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Life Sciences Research

Research Article

Periodic changes in carbon and nitrogen in Vertisols under organic, inorganic, and integrated nutrient management

V. V. Gabhane, A. S. Ghare, P. R. Ramteke

Abstract

An experiment with seven treatments and three replications was established in a completely randomized design to assess the effect of gliricidia green leaf manuring on the mineralization of nitrogen and carbon in the soil during *kharif* 2014-15 in Dr. Panjabrao Deshmukh Krishi Vidyapeeth's Department of Soil Science and Agricultural Chemistry, Akola. The seven treatments comprised absolute control, two treatments of sole chemical fertilizers, two treatments of sole organics, and two treatments of integrated application of chemical fertilizers and gliricidia green leaves. The periodical (15 days interval) mineralization of nitrogen in the form of ammoniacal and nitrate nitrogen and carbon in the form of organic carbon and permanganate oxidizable carbon in soil were studied. The results indicate that the higher mineralization of nitrogen and carbon was recorded up to 45 days of incubation and it declined at subsequent (60 and 75 days) intervals, indicating that more than 60% of mineralization took place up to 45 days of incubation. Further, the higher mineralization of nitrogen and carbon was observed with the application of 50% $RDN_{(Gl)}$ + 50% $N_{(Inorg)}$ + 100% P + 25 kg K ha^{-1} (T7), followed by 50% $RDN_{(Gl)}$ + 50% $N_{(Inorg)}$ + 100% P (T6) and 100% NPK(T3).

Keywords carbon, gliricidia, mineralization, nitrogen, periodic change

Received: 12 May 2022
Accepted: 11 August 2022
Online: 17 August 2022

Authors:
V. V. Gabhane, A. S. Ghare,
P. R. Ramteke ✉
AICRP for Dryland Agriculture and Dept. of Soil Science and Agricultural Chemistry,
Dr. Panjabrao Deshmukh Krishi Vidyapeeth,
Akola, Maharashtra, India

✉ Pratik-soil@pau.edu

Emer Life Sci Res (2022) 8(2): 64-71

E-ISSN: 2395-6658
P-ISSN: 2395-664X

DOI: https://doi.org/10.31783/elsr.2022.826471

Introduction

The concept of sustainable management of environmental resources involves reducing fields' reliance on out-of-field inputs while maximizing the use of in-field inputs and reducing losses from resource-able inputs. Organic manures, in this regard, are considered one of the key inputs used in the field [1]. Under field conditions, plant residues undergo decomposition and release nutrients contained within them. Such release of nutrients is the major source of soil nitrogen. However, in soil, several biotic and abiotic factors affect this process. Among such factors, the quality (chemical composition) and quantity of residue and the elemental composition i.e. CN ratio are the major factors [2]. A plant residue with higher nitrogen, lower lignin and cellulose content and low CN ratio undergoes ready decomposition and mineralize the nitrogen [3].

As a result of their interrelationship, mineralization of carbon and nitrogen is crucial to sustaining soil fertility and soil quality. The gliricidia green leaves have been found to improve the soil properties when used in conjunction with inorganic fertilizers. The gliricidia green leaves undergo rapid decomposition in soil and enrich the nutrient pool of soil thus helping in the partial substitution of nitrogen and potassium. However, the pattern of nutrient release and their ultimate availability is highly dependent on the kinetics of the decomposition process. Not only is the application of organic sources but the time of their application is the most important aspect of the availability of nutrients to plants [4]. Since nutrients in plant residues release at a steady rate, there may occur a deficiency of nutrients in soils. Hence, the time of plant residue application and nutrient release must synchronize the nutrient demand of the crop. This calls for an effective study on the nutrient release pattern from the plant residue. Therefore, more insight into the kinetics of organics decomposition under field conditions and nutrient release patterns, and their bioavailability is required for the overall development of suitable nutrient management practices. Consequently, this study is directed at elucidating the release pattern of carbon and nitrogen pools under different treatment combinations supplied with gliricidia leaves.

