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Research Article

Decomposition Dynamics of Leaf Litter Mixtures Enriched with NPS Fertilizer and Resultant Effects on Common Bean Productivity in Nutrient Depleted Soil

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Organic materials have a nonreplaceable role to improve soil quality and productivity. Yet, processes related to decomposition and nutrient supply capacity are restricted under nutrient-depleted soils. Thus, a field experiment was conducted to evaluate the decomposition rate of leaf litter mixtures treated with mineral nitrogen (N), phosphorous (P), and sulfur (S) fertilizer in the form of NPS ($19N38P_2O_57S$), and their effects on agronomic performance of common bean (*Phaseolus vulgaris* L.). The mixtures of croton (*Croton macrostachyus*) and erythrina (*Erythrina brucei*) leaf litters (LLs) were placed at 20 cm depth in a litterbag at a rate equivalent to 2.5 and 5 t/ha, and treated with four NPS rates (0, 50, 100, and 150 kg/ha). The leaf litters have low carbon (C) to N ratio. The experiments (litterbag and crop response) were laid out in a randomized complete block design with three replications. The decomposition pattern was monitored at a two week interval (15, 30, 45, and 56 days after application) and assessed for daily decomposition rate (k), weight loss, and time required to decompose half of the residue (t_{50}). For the crop response experiment, selected growth and yield component parameters, and grain yield data were recorded. The results indicated that NPS fertilizer and the amount of LL were significantly ($p < 0.01$) influenced the k values and weight loss. The k at 14 days varied from 4.47% day^{-1} (150 NPS kg/ha × 2.5 t LL/ha) and 2.75% day^{-1} (sole 2.5 t/ha LL) in which application of mineral NPS fertilizer enhanced k by 62.5%. The k values, averaged over 56 days, revealed 2.68% day^{-1} (150 kg NPS/ha × 2.5 t LL/ha), and 1.78% day^{-1} in the unfertilized 2.5 LL. The decay rate was faster within 14 days and declined afterward. Over 56 days, 60.4% and 46.6% of the original mass remained in litters without NPS fertilizer, and 150 NPS kg/ha x 2.5 t LL/ha, respectively. The residue weight loss also significantly decreased with time ($r^2 > 0.98$). Half-lifetime was significantly ($p < 0.001$) decreased with the increasing rate of NPS application ($r = -0.86$). The t_{50} values, averaged over 56 days, were between 38.9 days (nontreated LL) and 27.8 days (150 kg NPS/ha), respectively. The result regarding agronomic performance indicated that the application of NPS fertilizer on the leaf litters significantly ($p < 0.01$) increased the growth, yield component, and grain yield of common bean. For instance, 150 kg NPS/ha on 2.5 t/ha LL has resulted in a 79% grain yield advantage over LL without NPS. Grain yield also showed significant relationship ($p < 0.01$) with k ($r = 0.67$), mass loss ($r = -0.67$), and t_{50} ($r = -0.66$). The finding suggests that for plant residues with a narrow C/N ratio in nutrient-depleted soils, the addition of mineral NPS fertilizer is advantageous for increased decomposition and yield of legume crops.

1. Introduction

Maintaining soil health is an increasing interest to researchers and policymakers to meet the ever-growing global demand for agricultural production to meet food and energy requirements. The effort is very challenging, especially in developing countries such as those in sub-Saharan Africa (SSA), for example, Ethiopia, where rapid population growth further fuels the degradation of natural resources and diminishes agriculturally suitable lands. Thus, understanding the soil processes as well as knowledge-based management of resources can improve soil productivity. In this regard, the use of plant litter and organic nutrient sources are among popular management practices to restore the soil ecosystem [1].

Litters of plant origin are sources of organic matter and play a vital role in soil quality as it influences soil physical properties, nutrient availability, and soil microbial activity as well as crop yield [2–5]. Organic materials are considered to be a storehouse and source of several essential plant nutrients that become available to subsequent crops through litter decomposition [1, 6, 7]. They are also used to correct the marginal deficiencies of secondary and micronutrients that are not addressed by mineral fertilizers. Furthermore, using organic sources can reduce the need for the excess addition of synthetic fertilizers by simultaneously increasing multiple ecosystem functions [1, 2].

