield of seed cotton was recorded in treatment T_4 as compared to control (T_1) and 100% RDF(60:30:30 NPK kg ha^{-1}) (T_2) respectively. The lowest seed cotton yield (537.03kg ha^{-1}) was recorded in treatment T_1 *i.e.* control.

The significantly higher cotton stalk yield (2133.29 kg ha^{-1}) was observed with the application of 100% NP + 10 kg K ha^{-1} (inorganic) + 20 kg K ha^{-1} through gliricidia (T_4) and it was found to be on par with application of 100% NP + 15 kg K (inorganic) + 15 kg K ha^{-1} through gliricidia (T_3) and treatment receiving 100% NP + 30 kg K ha^{-1} through gliricidia (T_5). It was also observed that 106.9% and 18.3% increase in yield of cotton stalk was recorded in treatment T_4 as compared to control (T_1) and 100% RDF (60:30:30 NPK kg ha^{-1}) (T_2) respectively. The lowest (1031.06 kg ha^{-1}) cotton stalk yield was recorded in treatment T_1, *i.e.* control.

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

Treatments		Cotton yield (kg ha^{-1})	
		Seed cotton	Stalk
T_1	Control	537.03	1031.06
T_2	100% RDF (60:30:30 NPK kg ha^{-1})	919.06	1802.46
T_3	100% NP + 15 kg K (inorganic) +15 kg K through gliricidia	986.96	1988.91
T_4	100% NP + 10 kg K (inorganic) + 20 kg K through gliricidia	1087.10	2133.29
T_5	100% NP + 30 kg K through gliricidia	941.01	1845.76
T_6	75% N + 100% P + 15 kg K (inorganic) + 15 kg K through gliricidia	840.19	1638.36
T_7	75% N + 100% P + 30 kg K through gliricidia	879.28	1706.94
T_8	50% N + 100% P + 30 kg Kthrough gliricidia	771.60	1506.95
T_9	100% K through gliricidia	744.17	1457.91
SE (m) ±		64.96	103.92

CD at 5%	194.76	311.56
CV (%)	13.14	10.72

Higher cotton yield with conjunctive application of gliricidia green leaf manure along with chemical fertilizers may be due to balanced supply of nutrients to the crops throughout the crop growth period. Green leaf manure undergo decomposition during which series ofnutrient transformation takes place, which helps in their higher availability to the crops and higher uptake of nutrients by the crops, resulting in higher yield. The results are in conformity with the findings of Raskar (2004) [12], Kamble *et al.* (2009) [6], Shirale and khating (2009) [15], Doli *et al*. (2015) [5], Simon *et al.* (2016) [16], Naik *et al.* (2018) [10], Yadav *et al.* (2019) [14, 19] and Satpute *et al*. (2019) [13].

Organic carbon pools in soil

Very labile carbon

The very labile carbon content of soil as influenced by different treatments was statistically significant (Table 2) and it ranged from 0.77 g kg^{-1} to 1.32 g kg^{-1} indicating that the highest very labile carbon (1.32 g kg^{-1}) was recorded with the application of 100% NP + 10 kg K (inorganic) + 20 kg K through gliricidia (T_4). It was observed that 0.55 g kg^{-1} and 0.45 g kg^{-1} increase in very labile carbon content was recorded with application of 100% NP + 10 kg K (inorganic) + 20 kg K through gliricidia (T_4) as compared to control (T_1) and 100% RDF (T_2) respectively. This may be due to the long term application of green leaf manure since last 5 years, which has resulted into significant increase in the very labile carbon pool. Similarly, it was reported by Das *et al*. (2016) [4, 11] and Shelke *et al.* (2019) [14, 19] that proper nutrient supply is crucial for stockpile of very labile carbon pool in soil. The lower value (0.77 g kg^{-1}) of very labile carbon was found in treatment T_1, *i.e.* control due to comparatively lower addition of biomass.