Methodology

Experimental site

A controlled laboratory investigation was conducted during 2014-15 in the Soil Science and Agricultural Chemistry Department of Dr. PDKV, Akola, using Vertisols soil, a fine, smectitic, hyperthermic soil. Soil samples were properly processed (air dried and sieved on 2 mm sieve) and chemical analyses of the soil samples were performed before the laboratory investigation. The rate of decomposition in terms of carbon and nitrogen mineralization from organic materials was studied at 15 days intervals during the decomposition of organic materials in the soil. Seven treatment combinations viz. T1-Control, T2-100% NP (30:75 NP kg ha^{-1}), T3-100% NPK (30:75:25 kg ha^{-1}), T4-100% RDN farm yard manure (FYM), T5-100% RDN Gliricidia$_{(Gl)}$, T6- 50% RDN$_{(Gl)}$ + 50% N inorganics (Inorg) + 100% P , T7-50% RDN$_{(Gl)}$+ 50% N$_{(Inor)}$ + 100% P + 25 kg K ha^{-1} and seed treatment with Rhizobium and PSB @ 25 g kg^{-1} seed, were tested in completely randomized design (CRD) with three replicates.

Experimental setup

Farm yard manure (FYM) @ 15.62 g pot^{-1} was thoroughly mixed with soil. Gliricidia (Gl) @ 12.5 g pot^{-1} was applied. FYM was collected in bulk and Gl (*Gliricidia sepium*) leaves were collected and chopped into pieces. The chemical composition of organic materials used during experimentation is given in Table 1. Each pot was filled with 7 kg of soil. An incubation study was undertaken with seven treatments and three replications in CRD to find out the mineralization of nitrogen and carbon at 15 days intervals.

Table 1. Chemical composition of organic materials

Source	N (%)	P (%)	K (%)
FYM	0.54	0.18	0.60
Gliricidia (green basis)	0.67	0.08	0.45

Statistical analysis

The data obtained from the experiment were subjected to statistical analysis using OPSTAT-based software in CRD. To compare the treatment means, the relevant standard error of the mean (SEM) was determined in each case, as well as the critical difference (CD) at a 5% level of probability.

Results and Discussion

Organic matter decomposition in the soil is a stepwise microbial-mediated process; initially, ammonium ions are formed followed by nitrite and then nitrate [5]. The data about the mineralization of nitrogen i.e. ammoniacal and nitrate nitrogen within two soil depths (0-10 and 10-20 cm) is given in Tables 2 and 3, respectively. The data showed that, in the control treatment (T1), the nitrogen content of soil continuously goes on decreasing, throughout the incubation period which was again significantly least (48.84 and 20.93 mg kg^{-1} for ammoniacal and nitrate-N) after 30 days of incubation. In the rest of the treatments, the highest mineralization occurs within 30 days of incubation. The chemically fertilized treatments i.e. T2 (100% NP) and T3 (100% NPK) showed a reduction of nitrogen content from 45 days of incubation. While organic treatments i.e. T4 (100% RDN_{FYM}) and T5 (100% RDN_{Gl}) were just sufficient to maintain the rate

Table 2. Periodic mineralization of ammoniacal nitrogen (mg kg^{-1}) under different treatments

Treatments		0-10 cm Soil					10-20 cm Soil				
		15 days	30 days	45 days	60 days	75 days	15 days	30 days	45 days	60 days	75 days
T1	Control	49.24	48.84	48.02	47.27	46.21	48.69	47.99	47.58	47.19	44.63
T2	100 % NP (30:75 NP kg ha^{-1})	51.11	52.77	51.65	51.08	49.80	49.81	51.36	50.77	49.92	47.58
T3	100 % NPK (30:75:25 kg ha^{-1})	55.12	56.20	55.44	55.23	52.96	54.06	55.07	54.56	53.92	51.65
T4	100 % RDN_{FYM}	50.17	50.59	50.98	50.39	49.28	49.49	50.05	50.79	50.26	47.81
T5	100% RDN_{Gl}	49.17	49.53	49.87	48.80	48.37	49.02	49.17	49.87	49.42	46.99
T6	50% RDNGl + 50% N_{Inorg} + 100% P	55.46	56.27	56.63	55.79	53.07	54.95	55.39	55.71	54.78	52.49
T7	50% RDNGl + 50% N_{Inorg} + 100% P+ 25 kg K ha^{-1}	53.55	57.08	57.57	56.67	55.05	55.73	56.31	57.02	56.93	53.83
SE (m) ±		1.26	2.04	2.13	2.12	1.61	1.69	1.61	1.71	1.69	1.98
CD at 5%		3.82	6.20	6.46	6.44	4.87	5.14	4.88	5.18	5.12	6.00