Decomposition and mineralization of organic materials are fundamental processes that support ecosystem functioning. Factors such as climate and soil conditions, the size and composition of the microbial community, litter quality (i.e., physical and chemical properties) and quantity influence decomposition dynamics [1]. For instance, the carbon-nitrogen ratio (C/N ratio) is a parameter that is related to the decomposition of organic matter, indicating the availability of nitrogen in the soil [8]. The C/N ratio influences the decomposition processes (fast/slow) [1]. When the organic matter has high N content, microorganisms have greater mineralization since the microflora (bacteria, fungi, and actinomycetes) satisfy the N requirements so that it is not a limiting factor. On the other hand, the rate of organic matter decomposition decreases if the N content is low. Under such cases, the addition of nitrogenous sources influenced the rate of carbon mineralization [9].

Smallholder farming systems including in Ethiopia are mostly being commenced under widespread depletion of soil organic matter [10–13] and multinutrient deficiency of the soils such as nitrogen (N), phosphorous (P), sulfur (S), and boron (B) [10]. Under depleted soil conditions, the litter decomposition process would be affected [1, 14]. The effect may include mineralization processes of N-rich litters upon incorporation into the soil. Thus, to enhance residues decomposition and subsequent release of essential nutrients for crop use, the addition of mineral nutrients under nutrient-poor soils is suggested [7, 14, 15].

A plurality of studies on the combined use of organic and mineral fertilizers have indicated positive effects on the soil-plant relationship [7, 16–19]. Moreover, increased decomposition due to improved soil fertility because of improved biological activity was reported [1]. The findings of Li et al. [20] on the other hand indicated a slowed decomposition of maize residues through N fertilization. According to Li et al. [20], the effects of mineral fertilization are still very uncertain and depend on living plants. Meanwhile, it is assumed that organic materials with low C/N litter undertake mineralization and would furnish nutrients to the growing crop. However, limited empirical pieces of evidence exist on the decomposition patterns of low C/N litters within nutrient-depleted soils. Additionally, evidence on the effects of mineral fertilizers on decomposition processes of low C/N ratio litters in nutrient-depleted soils and their subsequent effects on crop growth and yield are also scant. The information has paramount importance to understanding how decomposition dynamics of narrow C/N ratio respond to the addition of synthetic fertilizers by addressing soil limited nutrients, their potential benefits for growing crops, and therefore used to advise the soil management practices. It would also be of particular interest to see the response of the N-fixing legume crop. Thus, the objectives were i) to investigate the effects of mineral NPS fertilizer application on decomposition processes of tree leaf litter with low C/N incubated in soils with low levels of soil organic matter and multinutrient deficiency and 2) to evaluate their effects under field using common bean (*Phaseolus vulgaris* L.) as a test crop.

2. Methodology

2.1. Location. The study was carried out in Wolaita Sodo University (WSU) research and practical farm in Sodo town, southern Ethiopia in 2017 and 2018. Geographically, it is located at 06°50′00″N latitude and 37°45′07″E longitude with an altitude of 1882 m above mean sea level. The annual average rainfall is 1212 mm and is characterized by having a bimodal rainfall pattern that forms two cropping seasons *viz. belg* (February–May) and *meher* (June–September).

Nitisol is the dominant soil type that occurs in the experimental location and district. The site has a clay textural class. In terms of chemical properties, the soil was slightly acidic (pH = 5.9) with low content of organic carbon (OC) (0.17%), total nitrogen (0.01), and available P (5.4 mg/kg) [21]. In addition, the soils in the study area are deficient in sulfur [12]. The low OC could be explained by the lack of addition of organic resources [12]. Major annual crops growing in the area includes common bean (*Phaseolus vulgaris* L.), wheat (*Triticum aestivum* L.), and maize (*Zea mays* L).

2.2. Experimental Setup. The decomposition experiment was performed using the litterbag method [14, 22]. The treatments were formed from two factors (leaf litter (LL) mixture as organic fertilizer and mineral NPS ($19N38P_2O_57S$)). The litter mixture was prepared from two agroforestry tree leaves such as croton (*Croton macrostachyus*) and erythrina (*Erythrina brucei*). These trees are growing in crop fields and/or farm boundaries, and farmers prune the tree branches and used the leaves to enhance soil fertility.

