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

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DOI: https://doi.org/10.22271/chemi.2021.v9.i2l.11913

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 cotton tons. 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 includes 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 H₂SO₄ 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: CᵥL), labile (pool II: CᵥL), less labile (pool III: CᵥL) and non-labile (pool IV: CᵥL) using 5, 10 and 20 ml of concentrated (36.0 N) H₂SO₄ that resulted in three acid-equation ratios of 0.5:1, 1:1 and 2:1 (corresponding to 12.0, 18.0 and 24.0 N of H₂SO₄, 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.

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 (T₂) and it was on par with the application of 100% NP + 15 kg K (inorganic) + 15 kg K ha⁻¹ through gliricidia (T₃), application of 100% RDF (60:30:30 NPK kg ha⁻¹) (T₁) and treatment receiving 100% NP + 30 kg K ha⁻¹ through gliricidia (T₄). It was also observed that 102.4% and 18.3% increase in yield of seed cotton was recorded in treatment T₁ as compared to control (T₀) and 100% RDF(60:30:30 NPK kg ha⁻¹) (T₂) respectively. The lowest seed cotton yield (537.03 kg ha⁻¹) was recorded in treatment T₄, 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 (T₂) and it was found to be on par with application of 100% NP + 15 kg K (inorganic) + 15 kg K ha⁻¹ through gliricidia (T₃) and treatment receiving 100% NP + 30 kg K ha⁻¹ through gliricidia (T₄). It was also observed that 106.9% and 18.3% increase in yield of cotton stalk was recorded in treatment T₂ as compared to control (T₀) and 100% RDF (60:30:30 NPK kg ha⁻¹) (T₁) respectively. The lowest (1031.06 kg ha⁻¹) cotton stalk yield was recorded in treatment T₄, 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        |
| T₀ (Control)             | 537.03      | 1031.06      |
| T₁ 100% RDF (60:30:30 NPK kg ha⁻¹) | 919.06     | 1802.46      |
| T₂ 100% NP + 15 kg K (inorganic) +15 kg K through gliricidia | 986.96     | 1988.91      |
| T₃ 100% NP + 15 kg K (inorganic) + 20 kg K through gliricidia | 1087.10    | 2133.29      |
| T₄ 100% NP + 30 kg K through gliricidia | 941.01     | 1845.76      |
| T₅ 75% N + 100% P + 15 kg K (inorganic) + 15 kg K through gliricidia | 840.19     | 1638.36      |
| T₆ 75% N + 100% P + 30 kg K through gliricidia | 879.28     | 1706.94      |
| T₇ 50% N + 100% P + 30 kg K through gliricidia | 771.60     | 1506.95      |
| T₈ 100% K through gliricidia | 744.17     | 1457.91      |
| SE (m) ±                 | 64.96       | 103.92       |
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 of nutrient 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 khatting (2009) [15], Doli et al. (2015) [9], Simon et al. (2016) [16], Naik et al. (2018) [10], Yadav et al. (2019) [14, 19] and Satpute et al. (2019) [15].

**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\(_1\)). It was observed that 0.55 g kg\(^{-1}\) and 0.45 g kg\(^{-1}\) increase in very labile carbon 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 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.

### 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 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.

### 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 |
|---------------------|------------------------------------------|-------------|--------|-------------|------------|-----------|
| Control             |                                          | 0.77        | 0.37   | 0.24        | 6.93       | 8.3       |
| T\(_1\) 100% RDF (60:30:30 NPK kg ha\(^{-1}\)) |                                          | 0.87        | 0.47   | 0.32        | 7.84       | 9.5       |
| T\(_2\) 100% NP + 15 kg K (inorganic) + 15 kg K through gliricidia |                                          | 1.06        | 0.69   | 0.47        | 14.88      | 17.1      |
| T\(_3\) 100% NP + 10 kg K (inorganic) + 20 kg K through gliricidia |                                          | 1.32        | 0.84   | 0.53        | 14.91      | 17.6      |
| T\(_4\) 100% NP + 30 kg K through gliricidia |                                          | 1.13        | 0.66   | 0.45        | 14.36      | 16.6      |
| T\(_5\) 75% N + 100% P +15 kg K (inorganic) + 15 kg K through gliricidia |                                          | 1.08        | 0.58   | 0.40        | 13.64      | 15.7      |
| T\(_6\) 75% N + 100% P + 30 kg K through gliricidia |                                          | 1.03        | 0.53   | 0.34        | 12.50      | 14.4      |
| T\(_7\) 50% N + 100% P + 30 kg K through gliricidia |                                          | 0.98        | 0.47   | 0.32        | 11.23      | 13.0      |
| T\(_8\) 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      |

**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\(_4\)) 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\(_3\)) 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\(_4\)) 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               |

Averaged across different treatments the contribution of C\(_{VL}\), 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\(_{VL}+C_{LL}\)) (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.

### 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 4: Correlation among crop yield and various carbon pools

| Seed cotton yield | Yield | 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

### 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) [13], 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.

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