Table 3. Periodic mineralization of nitrate nitrogen (mg kg^{-1}) under different treatments

Treatments		0-10 cm Soil					10-20 cm Soil				
		15 days	30 days	45 days	60 days	75 days	15 days	30 days	45 days	60 days	75 days
T1	Control	21.14	20.93	20.58	20.26	20.22	20.87	20.57	20.39	20.30	19.98
T2	100 % NP (30:75 NP kg ha^{-1})	21.99	22.40	22.14	21.89	21.72	21.45	22.05	21.73	21.44	21.19
T3	100 % NPK (30:75:25 kg ha^{-1})	23.60	24.09	23.76	23.67	23.41	23.17	23.60	23.38	23.11	22.99
T4	100 % RDN_{FYM}	21.50	21.68	21.85	21.60	21.50	21.21	21.45	21.77	21.54	21.35
T5	100% RDN_{Gl}	21.07	21.23	21.37	20.91	21.11	21.01	21.07	21.37	21.18	21.00
T6	50% RDN_{Gl} + 50% N_{Inorg} + 100% P	23.89	24.14	24.27	23.91	23.13	23.55	23.81	23.88	23.39	23.35
T7	50% RDN_{Gl} + 50% N_{Inorg} + 100% P+ 25 kg K ha^{-1}	24.18	24.46	24.72	24.23	23.97	24.01	24.17	24.53	24.21	23.77
SE (m) ±		0.68	0.74	0.92	0.91	0.74	0.75	0.77	0.76	0.80	0.84
CD at 5%		2.08	2.26	2.80	2.76	2.24	2.26	2.32	2.31	2.41	2.54

of mineralization. The integrated nutrient management treatments particularly treatment T7 (50% RDN_{Gl} + 50% N_{Inorg} + 100% P + 25 kg K ha^{-1}) showed increased mineralization of nitrogen up to 45 days, and again at 75 days, indicating that the presence of sufficient quantity of available nutrients in soil has enhanced the microbial activity, hence the mineralization of nitrogen in the soil amended with INM treatment. Sub-surface soil layer i.e. 10-20 cm also exhibited a similar trend however, the magnitude of mineralization was significantly lower than that of surface soil constrained by the availability of nutrients and activity of soil micro flora. Irrespective of the incubation period, within the different treatments the higher mineralization of nitrogen was observed in treatment T7 with the application of 50% RDN_{Gl} + 50% N_{Inorg} + 100% P + 25 kg K ha^{-1}, followed by T6 (50% RDN_{Gl} + 50% N_{Inorg} + 100% P), and T3 (100% NPK).

Further, the chemically fertilized treatments i.e. T2 (100% NP) and T3 (100% NPK) resulted in higher mineralization up to 30 days of incubation while in the case of organics i.e. T4 (100% RDN_{FYM}) and T5 (100% RDN_{Gl}) higher mineralization was observed up to 45 days indicating the slow release of nitrogen. This was due to due to lack of a sufficient quantity of nutrients in the soil to carry out the net mineralization process. These results are similar to the findings of Bhat and Kuchroo [6], and Vivanco and Austin [7]. The highest mineralization of N in T7 (50% RDN_{Gl} + 50% N_{Inorg} + 100% P + 25 kg K ha^{-1}) was due to an additional supply of N and P. This was also supported by the studies of Song et al. 2011 [8]. They observed an increased rate of decomposition with the increase in N availability, as N is responsible for improving the quality and degradability of plant remains as well as enhancing microbial activity. According to Chen et al., [9], not only nitrogen but also phosphorus can support improved decomposition by stimulating microbial growth. A decline in N mineralization after 45 days in the present manuring experiment could be due to the immobilization of nitrogen.

