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DECOMPOSITION AND NUTRIENT RELEASE OF SELECTED GREEN MANURE SPECIES AT DIFFERENT STAGES OF GROWTH ON ALISOLS AT AREKA, SOUTHERN ETHIOPIA

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ABSTRACT

Decline in soil fertility is major constraint to agricultural production and food security in Ethiopian highland farming systems. Since farmers have limited capacity to invest in fertilizers, potential solution to the problem is to use green manure (GM) for their multiple advantages. Thus, this study was conducted to determine optimum time for decomposition and nutrient release from GM at different ages. The treatments were three levels of age (3, 4 and 5) months after planting (MAP), three GM species (Tithoniadiversifolia, Tephrosiavogelii and Crotalaria juncea) and five times of decomposition (7, 14, 21, 28 and 35) days after incorporation (DAI) laid out in Split-split plot design with three replications. Age, species and decomposition time were assigned to the main, sub and sub-sub plots, respectively. The interaction effect of age, species and decomposition time was significant ($P < 0.05$) on soil pH, OM and NO_3^--N. During the decomposition process decline in soil pH was observed whereas other parameters increased as decomposition time extended. Organic matter increased from 4.45% (non-treated) to 5.76, 5.40 and 5.96% due to C. juncea, T. diversifolia and T. vogelii, respectively, 28 DAI. On plots treated by C. juncea, soil NO^-_3-N was increased by 17.60 and 12.10 mg kg^{-1} compared to the control (11.31 mg kg^{-1}) 35 and 21 DAI, respectively. In plots amended by T. diversifolia and T. vogelii the increment was 33.43 and 24.63 mg kg^{-1}, respectively, 21 DAI compared to the control. Total N, available P and K were significantly ($P<0.05$) influenced only by time of decomposition. Significantly higher N (1.80 g kg^{-1}) was observed at 28 and 35 DAI whereas higher available K (655.93 mg kg^{-1}) was obtained at 35 DAI.

Keywords: Green manure, Species, Age, Nutrient, Decomposition, Availability.

1. INTRODUCTION

Low soil fertility has been recognized as a fundamental biophysical cause for declining food production among small-farm households in Sub-Saharan Africa (SSA) [1]. According to Kumwenda, et al. [2], the low level of chemical fertilizer use and decline in soil organic matter (OM) contribute the most to the loss of soil fertility in the region. Therefore, in order to improve soil fertility, use of inorganic fertilizers to provide nitrogen (N), phosphorus (P) and potassium

(K), are important , however, mineral fertilizers are not an option for the majority of African subsistence farmers for being expensive [3].

Ethiopia is one of the countries situated in SSA and faces accelerated soil fertility reduction and consequently food shortage. The problems might be more in the case of the Southern Nations, Nationalities and Peoples' Regional State (SNNPRS) due to high population density and fragmented farm land as well as continues farming. According to Tilahun [4], soil fertility decline is the major constraint to agricultural production and food security in the Ethiopian highland farming systems. Farmers have very limited capacity to invest in fertilizers or soil conservation measures. As a result, yields are low and many farmers are forced to put fallow and marginal lands into production to meet their food needs [4].

According to Rutunga, et al. [5], use of local inputs such as farmyard manure, tree and shrub biomass that are easily available in the farm may be a realistic option to improve soil fertility. In a highly nutrient depleted soils, high amount (10 t or more on dry matter basis) of farmyard manure is needed to match the crop demand for nutrients but it is not available in such quantities [5]. Therefore, this insufficient availability of farmyard manures coupled with high costs of inorganic nutrient sources makes it increasingly important to re-examine GM crops [3]. Accordingly, green manuring with legumes and other GM species are recommended to maintain soil fertility particularly to provide N which is the most limiting nutrient for crop production [6].

Because of the quality, low cost, availability and other benefits to improve soil fertility and soil environment at large, promoting these GMs to the areas practicing small-scale farming systems like the SNNPRS is crucial. However, undertaking research on decomposition process which determines the time for nutrient release of the species at different ages is vital. Because, if legume GMs are to be considered effective N sources for crops, they must supply sufficient N and their N release must be in synchrony with crop N demand. Green manure decomposition and subsequent N release depend largely on residue quality and quantity, soil moisture and temperature, soil texture, mineralogy and acidity, biological activity, and the presence of other nutrients in sufficient quantities [7]. According to Kong, et al. [8], amount of biomass and N provided by the GM crops depend on growth stage at the time of incorporation. Selection of suitable legume species and age at termination determines the amount of biomass, N accumulation and the rate of nutrients release in available form.