Labile carbon

The labile carbon content of soil as influenced by different treatments was statistically significant (Table 2) and it ranged from 0.37 g kg^{-1} to 0.84 g kg^{-1} indicating that the highest labile carbon (0.84 g kg^{-1}) was recorded with the application of 100% NP + 10 kg K (inorganic) + 20 kg K through gliricidia (T_4) and it was found to be on par with the application of 100% NP + 15 kg K (inorganic) + 15 kg K through gliricidia (T_3) under the long term fertilizer experiment where potash management through gliricidia green leaf manure was followed. The increase in labile carbon content was 0.47 g kg^{-1} and 0.37 g kg^{-1} higher with application of 100% NP + 10 kg K (inorganic) + 20 kg K through gliricidia (T_4) as compared to control (T_1) and 100% RDF (T_2) respectively. This may be due to long term application of green leaf manure since last 5 years, which has resulted into significant increase in the labile carbon pool. Labile soil organic carbon is considered as the readily accessible source of microorganisms which turns over rapidly and has direct impact on nutrient supply. Labile soil organic carbon pool generally includes light fraction of organic matter and microbial biomass. The significant increase in labile carbon under potash management through gliricidia green leaf manuring system indicated its superiority over the management by organic and chemical fertilizer alone in sustaining crop productivity. Similar observations were also reported by Das *et al*. (2016) [4, 11], Kumar *et al*. (2018) [11, 18] and Shelke *et al.* (2019) [14, 19] that combination of inorganic fertilizers with organic fertilizer encouraged the accumulation of labile carbon pool in soil. The lower value (0.37 g kg^{-1}) of labile carbon was found in treatment T_1, *i.e.* control due to comparatively lower addition of biomass.

Table 2: Effect of potash management through gliricidia green leaf manuring on soil organic carbon pools

Treatments		Soil organic carbon pools (g kg^{-1})				
		Very labile	Labile	Less labile	Non labile	Total SOC
T_1	Control	0.77	0.37	0.24	6.93	8.3
T_2	100% RDF (60:30:30 NPK kg ha^{-1})	0.87	0.47	0.32	7.84	9.5
T_3	100% NP + 15 kg K (inorganic) + 15 kg K through gliricidia	1.06	0.69	0.47	14.88	17.1
T_4	100% NP + 10 kg K (inorganic) + 20 kg K through gliricidia	1.32	0.84	0.53	14.91	17.6
T_5	100% NP + 30 kg K through gliricidia	1.13	0.66	0.45	14.36	16.6
T_6	75% N + 100% P +15 kg K (inorganic) + 15 kg K through gliricidia	1.08	0.58	0.40	13.64	15.7
T_7	75% N + 100% P + 30 kg K through gliricidia	1.03	0.53	0.34	12.50	14.4
T_8	50% N + 100% P+ 30 kg K through gliricidia	0.98	0.47	0.32	11.23	13.0
T_9	100% K through gliricidia	0.92	0.42	0.29	10.46	12.1
SE(m)±		0.03	0.06	0.03	0.47	1.50
CD at 5%		0.10	0.17	0.10	1.40	4.50

Less labile carbon: The less labile carbon content of soil (Table 2) as influenced by different treatments was statistically significant and it ranged from 0.24 g kg^{-1} to 0.53 g kg^{-1} indicating that the highest less labile carbon (0.53 g kg^{-1}) was recorded with the application of 100% NP + 10 kg K (inorganic) + 20 kg K through gliricidia (T_4) and it was found to be on par with the application of 100% NP + 15 kg K (inorganic) + 15 kg K through gliricidia (T_3) and 100% NP + 30 kg K through gliricidia (T_5) under the long term fertilizer experiment where the potash management through gliricidia green leaf manure was followed. The increase in less labile carbon content was 0.29 g kg^{-1} and 0.21 g kg^{-1} higher with application of 100% NP + 10 kg K (inorganic) + 20 kg K through gliricidia (T_4) as compared to control (T_1) and 100% RDF (T_2). This may be due to long term application of potash management through gliricidia green leaf manure, which has resulted into significant increase in the less labile carbon pool. Similar observations were also reported by Nath *et al.* (2016) [11], Das *et al*. (2016) [4, 11], Mundhe *et al.* (2018) [9] and Shelke *et al*. (2019) [14, 19]. The lower value (0.24 g kg^{-1}) of less labile carbon was found in treatment T_1, *i.e.* control due to comparatively lower addition of biomass.