Mineralization of organic carbon

The data pertaining to the mineralization of organic carbon in soil are presented in Table 4. It can be seen that the organic carbon content of the soil was lowest in treatment T1 (control) throughout the period of incubation. Since, the mineralization of nutrients particularly nitrogen, phosphorus, and sulfur require the presence of a sufficient source of carbon in the soil, it was depleted throughout the incubation period. In chemically fertilizer treatments i.e. T2 (100% NP) and T3 (100% NPK), abundant growth of above ground and below ground biomass may have contributed to the organic matter of the soil and hence these treatments were just sufficient to maintain the mineralization rate of organic carbon in the soil. In the sole organic treatments i.e. T4 (100% RDN_{FYM}) and T5 (100% RDN_{Gl}), gliricidia and FYM as a source of nitrogen were added and hence it goes on steady microbial decomposition which was again reflected in the ability of organic treatments to maintain the organic carbon content of the soil.

Table 4. Periodic mineralization of organic carbon (mg kg^{-1}) under different treatments

Treatments		0-10 cm Soil					10-20 cm Soil				
		15 days	30 days	45 days	60 days	75 days	15 days	30 days	45 days	60 days	75 days
T1	Control	6.42	6.40	6.36	6.35	6.33	6.40	6.32	6.35	6.34	6.32
T2	100 % NP (30:75 NP kg ha^{-1})	6.48	6.47	6.48	6.46	6.45	6.46	6.45	6.46	6.43	6.41
T3	100 % NPK (30:75:25 kg ha^{-1})	6.55	6.56	6.58	6.57	6.56	6.52	6.53	6.55	6.54	6.52
T4	100 % RDN_{FYM}	6.49	6.47	6.48	6.46	6.45	6.46	6.45	6.47	6.45	6.44
T5	100% RDN_{Gl}	6.47	6.46	6.47	6.45	6.44	6.45	6.43	6.46	6.44	6.43
T6	50% RDN_{Gl} + 50% N_{Inorg} + 100% P	6.59	6.58	6.60	6.59	6.58	6.57	6.59	6.60	6.59	6.56
T7	50% RDN_{Gl} + 50% N_{Inorg} + 100% P+ 25 kg K ha^{-1}	6.61	6.60	6.62	6.61	6.59	6.59	6.61	6.63	6.62	6.61
SE (m) ±		0.04	0.04	0.05	0.05	0.05	0.04	0.06	0.05	0.05	0.05
CD at 5%		0.13	0.12	0.15	0.16	0.16	0.12	0.18	0.16	0.16	0.15

However, in INM treatments i.e. T6 (50% RDN_{Gl} + 50% N_{Inorg} + 100% P) and T7 (50% RDN_{Gl} + 50% N_{Inorg} + 100% P + 25 kg K ha^{-1}), the organic carbon content of soil during 15 days was increased at 45 days of incubation. The organic carbon in Indian soils because of higher temperature goes on decreasing with continuous cropping and the absence of any organic source of nutrients. Therefore, the INM treatments in this experiment showed increased or fairly maintenance of organic carbon in the soil. In 10-20 cm depth of soil, a similar trend of organic carbon was observed as in the case of 0-10 cm depth but the quantity of organic carbon in 10-20 cm depth of soil was less as compared to 0-10 cm depth. These results are similar to the findings of different researchers [10-12].