A mixture of LL at two rates *viz.* 2.5 ton/ha and 5 ton/ha, and four levels of NPS fertilizer (0, 50 100, and 150 kg/ha) were evaluated using the factorial arrangement in three replications. All treatments were laid out in a randomized complete block design (RCBD). The LL was inserted into a 0.2 m × 0.2 m (0.04 m^2) nylon bag with 50 μm openings, at a rate of 10 g bag^{-1} and 20 g bag^{-1} which is equivalent to 2.5 ton/ha and 5 ton LL ha^{-1} on a dry matter basis, respectively. The litter bags containing mixtures of LL treated with different levels of NPS fertilizer were buried. The LL mixture was prepared on a 2 : 1 proportion of croton and erythrina, respectively.

The decomposition pattern was monitored at two-week intervals (14, 28, 42, and 56 days); thus, 96 nylon bags were buried (2 rates of LL × 4 rates of NPS × 4 litter bags/ treatment × 3 replications). The residue-containing bags were placed into the soil at 20 cm depth to represent plow depth.

2.3. Data Collected

2.3.1. Chemical Composition of Organic Residues. Organic materials collected from the tree leaves were chopped, dried in shade, and then oven-dried at 70°C until constant weight. The leaf litters were ground and used for the characterization of chemical composition. The chemical compositions *viz.* N, P, K, O, C, and C:N contents were determined according to Sahlemedhin and Taye [23]. The samples were analyzed at the JIJE Analytical Testing Service Laboratory, Addis Ababa, Ethiopia. The litters have high nutrient contents and a narrow C/N ratio with OC ranging between 50.8 and 51.8% (Table 1).

2.3.2. Dry Mass Loss (Remaining). The litter bags were carefully retrieved at 14, 28, 42, and 56 days after application. The materials that were attached to the litter bags such as soil, worms, and plant roots, were removed carefully and placed into a sample bag made of paper and transported to the laboratory for analysis. Then, the residues were taken out from the bags and dried in a laboratory oven at 70°C until constant weight. Dry mass (DM) remaining in each bag was then measured and presented as the percentage remaining in each period of time in comparison to their initial amounts using the following equation:

$$\mathrm{DM}\,(\%) = \frac{\mathrm{W_t}}{\mathrm{W_0}} \times 100, \tag{1}$$

where $\mathrm{W_t}$ is the weight that remained after each sampling time (g) and $\mathrm{W_0}$ is the initial weight (g) which is potentially decomposable.

The data for DM from each treatment were fitted to a negative exponential model that has been extensively used to describe the decomposition of litter in litter bags [4, 14].

$$\mathrm{W_t} = \mathrm{W_0} e^{(-kt)}, \tag{2}$$

where $\mathrm{W_t}$ is the litter remaining after a given time (t), $\mathrm{W_0}$ initial residue weight at time zero, t is the time interval of sampling expressed in weeks, k is the constant of decomposition per day, and e is the base of natural logarithms ($e = 2.718$).

2.3.3. Daily Decomposition. To determine the values of k, the exponential model was transformed into a natural logarithm as

$$\ln\left(\frac{X_t}{X_0}\right) = -k\mathrm{t}. \tag{3}$$

Table 1: Chemical characteristics of organic nutrient sources.

Leaf litters	OC	N	P	K	C:N	C:P
	%	%	g/kg	%	—	
Croton (*Croton macrostachyus*)	50.83	5.2	1.107	3.07	10	45.9
Erythrina (*Erythrina brucei*)	51.83	4.7	1.859	2.12	11	27.88

The regression of $\ln(X_t/X_0) = -k\mathrm{t}$ overtime was also performed separately to provide independent estimates of k for each treatment.

2.3.4. Half-Life Time (t½). Half-life ($t½$) was calculated from the k value as $t½ = -\ln(0.5)/k = (0.693/k)$ [24], which expresses the time required for half of the residues to be decomposed or for half of the nutrients contained in the residues to be released.