In line with these, Thonnissen [9] reported that legume biomass accumulation and chemical composition such as C:N ratio, N, lignin, polyphenol and tannin contents of plants of the same age varied between location and growing season. These variations make it difficult to predict their decomposition and nutrient release rates when grown under different conditions. Generally, as Gabriela, et al. [10] reported, in order to develop more efficient systems to improve soil nutrient dynamics, a well-synchronized balance must be established between high crop demands and the supply of nutrients from decomposition process. This implies that to benefit farmers from green manure species, their decomposition and nutrient contribution to the soil should be studied. This investigation was, therefore, initiated to determine the optimum time for decomposition and nutrient release from selected green manure species and their effect on soil fertility.

2. MATERIALS AND METHODS

This field experiment was conducted at Areka Agricultural Research Center in Wolaita Administrative Zone of the Southern Nations, Nationalities and Peoples' Regional State (SNNPRS). Geographically, it is situated at the coordinates of 7^{0}07' N and 37^{0}47' E with an average altitude of 1,800 meters above sea level (masl) and the area receives an average (1999 to 2008) annual rainfall of 1539 mm. The annual average air temperature at the study site is about 20.1 ^{o}C. The mean maximum and minimum air temperatures during the experimentation period were 24.9 and 14.2 ^{o}C, respectively [11].

The soils at the station are well drained with slopes ranging from 2 to 10% on the upper and middle elevations of the research fields. Generally, the soils vary from loam through silt loam to clay loam in texture. Structurally, the soils have sub angular blocky structure with good porosity on the surface layer (0-30 cm) and are very deep (> 150 cm) [12]. Chemically, the soils in the farm are very strongly to moderately acid reaction with pH of the surface 0-30 cm depth ranging between 4.8 and 5.6 and contain 2.65 to 5.67% OM, 0.182 to 0.531% total N and 1.2 to 4.3 mg kg^{-1}available phosphorus. Concerning the micronutrients, the soils contain relatively higher amounts of Fe and Mn ranging between 15.6 - 109 and 12.1 - 134.3 mg kg^{-1}, respectively. On the other hand, the amounts of Zn and Cu are low; which fall in the range of 1.1 - 29.0 and 0.0- 0.5 mg kg^{-1}, respectively. The major soil type of research fields of the center is Alisol [12].

The experiment was laid out in split-split plot designwith three replications. The treatments were three GM species (*Tithoniadiversifolia*, *Tephrosiavogelii* and *Crotalaria juncea*), three different ages of the GMs (three, four and five months) and five sampling days (7, 14, 21, 28 and 35 after incorporation). Ages, species and sampling days of the GMs were assigned to the main plots, subplot and sub-sub plots, respectively. Before the incorporation of the GMs, the field was prepared and cleaned manually from plant residues and any other decomposable materials. The treatments were applied on plots of 1.5 m x 1.5 m which were separated by 1 m and 1.5 m between plots and blocks, respectively. The plant parts (leaves + soft twigs) of the GMs were chopped uniformly into small pieces and the same amount (5 t ha^{-1}) of green foliage was applied to all plots in all replications at the same time except the control (no GM). The GMs were distributed evenly on the study plots and incorporated in to 0 to 15 cm soil depth.

Soil samples were taken every seven days interval for consequent five weeks after the GMs were incorporated into the soil. Soil samples were collected from 0-20 cm soil depth using auger from 10 randomly taken spots of each plot and composited. The samples taken from each plot were analyzed for particle size (texture), pH, organic carbon, total N, NH_4-N, NO_3-N, available P and available K contents following standard laboratory procedures developed for each parameters.