Non labile carbon

The non-labile carbon content of soil as influenced by different treatments was statistically significant (Table 2) and it ranged from 6.93 g kg^{-1} to 14.91 g kg^{-1} indicating that the highest non labile carbon (14.91 g kg^{-1}) was recorded with the application of 100% NP + 10 kg K (inorganic) + 20 kg K through gliricidia (T_4) and it was found to be on par with the application of 100% NP + 15 kg K (inorganic) + 15 kg K through gliricidia (T_3), 100% NP + 30 kg K through gliricidia (T_5) and 75% N + 100% P + 15 kg K (inorganic) + 15 kg K through gliricidia (T_6) under potash management experiment. It was noted that 7.98 g kg^{-1} and 7.07 g kg^{-1} increase in non-labile carbon content was recorded with application of 100% NP + 10 kg K (inorganic) + 20 kg K through gliricidia (T_4) as compared to control (T_1) and 100% RDF (T_2) respectively. This may be due to the effect of integrated use of organics with inorganic fertilizers that enhances the productivity and appreciable increase in SOC over control. Similar findings were reported by Nath *et al*. (2016) [11], Das *et al*. (2016) [4, 11], Mundhe *et al.* (2018) [9] and Shelke *et al*. (2019) [14, 19]. The lower value (6.93 g kg^{-1}) of non-labile carbon was found in treatment T_1, *i.e.* control due to comparatively lower addition of biomass.

The total soil organic carbon content of soil as influenced by different treatments was found to be significant (Table 2) and it ranged from 8.3 g kg^{-1} to 17.6 g kg^{-1} indicating that the significantly higher total soil organic carbon content (17.6 g kg^{-1}) was recorded with the application of 100% NP + 10 kg K (inorganic) + 20 kg K through gliricidia (T_4) followed by 100% NP + 15 kg K (inorganic) + 15 kg K through gliricidia (T_3), 100% NP + 30 kg K through gliricidia (T_5), 75% N + 100% P +15 kg K (inorganic) + 15 kg K through gliricidia (T_6) and 75% N + 100% P + 30 kg K through gliricidia (T_7), which were found to be on par with each other.

Contribution of different soil organic carbon fractions to TOC: The different soil organic carbon pools were analyzed and contribution of each pool was calculated against total organic carbon in percent. The data of the same is presented in Table 3.The data indicates the higher contribution of non-labile carbon pool to the total soil organic carbon and it varied from 83.32% to 87.03% under various treatments. Among all the pools, less labile carbon pool contributed less. The contribution made by less labile and labile pools were more or less similar.

Table 3: Contribution of different soil organic carbon fractions to TOC

Treatments		Very labile pool (%)	Labile pool (%)	Less labile pool (%)	Non labile pool (%)
T_1	Control	9.30	4.49	2.89	83.32
T_2	100% RDF (60:30:30 NPK kg ha^{-1})	9.15	4.98	3.33	82.53
T_3	100% NP + 15 kg K (inorganic) + 15 kg K through gliricidia	6.18	4.02	2.77	87.03
T_4	100% NP + 10 kg K (inorganic) + 20 kg K through gliricidia	7.50	4.77	2.99	84.73
T_5	100% NP + 30 kg K through gliricidia	6.81	3.96	2.71	86.53
T_6	75% N + 100% P +15 kg K (inorganic) + 15 kg K through gliricidia	6.86	3.67	2.57	86.90
T_7	75% N + 100% P + 30 kg K through gliricidia	7.16	3.66	2.34	86.85
T_8	50% N + 100% P+ 30 kg K through gliricidia	7.54	3.59	2.49	86.38
T_9	100% K through gliricidia	7.61	3.47	2.37	86.55
Average		7.57	4.07	2.72	85.65
		Active pool = 11.64		Passive pool = 88.36	