2.3.5. Crop Response Experiment. A crop response experiment was simultaneously conducted on the field where a decomposition experiment was undertaken. The two levels of LL (2.5 and 5 t $\mathrm{ha^{-1}}$) and four levels of NPS fertilizer (0, 50, 100, and 150 kg $\mathrm{ha^{-1}}$) were tested using randomized complete block design (RCBD) with three replications. The crop performance was tested on common bean (*Phaseolus vulgaris* L.) using the Nasir variety.

The plot size was 2.40 m in length × 1 m in width (2.4 $\mathrm{m^2}$). Two seeds per hill were planted at 40 cm intervals and 10 cm between seeds. Each row was opened at 20 cm depth (i.e., average plow layer) and the whole doses of organic and inorganic fertilizers as per the treatment were applied into the soil two weeks prior to sowing of the test crop. A distance of 0.5 m × 1 m was left between plots and blocks, respectively. Thinning was performed after the full emergence of the crop by leaving one seedling per hill. Weeding and other necessary agronomic management practices were carried out properly.

2.3.6. Statistical Data Analysis. Data were analyzed following the procedure appropriate to the experimental design. When effects were significant, means were compared using the least significant difference (LSD) test at a probability level of 5%. Linear or nonlinear regression models were tested for measurements over time, and the most appropriate regression model was chosen based on the significance of the model and the highest r^2. Then, regression equations were generated. In addition, decomposition patterns and their relationship with agronomic parameters were also compared through Pearson correlation analyses. Data were analyzed using the Statistix software 8. Microsoft excel was used for generating graphs of regression analysis.

3. Results

3.1. Daily Decomposition Rate. The daily litter decomposition rate (k) (% $\mathrm{day^{-1}}$) over most of the experimental period was significantly influenced by NPS fertilizer, the litter

Table 2: Daily decay rate (k) (% day^{-1}) (dry weight bases) over 56 days of decomposition.

NPS (kg/ha)	Decomposition time (days)					
	Initial	14	28	42	56	Average
0	0.0	2.8c	1.83c	1.33c	1.21c	1.79d
50	0.0	3.4b	2.25b	1.59b	1.42b	2.17c
100	0.0	3.6b	2.43a	1.79a	1.48ab	2.33b
150	0.0	4.1a	2.52a	1.90a	1.54a	2.51a
$LSD_{0.05}$	—	0.32**	0.14**	0.13**	0.11**	0.11**
LL (t/ha)						
2.5	0.0	3.6a	2.35a	1.67	1.47a	2.27a
5.0	0.0	3.4b	2.17b	1.63	1.36b	2.13b
$LSD_{0.05}$	—	0.23*	0.10**	NS	0.07	0.08
CV (%)		7.56	5.14	6.6	6.0	4.1
NPS		**	**	**	**	**
LL		*	*	NS	**	**
NPS*LL		*	NS	NS	NS	*
		14 days				
NPS (kg/ha)	Initial	2.5t/ha	5t/ha	—	—	—
0	0.0	2.75c	2.81c	—	—	—
50	0.0	3.43b	3.46b	—	—	—
100	0.0	3.73b	3.49b	—	—	—
150	0.0	4.47a	3.67b	—	—	—
$LSD_{0.05}$	—	0.46*				
CV (%)	—	7.56				

NS, not significant; * and ** significant at 1% and 5%, respectively.

amount, and their interaction (at 14 and average of 56 days) (Table 2). Daily decomposition, regardless of treatments, was faster during the initial days and declined afterwards (Table 2). The highest (4.47% day^{-1}) k value within the first 14 days was recorded from 2.5 t/ha LL with 150 NPS kg/ha whereas it was the least (2.75% day^{-1}) from 2.5 t/ha without NPS fertilizer application (Table 2). Thus, the addition of mineral NPS fertilizer makes the decomposition rate to be faster by 62.5% over the minimum.

Data regarding k values of LL rates (% day^{-1}) at 28, 42, and 56 days after residue incorporation were (2.34, 2.17), (1.67, 1.67) and (1.47, 1.36) for 2.5 t/ha and 5 t/ha, respectively. Here also, the daily decomposition rate was declined with the increasing rate of LL (Table 2). The k values, averaged over 56 days of incubation, were 2.68% day^{-1} (2.5 t/ha LL x + 150 kg NPS/ha) and 1.78% day^{-1} (sole 2.5 t/ha LL) in which NPS fertilizers at a lower rate of litter application improved the decay rate ($r^2 > 0.98$) (Figure 1). Generally, residues incorporated at a relatively lower rate decomposed more rapidly, and the values regardless of litter amount decreased with time (Table 2).