3. RESULTS AND DISCUSSION

Before the effects of GM on soil chemical properties were evaluated, the physiochemical properties of untreated soil (control) were measured. Based on the result of soil analysis measured from the non-treated plots, the surface soil (0-20 cm) was loam in texture while the pH was 5.5 (Table 1). The OM and N contents of the surface layer (0-20 cm) were high and medium, respectively (Table 1) [13]. Based on Ryan, et al. [14] who described the nitrate content of the soil as low (< 11 mg kg^{-1}), marginal (11-20 mg kg^{-1}) and adequate (> 20 mg kg^{-1}), the untreated soil met the requirement to be rated as marginal. The P content of the surface soil was 0.117 mg kg^{-1} and is classified as very low [15]. The K content of the soil was very high [16].

3.1. Soil pH

Soil pH was one of the parameters considered to see any changes due to the GMs. The interaction effects of the three factors (age, species and time of decomposition) were significant ($P < 0.05$) on soil pH. Generally, the results indicated decreasing trend in pH from 7 to 35 day after incorporation (DAI) except on plots treated with five month old *Tephrosiavogelii*at 7 and14 DAI (Table 2). On plots amended by *Crotalaria juncea*, except at 7 DAI, on all plots treated by all ages significantly ($P < 0.05$) lower pH was observed throughout the observation period. The lowest soil pH was recorded from plots amended by four months old *Crotalaria juncea*at 21 DAI (Table 2). And the reduction due to the GM decomposition was 0.37 compared with the control. Plots amended with *Tithoniadiversifolia*also affected soil pH at all ages starting from 7 DAI compared to the non-treated one (5.5). This could probably be due to the onset of decomposition. Significantly ($P < 0.05$) lower pH (5.10) was recorded at 35 DAI (Table 5) and the reduction in pH was 0.4 due to *Tithoniadiversifolia*added into the soil at three MAP. Similarly, lower pH (5.17) was observed on plots treated with three months old *Tephrosiavogelii.*

Many investigators agreed that decomposition of GM bring change on soil pH.Sangakkara*et al.* (2004) reported that addition of *Crotalaria juncea* and *Tithoniadiversifolia*decreased soil pH from 6.25 to 6.12 and from 6.25 to 6.18, respectively. Tisdale, et al. [15] stated that nitrification of one mole NH_4^+ produces 2 mole of H^+, and soil acidification is accelerated with application of NH_4^+ containing or forming fertilizers. Brady and Weil [17] stated that H^+ ions are generated as a net result of a complex series of reactions as OM decomposes. Accordingly, there is a considerable variation in pH of the soil solution at sites only a few centimeters apart. For example, soil pH of the rhizosphere immediately around the root is lower than in the surrounding because when NH_4^+ ions are absorbed by plants, they replace H^+ ions on the root surface, thereby reducing the pH reduction [18]. Sangakkara, et al. [19] also reported that decomposition of organic residues affect soil pH usually causing or aggravating acidity. Therefore, the variation on soil pH observed in the present study could probably be due to the hydrogen ions added in to the soil solution during the decomposition process.

3.2. Soil Organic Matter

Interaction effect of age, plant species and decomposition time were significant on soil OM content. Accordingly, significantly ($P < 0.05$) higher OM was measured at 28 and 35 DAI on the experimental plots treated by 3 month old *Crotalaria juncea*(Table 3). At 28 and 35 DAI soil OM increased from 4.45% (non-treated) to 5.76 and 5.34%, respectively, due to decomposed GM. However, on these days significant difference was not observed as age varied. Low soil OM contents were obtained at 7 and 14 DAI. Similarly, on plots amended with *Tithoniadiversifolia* higher OM was obtained at 28 DAI although significant difference was not observed 21 DAI and onward on all plots treated by different ages (Table 3). Soil OM was increased from 4.45% (non-treated) to 5.40% due to decomposed GM. On these plots treated with *Tithoniadiversifolia* low OM content was observed at 7 and 14 DAI. Soil OM was also significantly ($P < 0.05$) influenced on plots treated with *Tephrosiavogelii.* Higher OM content was recorded at 28 DAI though significant difference was not observed between 21, 28 and 35 DAI (Table 3). Soil OM was increased by 1.51% due to *Tephrosiavogelii*at 28 DAI.