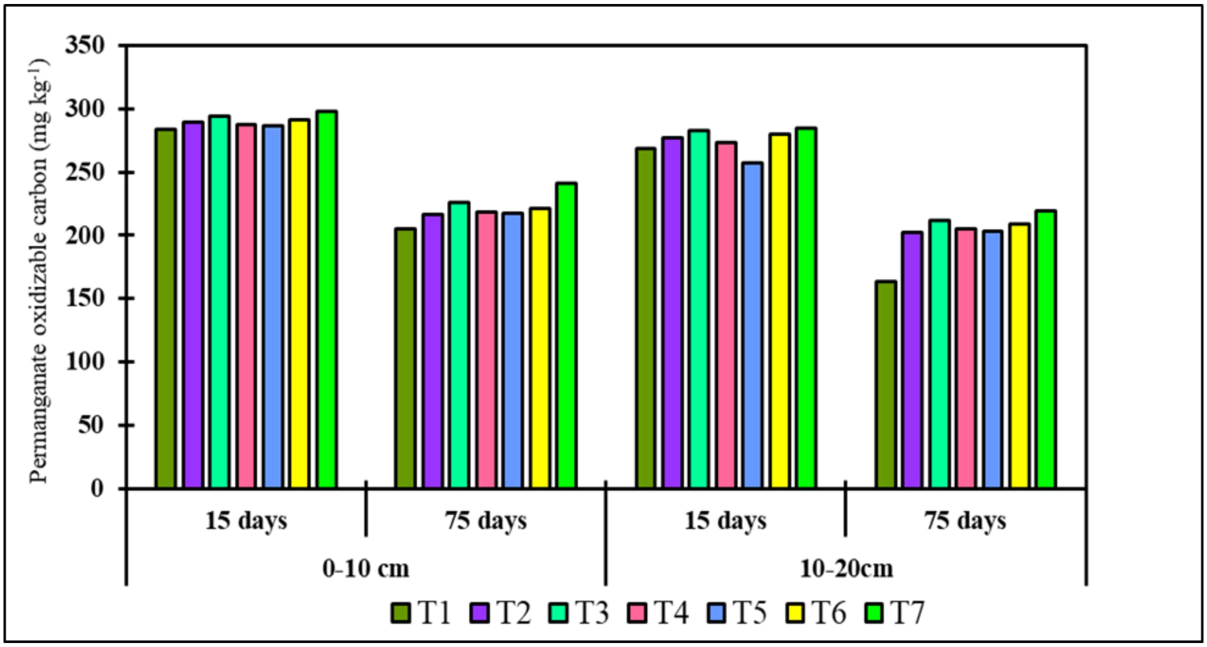

Figure 1. Periodic mineralization of permanganate oxidisable carbon (mg kg-1) under different treatments
T1: Control, T2: 100 % NP (30:75 NP kg ha^{-1}), T3: 100 % NPK (30:75:25 kg ha^{-1}), T4: 100 % RDN$_{FYM}$, T5: 100% RDN$_{Gl}$, T6: 50% RDN$_{Gl}$ + 50% N$_{Inorg}$ + 100% P, T7: 50% RDN$_{Gl}$ + 50% N$_{Inorg}$ + 100% P + 25 kg K ha^{-1}

Permanganate oxidizable carbon

The mineralization of permanganate oxidizable carbon (POXC) or labile fraction of organic carbon was studied for 15 and 75 days after incubation. In both the soil depths (0-10 and 10-20 cm) there occurs a reduction in the content of POXC from 15 to 75 days (Figure 1). Throughout the incubation period, POXC was lowest in treatment T1 (Control), significantly higher in chemically fertilized i.e. T2 (100% NP) and T3 (100% NPK), organic treatments i.e. T4 (100% RDN$_{FYM}$) and T5 (100% RDN$_{Gl}$) as well as INM treatments i.e. T6 (50% RDN$_{Gl}$ + 50% N$_{Inorg}$ + 100% P) and T7 (50% RDN$_{Gl}$ + 50% N$_{Inorg}$ + 100% P + 25 kg K ha^{-1}). Further, these treatment sets were statistically at par with each other. Further, it can be seen that at 15 days the magnitude of difference in POXC in T1 (Control) and other treatments was lowest, but, at 75 days of incubation, treatment T7 (50% RDN$_{Gl}$ + 50% N$_{Inorg}$ + 100% P+ 25 kg K ha^{-1}) had about 17 and 27% higher POXC than T1 (Control) in 0-10 and 10-20 cm soil depth, respectively. This indicates that INM fertilized treatments are capable of supplying a sufficient quantity of labile carbon in the soil which plays a very crucial role in improving soil biotic activity and thus nutrient transformations. The carbon from the organic manures disappears in two stages, the first consistent with a fast pool (easily decomposable) and a slower pool. The POXC is regarded as the labile fraction of organic carbon which undergoes rapid decomposition in soil. These results are in conformity with the findings of Manna et al., [13].