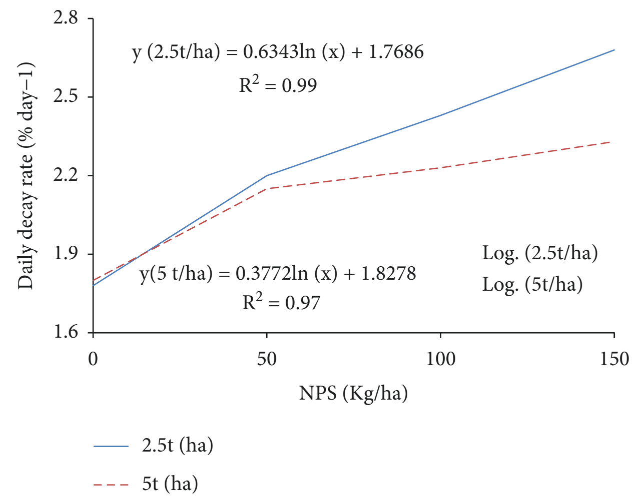

Figure 1: Daily decay rate (k) (average of 56 days decomposition) as affected by NPS and LL rates.

Table 3: Dry mass remaining (% dry weight bases) over 56 days of decomposition.

NPS (kg/ha)	Decomposition time (days)					
	Initial	14	28	42	56	Average
0	100	68.6a	61.2a	58.7a	51.9a	60.1a
50	100	62.2b	53.7b	51.9b	45.8b	53.4b
100	100	60.9b	50.9c	47.7c	44.3bc	50.9c
150	100	57.2c	49.7c	45.3c	42.9c	48.8d
$LSD_{0.05}$		2.83*	2.2**	2.8**	2.45**	1.64**
LL (t/ha)						
2.5	100	61.3	52.7b	50.6	44.9b	52.4b
5	100	63.1	55.1a	51.2	47.5a	54.2a
$LSD_{0.05}$		NS	1.87**	NS	1.7	1.2
CV (%)		3.67	3.26	4.5	4.29	2.48
NPS		*	**	**	**	**
LL		NS	*	NS	**	**
NPS*LL		*	NS	NS	NS	*
		14 days				
NPS (kg/ha)	Initial	2.5 t/ha	5 t/ha	—	—	—
0	100	68.9a	68.3a	—	—	—
50	100	62.4b	62.0b	—	—	—
100	100	61.1b	61.7b	—	—	—
150	100	53.7c	60.6b	—	—	—
$LSD_{0.05}$		3.99*				
CV (%)		3.67				

NS, not significant; * and ** significant at 1% and 5%, respectively.

3.2. Dry Mass Loss. Dry mass loss of leaf litter mixtures within 14 days and an average of 56 days was significantly affected by interaction effects of NPS and LL. The mass loss at 28 and 56 days after placement was significantly influenced by NPS fertilizer and leaf litter rates, respectively (Table 3). The dry mass loss followed the trend of the decay rate.

The maximum dry mass remained (68.9%) two weeks after placement was recorded from sole LL at 2.5 t/ha whereas 53.7% of the initial mass remained from 2.5 t/ha × 150 NPS kg/ha. During experimental periods, increasing rates of mineral fertilizer in the order of 150 > 100 > 50 > 0 kg NPS/ha enhanced residue decomposition. It was also noted that the weight loss was more as the LL rate decreased. That is, LL at 2.5 t/ha compared to 5 t/ha, had the highest weight loss (the lesser mass remained) (Table 3). Data regarding the rate of plant residue revealed a decreased mass loss with time. The average mass remained after 56 days of placement, was 60.4% and 46.6% that was recorded from sole LL and 2.5 t/ha × 150 NPS kg/ha, respectively. Successive increase of mineral fertilizers accelerated the mass loss. This pattern was best described using a polynomial function at a regression coefficient of $r^2 > 0.98$ (Figure 2).