Soil OM was similarly influenced as age increased from three to five MAP. This could probably be due to all these GM species were soft enough to breakdown by soil microorganisms since they were incorporated to the soil before flowering, and this could be expressed by the water content measured from the leaves of the GM. The water content was not changed as age increased. For *Crotalaria juncea* 87.5, 87.3 and 87.0%; for *Tithoniadiversifolia* 85.2, 85.0 and 84.7% and for *Tephrosiavogelii*77.9, 75.3 and 72.6% water content was measured at three, four and five MAP, respectively.

As an evidence for the findings of the present study, Shokalu, et al. [20] reported that *Tithoniadiversifolia* improved OM content of the soil amended by fresh leaves and young stem. Based on result, the OM content of the soil amended by 2.5, 5, 7.5, 10, and 20 t ha^{-1} fresh leaves and young stem was increased from 1.14% (untreated) to 1.27, 1.28, 1.33, 1.37 and 1.45%, respectively. In line with this, Sangakkara, et al. [19] reported that additions of *Crotalaria juncea* and *Tithoniadiversifolia* over 3 seasons increased soil OM content by 8 and 12%, respectively, when compared with untreated soil. According to Njeru, et al. [21], OM of the soil amended by *Tithoniadiversifolia* increased from 4.96 to 5.41%.

3.3. Mineralization of Organic Nitrogen

Nitrate and ammonium N on GM treated plots were not significantly ($P < 0.05$) influenced by age and species difference of the GM. However, significant difference ($P < 0.05$) was observed among time of decomposition. Generally, NO^{-}_{3}-N was the dominant inorganic N as compared to NH_4-N in the soil. This could probably be due to rapid nitrification [22].

Interaction effect of age, species and time of decomposition on soil NO^{-}_{3}-N content was significant. Accordingly, on plots treated with *Crotalaria juncea* significantly ($P < 0.05$) higher NO^{-}_{3}-N was obtained at 35 DAI although not significantly differ from 21 DAI (Table 4). The increment due to decomposition of 4 month old Crotalaria was 17.6 mg kg^{-1} which accounts 155.6 at 35 DAI, while 11.31 mg kg^{-1} was measured from the control (Table 1). Although higher NO^{-}_{3}-N was measured from plots treated by three and four months old *Crotalaria juncea*, significant difference was not observed among ages.

On plots amended by *Tithoniadiversifolia* higher NO^{-}_{3}-N was obtained at 21 followed by 35 DAI (Table 4). During these times NO^{-}_{3}-N increased from 11.31 mg kg^{-1} (non-treated) to 33.43 and 30.41 mg kg^{-1} GM treated plots, respectively. Thus, the difference 22.12 and 19.10 mg kg^{-1} obtained at 21 and 35 DAI was contributed from the incorporated GM. Plots treated by *Tephrosiavogelii* also significantly influenced at 21 and 35 DAI (Table 4). Accordingly, NO^{-}_{3}-N increased by 24.63 and 18.85 mg kg^{-1} over the non-treated plot (11.31) due to GM. Generally, the GM species contributed higher NO^{-}_{3}-N to the soil at 21 DAI although there were some irregularities. At this day either higher NO^{-}_{3}-N was recorded or not significantly lowers than the highest value and this indicates mineralization was peaked at 21 DAI on plots treated by all the GM species.

This finding was in agreement with Carmen, et al. [23] who found that at three locations, N released in soil peaked from 36 mg kg^{-1} to 54.5 mg kg^{-1} with soybean GM. This peak N release occurred at 2 to 6 weeks after incorporation. In line with this, Mazzoncini, et al. [24] reported soil NO_3-N increased one month after incorporation of cover crop, presumably due to the onset of the mineralization process. Red clove and Crimoson clover showed the highest NO_3-N values of 43.03 and 41.52 mg kg^{-1}, respectively, between 30 and 44 days after incorporation [24].

In most comparison, plant chemical composition appeared to affect the decomposition rate of GMs. Among major constituents of the GMs, C:N ratio could be responsible for fast decomposition. The lower C:N ratio of most woody legumes enables them to decompose rapidly, thereby serving as efficient sources of nitrogen when used as GMs [25]. According to Palaniappan and Annadurai [26], when GM with very narrow C:N ratio, below 20:1 applied to the soil, the availability of N was more due to great mineralization. Olabode, et al. [27] also reported, lower C:N ratio of *Tithoniadiversifolia* compared to *chromolaena* and *panicum* indicated a faster rate of decomposition.