SOC stock

The total SOC stock of soil for the 0-20 cm soil depth under various treatments is depicted in Figure 2. It was observed that SOC stock declined with the days of incubation in most of the treatments, particularly in T1 (Control), but INM amended treatments i.e. T6 (50% RDN$_{Gl}$ + 50% N$_{Inorg}$ + 100% P) and T7 (50% RDN$_{Gl}$ + 50% N$_{Inorg}$ + 100% P + 25 kg K ha^{-1}) were capable of maintaining the SOC stock throughout the incubation period. Since SOC stock consists of various fractions of organic carbon with varying ease of decomposition and turnover period, the gliricidia application in INM treatments causes the release of easily decomposable carbon in the early period while intermediate and highly resistant components remained in the soil. The SOC stock in treatment T7 (50% RDN$_{Gl}$ + 50% N$_{Inorg}$ + 100% P + 25 kg K ha^{-1}) was increased by 2.93, 4.24, and 4.31% as compared to T1 (Control), after 15, 45, and 75 days of incubation, respectively. Similar results were also reported by Benbi et al., and Srinivasarao et al., [14-15].

Relationship between ammoniacal and nitrate nitrogen with organic carbon content

For the data pooled across treatments, soil depths, and incubation period, the content of ammoniacal and nitrate nitrogen was linearly and significantly related to OC content (Figures 3 and 4). The relationship could best be described by linear regression (Eq. 1-2).