3.3. Half-Life Values. The days taken for 50% of the residue to decompose (t_{50}) were significantly ($p < 0.01$) affected by NPS fertilizer, and LL (at 28, 56, and average) (Table 3). It showed an opposite trend from daily decomposition rates.

An increasing rate of NPS in the following order: 150 > 100 > 50 > 0 kg/ha shortened days to attain 50% of the dry mass disappearance. The average days required were 38.8, 32, 29.8, and 27.8 for 0, 50, 100, and 150 kg NPS/ha, respectively (Table 4). This indicates that half-life time decreases with the increasing rate of NPS fertilizer. Application of mineral fertilizer at 150 kg NPS/ha over untreated LL shortened the time for 50% decomposition by 11 days. Pearson correlation analysis also demonstrated a significant ($p < 0.001$) and negative relationship ($r = -0.86$) between t_{50} and NPS fertilizer application. Overall, t_{50} values, regardless of NPS application, were increased with time (Table 4).

3.4. Crop Response. Agronomic parameters such as leaf area index (LAI), pods per plant, and grain yield of common bean were significantly influenced by the combined effects of NPS and LL application (Table 5). Increasing NPS fertilizer successively with 2.5 t LL/ha significantly enhanced LAI, number of pods per plant, and grain yield of common bean. Combined application of 150 kg NPS/ha + 2.5 ton LL/ha resulted in 79% more grain yield compared to unfertilized. This was also best described with regression coefficient values (r^2) > 0.97 (Figure 3).

4. Discussions

The leaf litter mixtures used had narrow C/N < 11 with high N, P, and K content. This might indicate that the residue has less resistant structures and organic compounds. Hence, a faster rate of decomposition and release of essential nutrients to the crop is expected. In agreement, Gindaba et al. [4] on green leaves of croton and Wasie [5] on erythrina found the C : N ratio of less than 20, and higher N content (4.83%), respectively. Overall, the chemical characteristics of organic nutrient sources were found to be high and encouraging to use as a soil amendment.

The high dose of NPS application at 150 kg/ha boosted the decomposition of the low C/N litters of 2.5 t/ha within two weeks and averaged over 56 days. This may signify that under nutrient-depleted soils, microorganisms might get nutrients like N from external sources to rapidly colonize and thereby decompose the litter at faster rates. Decomposition processes during 28–56 days were affected by the main effects of NPS and LL. Yet, k was increasing with increasing rates of NPS fertilizer and decreased as litter amount increases from 2.5 t/ha to 5.0 t/ha.

The result signifies synergistic effects of mineral fertilizer on organic residue decomposition. Rezig et al. [14] also reported enhanced decomposition with the application of mineral fertilizer. This is also supported by a significant ($p < 0.001$) relationship ($r = 0.89$) between k and NPS fertilizer. The possible reason for faster residue decomposition with mineral fertilizer application under nutrient-depleted soils like the study area was likely linked to a better supply of N, P, and S nutrients that enhanced soil microbial activities [15]. The finding was consistent with an earlier study by Rezig et al. [14] who reported that an increasing supply of N and P nutrients resulted in increased litter decomposition of wheat. Abdou et al. [22] reported that the combined application of organic and inorganic nutrient sources resulted in synergistic effects and improved synchronization of nutrient release and uptake by plants leading to higher yields. In addition, mixing the organic nutrient sources with mineral fertilizer enhanced decomposition and mineralization [6, 7] and consequently improved nutrient release and uptake leading to higher yield [6, 15].

Overall, the k values in the present study varied from 1.21% (i.e., 0.0121 gm/gm) to 4.47% day^{-1} (i.e., 0.0447 gm/gm) which represents a faster decay rates based on Barlocher [25] who stated as fast ($k > 0.01$), medium ($k = 0.005$–0.001), and slow ($k < 0.005$). Gindaba et al. [4]