Therefore, this fast decomposition occurred in the present study, probably caused by their low C:N ratio and other qualities of the GMs. Ayuke, et al. [28] and Sangakkara, et al. [29] reported, 10.1:1 and 14.8:1 C:N ratio for *Tithoniadiversifolia* and *Crotalaria juncea*, respectively. These C:N ratios were by far narrower than 20:1 C:N ratio which was reported as dividing line between immobilization and mineralization [15]. In addition to C:N ratio, low lignin and polyphenols content of the GMs also responsibly for fast decomposition. According to Palm and Rowland [30], the overall level of secondary compounds (lignin and polyphenols) in *Tithoniadiversifolia* was low compared with foliage of many trees and shrubs. This quality of the GM might also have contribution for fast decomposition and thereby nutrient release.

In addition, the moisture content of the GMs may influence the decomposition process as expressed in Palaniappan and Annadurai [26]. In the present study, *Tithoniadiversifolia*, *Tephrosiavogelii* and *Crotalaria juncea* (leaves + soft twigs) was contained in average 85, 75 and 87% water, respectively. Therefore, this high water content could probably have contributed to the rapid decomposition. In line with this, Ayuke, et al. [28] reported that *Tithoniadiversifolia* contained 80% water that further contributed to rapid decomposition.

Many investigators have observed that soil physical condition also affected decomposition process. Decomposition of organic residue was slow in soil with higher clay content [31]. Because, microbial activity is controlled by soil physical conditions such as compaction, temperature and oxygen [32]. Therefore, good soil aeration or oxygen in the loamy soil (Table 1) of the experimental field may further contributed to fast decomposition.

Ammonium mineralization was influenced by the interaction effect of species and time of decomposition was significant ($P < 0.05$) on (Figure 1). Accordingly, plots treated with *Crotalaria juncea* had significantly ($P < 0.05$) lower NH^+_4-N at 7 DAI whereas no significant difference was recorded between 14 and 35 DAI. On the plots treated by *Tithoniadiversifolia* significant difference was not observed throughout the observation period but, relatively higher and lower amount of NH^+_4-N was recorded at 28 and 7 DAI, respectively. Similarly, on *Tephrosiavogelii* treated plots, there was no significant difference between 7, 14, 21, 28 and 35 DAI. In comparison across species, soil NH^+_4-N was not differently influenced by the GM.

Generally, there was low NH^+_4-N compared to NO^-_3 -N which could probably be due to the high conversion rate of NH^+_4-N to NO^-_2 and NO^-_3 by the process of nitrification, or it may be utilized by heterotrophic organisms in further decomposing organic carbon residues and/or it may be released back to the atmosphere as NO_2 [15].

3.4. Soil Nitrogen, Phosphorus and Potassium Content of the Soil

Total soil N, available P and K did not significantly differ in plots treated by GMs species and ages. However, soil N, P and K were significantly ($P < 0.05$) affected by time of decomposition (Table 8). Total N was significantly ($P < 0.05$) higher at 28 and 35 DAI, and it was increased from 0.124% in the non-treated to 0.180% treated with GM (Table 5). The lowest N was obtained at 7 DAI and there was no significant difference between 14 and 21 DAI. The onset of decomposition appeared 7 DAI since variation in total N was recorded this day onward. This finding was in agreement with Agyenim [33] who reported that total N increased from 0.14 to 0.18% within 4 weeks after application of GM. Fosu, et al. [34] reported that within the first two weeks of application, 47 and 26% dry matter was lost from *Crotalaria juncea* and velvet bean *(Mucuna)*, respectively. This represents N release of 50% from *Crotalaria juncea* and 25% in *Mucuna*. In agreement with the current study, high N release was reported at 38 DAI at which losses of 67 and 53% of the dry matter were recorded from *Crotalaria juncea* and *Mucuna*, respectively [34]. These represent N release of 71% in *Crotalaria juncea* and 51% in *Mucuna*. Tisdale, et al. [15] also reported that most of the N in the GMs became available within the first 2 to 4 weeks after application of organic materials.