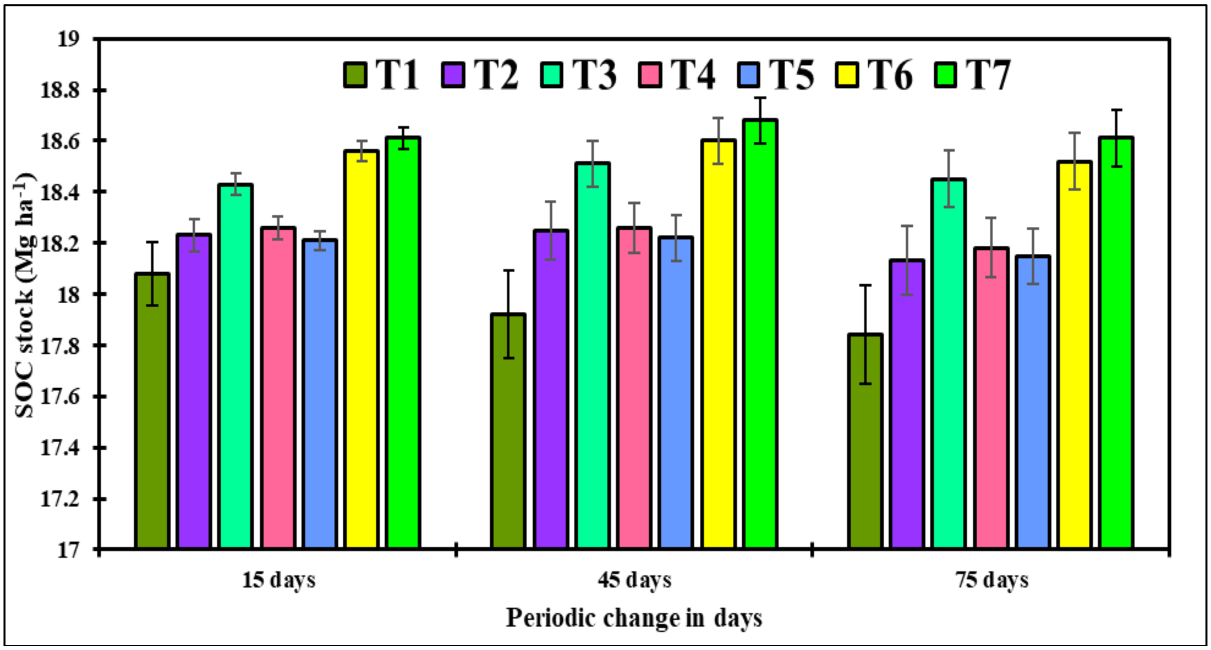

Figure 2. SOC stock in soil under different treatments at periodic intervals
T1: Control, T2: 100 % NP (30:75 NP kg ha^{-1}), T3: 100 % NPK (30:75:25 kg ha^{-1}), T4: 100 % RDN$_{FYM}$, T5: 100% RDN$_{Gl}$, T6: 50% RDN$_{Gl}$ + 50% N$_{Inorg}$ + 100% P, T7: 50% RDN$_{Gl}$ + 50% N$_{Inorg}$ + 100% P + 25 kg K ha^{-1}

The gliricidia application resulted in an increase of organic carbon in the soil which might have provided a favorable effect on ammoniacal and nitrate nitrogen in the soil. A similar positive relationship between organic carbon and nitrogen content was also observed by Singh and Benbi [16].

$$OC\ (g\ kg^{-1}) = 0.0242\ \times Ammoniacal\ N + 5.2404;\ \ R^2\ = 0.886 \qquad (1)$$

$$OC\ (g\ kg^{-1}) = 0.0595\ \times Nitrate\ N + 5.1659;\ \ R^2\ = 0.9283 \qquad (2)$$

Conclusion

Our study concludes that gliricidia leaves decompose quickly and release maximum nitrogen within 45 days in both surface applied and sub-surface conditions. It increases mineralization and mineral N pools in the soil. The net mineralized organic-N is positive in soil with the integrated application of gliricidia leaves and inorganic fertilizers (T6 and T7). The release of easily decomposable permanganate oxidizable carbon during initial days of incubation may have improved the mineralization and nutrient release from gliricidia green leaves. In the treatments receiving only organics (T4 and T5) or only chemical fertilizers