Averaged across different treatments the contribution of C_{VL}, C_L, C_{LL}, and C_{NL} towards total organic carbon under different treatments was in the range 6.18-9.30%, 3.47-4.98%, 2.34-3.33%, 83.32-87.03% respectively. The passive pool (C_{LL}+C_{NL}) contributed a relatively higher proportion (88.36%) than the active pool (C_{VL}+C_L) (11.64%). Similar results were found by Das *et al*. (2016) [4, 11] in long-term effects of fertilizers and organic sources on soil organic carbon fractions under a rice-wheat system in Indo-Gangetic Plains of north-west India.

Majumder *et al.* (2007) [8] also recorded similar contribution of passive pool of soil organic carbon towards total organic carbon under NPK and FYM treatments. Shelke *et al.* (2019) [14, 19] also reported similar effect of INM on soil organic carbon pools in cotton+greengram intercropping system on Vertisols.

The abundance of four soil organic carbon fractions was in the order non labile carbon (85.65%) > very labile carbon (7.57%) > labile carbon (4.07%) > less labile carbon (2.72%).

Correlation among crop yield and various carbon pools

The data on correlation among seed cotton yield and various carbon pools are presented in Table 4. The seed cotton yield was significantly and positively correlated with all the carbon pools. The coefficient of correlation ranged between 0.605** to 0.682**. The very labile carbon pool (r=0.682**) was highly correlated with seed cotton yield indicating influence of this pool on seed cotton yield.

Table 4: Correlation among crop yield and various carbon pools

	Seed cotton yield
Yield	1.000
Very labile (VL)	0.682**
Labile (L)	0.605**
Less Labile (LL)	0.661**
Non Labile (NL)	0.615**
Total organic carbon (TOC)	0.635**

** Significant at 1% level of significance

Correlation among various carbon pools

The correlation among various carbon pools (Table 5) indicated that, all the carbon pools showed significant and positive correlation with very labile pool indicating rapid establishment of equilibrium between these forms. Comparatively high degree of correlation of very labile pool with non-labile pool (r=0.830**) followed by labile carbon pool with non-labile carbon pool (r=0.791**) showed the rapid establishment of equilibrium between these forms.

Table 5: Correlation among various carbon pools

SOC pools	VL	L	LL	NL	TOC
VL	1.000				
L	0.733**	1.000			
LL	0.815**	0.721**	1.000		
NL	0.830**	0.791**	0.754**	1.000	
TOC	0.789**	0.709**	0.805**	0.906**	1.000

** Significant at 1% level of significance

Similar type of correlation was reported by Srinivasarao *et al*. (2011b) [17], Liang *et al.* (2012) [7], Venkatesh *et al.* (2013) [18], Nath *et al.* (2016) [11] and Shelke *et al.* (2019) [14, 19].

Conclusion

In view of the above, it is concluded that conjunctive application of 100% NP + 10 kg K (inorganic) + 20 kg K ha^{-1} through gliricidia green leaf manuring at 30 DAS resulted in higher organic carbon pools with higher yield of cotton grown in Vertisols under rainfed conditions.