At the first week of observation, significantly lower available P was observed (Table 5) which was similar to the non-treated plot (Table 1), although it did not significantly differ from 14 DAI. Significantly higher P was obtained at 35 DAI and available P increased from 0.117 in non-treated plots to 0.167% treated with GM. Available soil K was significantly higher at 35 DAI, but was at par with the K recorded at 21 DAI (Table 5). Available K was significantly ($P < 0.05$) lower at 7 and 14 days of observation; however, it was better than the control. Generally, the trend showed an increment of N, P and K as decomposition time extended from 7 to 35 DAI.

Almost all mineralization studies focused on inorganic N (NO_3-N and NH_4-N). Therefore, very limited information may be available concerning the effects of GMs on soil total N, available P, available K, OM and pH. As evidence to the present study, Gomes, et al. [35] reported that 90% of the K contained in the leaves of *Crotalaria juncea* was released during the first two weeks of decomposition. Cobo, et al. [36] also assessed decomposition and nutrient release of 12 plant materials at field study and reported that leaves of *Tithoniadiversifolia* and indigofora decomposed quickly and available K had the highest release rate. According to Sangakkara, et al. [19], the level of N, P and K in the soil treated with GMs were significantly greater than the untreated soil. Unlike the current study, Sangakkara, et al. [19] reported significant differences among species. Application of *Crotalaria juncea* increased soil N to a greater extent, while addition of *Tithoniadiversifolia* increased P content of the soil.

4. CONCLUSION

During the decomposition process decline in soil pH was observed whereas other parameters increased as decomposition time extended. It is well known that organic materials continue to decompose and release their nutrients till the decomposition process is completed. Similarly, in the present study, continuous variation was observed starting from the first observation in most of the GM species incorporated at different stages of growth. In conclusion, more attention should be given to NO_3-N and NH_4-N since they reflect the onset of mineralization process and to total N and available K, as they are highly concentrated in the leaves plus soft twigs of the GM species. This work confirmed that these GMs decompose rapidly, and revealed the trends of the decomposition process. For most of the important nutrients which are adequately concentrated in the leaves + soft twigs of the GMs, 21 DAI appeared to be the optimum time for their availability. One very important point that should be addressed in order to complete this work is studying the rate and critical time for N and K requirement of the crops to be produced using these GMs.

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Figure-1. Interaction effect of decomposition time and plant species on NH_4^+-N release

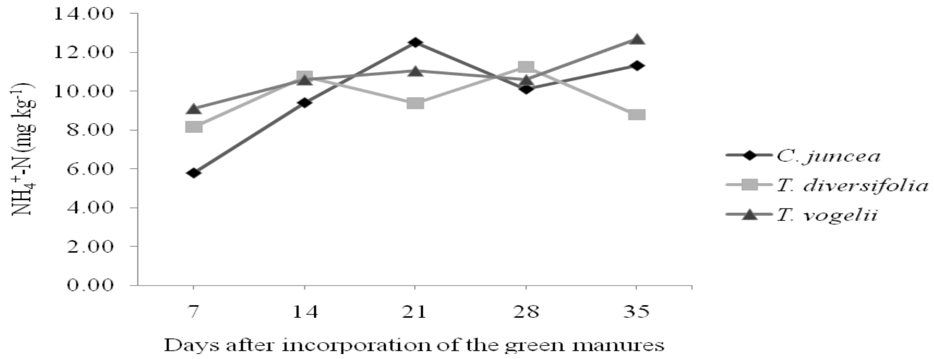

Table- 1. Physiochemical properties of soil of the experimental field (0-20 cm) measured from non-treated plots

Para-meter	Particle size (%)			Tex-ture	pH (H_2O)	*OM (%)	TN (%)	------- mg kg^{-1} -------			
	Sand	Silt	Clay					NO_3-N	NH_4-N	AP	AK
Value	36	39	25	Loam	5.5	4.45	0.124	11.31	9.0	0.117	540.7

*OM = Organic matter; TN = Total nitrogen; AP = Available phosphorus; AK = Available potassium

Table-2. Interaction effects of decomposition time, age and plant species on soil pH