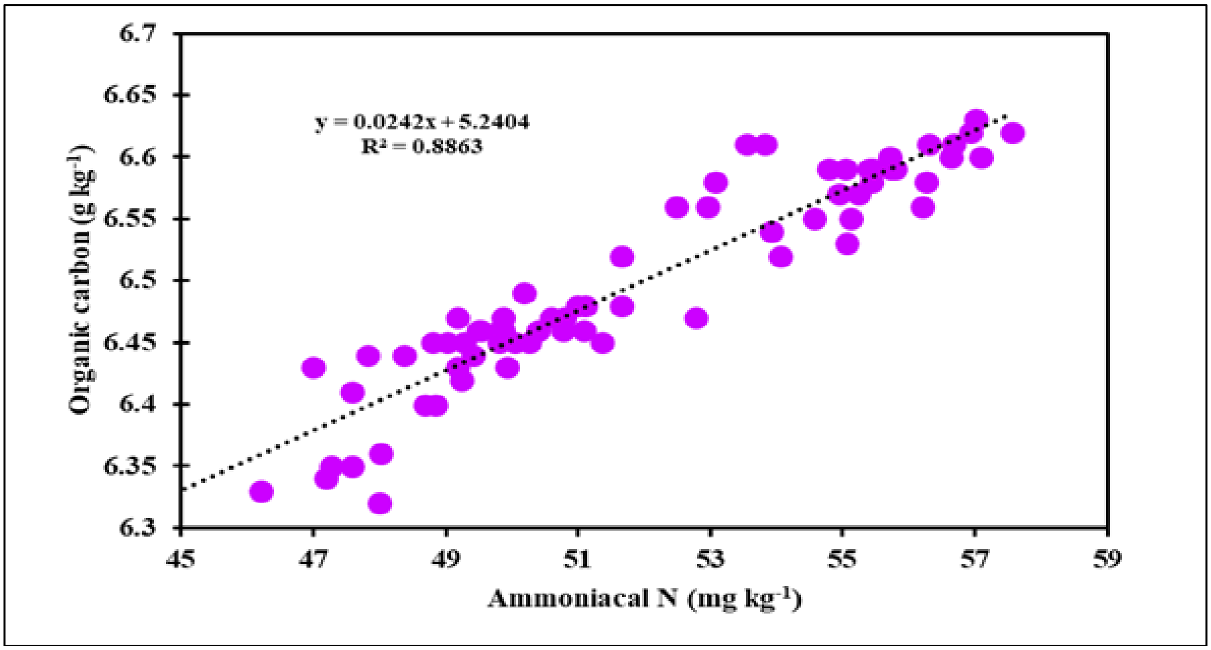

Figure 3. Relationship between organic carbon and ammoniacal nitrogen. Data pooled for treatments, soil depths, and incubation period. Points represent measurements, and the line represents the best fit to a linear function

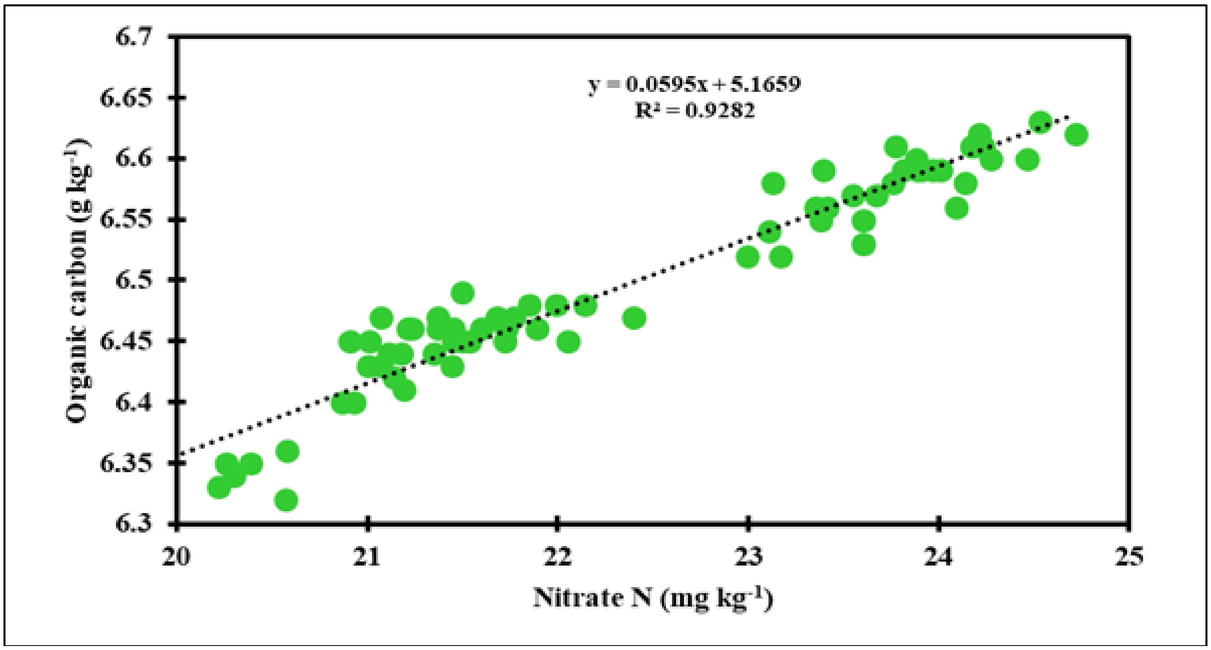

Figure 4. Relationship between organic carbon and nitrate nitrogen. Data pooled for treatments, soil depths, and incubation period. Points represent measurements, and the line represents the best fit to a linear function

(T2 and T3), the mineralization process was constrained by either lower substrate availability or nutrient availability. Therefore to get maximum benefits from the gliricidia green leaf manuring, it is advisable to integrate its application with mineral fertilizers taking into account that a major proportion of it undergoes decomposition within 45 days after its application.

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