References

1. Anonymous. ICAR AICRP (Cotton) Annual Report (2019-20), Coimbatore, Tamil Nadu, India-641 2019-20a, P003.
2. Anonymous. Department of Agriculture, Govt. of Maharashtra 2019-20b. http://krishi.maharashtra.gov.in
3. Chan KY, Bowman A, Oates AL. Oxidizable organic carbon fractions and quality changes in an Oxic Paleustalf under different pastures leys. Soil Science 2001;166:61-67.
4. Das D, Dwivedi BS, Singh VK, Datta SP, Meena MC, Chakraborty D *et al*. Long-term effects of fertilizers and organic sources on soil organic carbon fractions under a rice-wheat system in the IndoGangetic plains of north-west India. Soil Research 2016;55(3):296-308.
5. Doli AN, Pathrikar DT, Gourkhede PH. Effect of fertility levels and green manuring on Bt cotton. International Journal of Tropical Agriculture 2015;33(2):1805-1808.
6. Kamble AS, Palled YB, Channagoudar RF. Response of hybrid cotton (DHH-11) to *in-situ* green manuring and nitrogen levels in northern transitional tract of Karnataka. International Journal of Agricultural Sciences 2009;5(2):543-546.
7. Liang Q, Chen H, Gong M, Fan M, Yang H, Lal R *et al*. Effect of 15 years of manure and inorganic fertilizers on soil organic carbon fractions in a wheat-maize system in the north China plains. Nutrient Cycling in Agroecosystems 2012;92:21-33.
8. Majumder B, Mandal B, Bandyopadhyay PK, Chaudhury J. Soil organic carbon pools and productivity relationships for a 34 years old rice-wheat-jute agroecosystem under different fertilizer treatments. Plant and Soil 2007;297(1):53-67.
9. Mundhe Swati, Dhawan AS, Ismail Syed. Long-term effect of organic manure and fertilizers on soil organic carbon pools under soybean-safflower cropping system in Vertisol. International Journal of Agriculture Sciences 2018;10(10):6137-6140.
10. Naik Rajesh K, Gabhane VV, Chandel Ashwini, Nagdeve MB. Soil fertility and cotton productivity as influenced by potash management through gliricidia green leaf manuring in Vertisols. Special issue ICAAASTSD, Multilogic in Science 2018;7:207-209.
11. Nath AJ, Bhattacharyya Tapas, Ray SK, Deka Jyotirupa, Das Ashesh Kumar, Devi Huma. Assessment of rice farming management practices based on soil organic carbon pool analysis. Tropical Ecology 2016;57(3):607-611.
12. Raskar BS. Effect of irrigation methods, fertilizer level and green manuring on yields and nutrient balance in summer cotton. Journal of Cotton Research and Development 2004;18(2):180-183.
13. Satpute Usha V, Gabhane VV, Jawale SA, Jadhao VH. Impact of potash application through glyricidia green leaf manuring on yield and nutrient uptake by cotton in Vertisols. Journal of Pharmacognosy and Phytochemistry 2019;8(3):4111-4114.
14. Shelke A, Gabhane VV, Yadav J, Ganvir MM, Jadhao SD. Effect of long term integrated nutrient management on carbon pools and their relationship with yield of cotton + greengram (1:1) intercropping system in vertisols. International journal of chemical studies 2019;7(4):1862-1867.
15. Shirale ST, Khating LE. Effect of organic and inorganic nutrients on yield, nutrient uptake and balance in different cropping systems in Vertisol. Annals of Plant Physiology 2009;23(1):83- 85.
16. Simon Mngomba A, Festus Akinnifesi K, Amber Kerr, Salipira K, Alice Muchugi. Growth and yield responses of cotton (*Gossypium hirsutum*) to inorganic and organic fertilizers in southern Malawi. Springer Science+Business Media Dordrecht 2016.
17. Srinivasarao Ch, Venkateswarlu B, Babu Dinesh M, Wani SP, Dixit S, Sahrawat KL, Kundu Sumanta. Soil Health Improvement with *Gliricidia* Green Leaf Manuring in Rainfed Agriculture, On Farm Experiences. Central Research Institute for Dryland Agriculture, Hyderabad, Andhra Pradesh 2011, P16.
18. Venkatesh MS, Hazra KK, Gosh PK, Praharaj CS, Kumar N. Long term effect of pulse and nutrient management on soil carbon sequestration in Indo-Gangetic plains of India. Canadian Journal of Soil Science 2013;93:127-136.
19. Yadav Jaipal, Gabhane VV, Shelke Ajay, Patode RS, Rathod Arti. Effect of potash management through Gliricidia green leaf manuring on potassium fractions and their relationship with yield of soybean in Vertisols. International Journal of Chemical Studies 2019;7(4):1072-1076.