Time (DAI)	Age (MAP)	Species		
		Crotalaria	Tithonia	Tephrosia
7	3	5.50bc	5.33fgh	5.33fgh
	4	5.2jkl	5.47bcd	5.43cde
	5	5.2jkl	5.30ghi	5.60a
14	3	5.33fgh	5.26hij	5.33fgh
	4	5.30ghi	5.47bcd	5.37efg
	5	5.23ijk	5.43cde	5.53ab
21	3	5.30ghi	5.27hij	5.23ijk
	4	5.13lm	5.13lm	5.40def
	5	5.20jkl	5.23ijk	5.20jkl
28	3	5.33fgh	5.20jkl	5.20jkl
	4	5.20jkl	5.20jkl	5.33fgh
	5	5.27hij	5.13lm	5.40def
35	3	5.30ghi	5.10m	5.17klm
	4	5.23ijk	5.20jkl	5.20jkl
	5	5.23ijk	5.20jkl	5.27hij

*Means followed by the same letter across column and row are not significantly different at $P < 0.05$. DAI= Days after incorporation; MAP = Month after planting

Table-3. Interaction effects of age, species and decomposition time on soil organic matter (%)

Time (DAI)	Age (MAP)	species Crotalaria	Tithonia	Tephrosia
7	3	3.38ghi	3.82f-i	4.59b-g
	4	4.32c-h	3.91e-i	4.67b-f
	5	4.06e-i	4.56b-g	2.93i
14	3	3.17hi	3.83f-i	4.61b-f
	4	4.33c-h	3.93e-i	4.69b-f
	5	4.08d-i	4.57b-g	2.94i
21	3	4.32c-h	4.71b-f	4.77a-f
	4	4.37c-h	4.28c-h	5.07a-f
	5	4.24c-h	4.68b-f	4.68b-f
28	3	5.76ab	4.91a-f	4.97a-f
	4	4.91a-f	5.40abc	5.49abc
	5	4.75a-f	4.66b-f	5.96a
35	3	5.34abc	5.02a-f	5.33a-d
	4	4.98a-f	5.10a-e	5.12a-e
	5	5.01a-f	4.81a-f	5.09a-e

*Means followed by the same letter across column and row are not significantly different at $P < 0.05$; DAI= Days after incorporation; MAP = Month after planting

Table-4. Interaction effects of age, GM species and decomposition time on nitrate N (mg kg^{-1})

Time (DAI)	Age (MAP)	Species Crotalaria	Tithonia	Tephrosia
7	3	9.80p	16.34m-p	21.87e-o
	4	23.69c-n	18.35i-o	16.84l-p
	5	16.34m-p	20.61f-o	26.14b-j
14	3	18.85h-o	21.36e-o	21.11e-o
	4	18.34i-o	19.85g-o	22.12d-o
	5	18.85h-o	18.10j-o	15.08op
21	3	21.87e-o	17.84k-o	28.40b-f
	4	22.37c-o	33.43ab	35.94a
	5	23.37c-n	24.13c-m	27.90b-g
28	3	19.85g-o	22.37c-o	18.85h-o
	4	25.13c-k	20.36f-o	21.87e-o
	5	23.62c-n	15.83nop	26.39b-i
35	3	26.89b-h	26.89b-h	26.89b-h
	4	28.91a-e	21.86e-o	19.86g-o
	5	24.88c-l	30.41abc	30.16a-d

*Means followed by the same letter across column and row are not significantly different at $P < 0.05$. DAI= Days after incorporation; MAP = Month after planting

Table 5. Main effects of decomposition time on nutrient release from green manures

Treatment Time (DAI)	**TN (%)**	**Ava.P (mg kg^{-1})**	**Ava.K (mg kg^{-1})**
7	0.126c	0.116c	566.11c
14	0.164b	0.127bc	571.85c
21	0.168b	0.137b	641.11ab
28	0.180a	0.141b	616.37b
35	0.180a	0.167a	655.93a
Mean	0.164	0.138	610.27
LSD (5%)	0.011	0.014	32.241
CV%	12.206	18.786	9.737

*Main effect means followed by the same letter are not significantly different at $P < 0.05$. DAI = Days after incorporation; TN = Total nitrogen; Ava.P = Available phosphorus; Ava.K = Available potassium; LSD = Least significant difference; CV = Coefficient of variation.