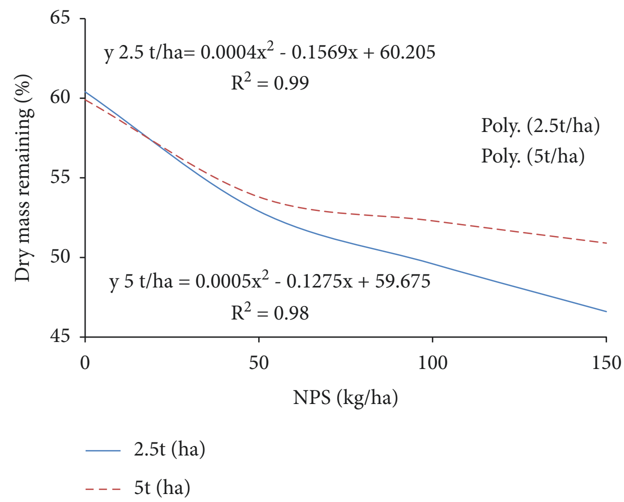

Figure 2: Dry mass remaining (% dry weight bases) (average of 56 days of decomposition) as affected by NPS and LL rates.

Table 4: Half-life (t_{50}) (days) over 56 days of decomposition.

NPS (Kg/ha)	Decomposition time (days)					
	Initial	14	28	42	56	Average
0	0.0	25.02a	38.0a	52.3a	57.3a	38.8a
50	0.0	20.21b	31.0b	44.1b	49.1b	32.0b
100	0.0	19.13b	28.7c	38.9c	47.1bc	29.8bc
150	0.0	17.21c	27.6b	36.5c	45.3c	27.8c
$LSD_{0.05}$	—	2.02**	1.96	3.82	3.56	1.73
LL (t/ha)						
2.5	0.0	19.94	30.3b	42.6	48.0b	31.3b
5.0	0.0	20.94	32.4a	43.3	51.4a	32.9a
$LSD_{0.05}$	—	NS	1.39	NS	2.51	1.22
CV (%)		7.99	5.07	7.20	5.79	4.36
NPS		**	**	**	**	**
LL		NS	*	NS	*	*
NPS*LL		NS	NS	NS	NS	NS

NS, not significant; * and ** significant at 1% and 5%, respectively.

Table 5: LAI, pods per plant, and grain yield of common bean affected by LL and NPS fertilizer.

LL	LAI		Pods per plant (PPPL)		Grain yield (ton/ha)	
	2.5 t/ha	5 t/ha	2.5 t/ha	5 t/ha	2.5 t/ha	5 t/ha
NPS (kg/ha)						
0	2.41c	3.59b	14.7e	19.9cd	2.32e	3.17d
50	3.61b	3.96ab	19.2d	21.6bcd	3.18d	3.27cd
100	4.39a	3.94ab	22.3abcd	23.0abc	3.81abc	3.43bcd
150	4.23ab	4.49a	25.5a	24.1ab	4.16a	3.93ab
$LSD_{0.05}$	0.6		3.29		0.56	
CV (%)	10.37		8.83		9.41	

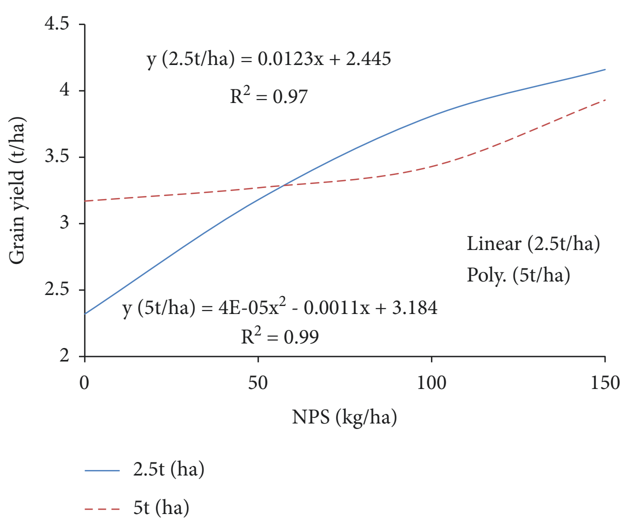

Figure 3: Grain yield of the common bean as affected by interaction effects of NPS and LL rates.

also reported that leaf litters containing a higher N concentration such as *C. macrostachyus* have higher *k* values and subsequently decompose faster than those of lower N-containing leaf litters.

The dry mass of a residue remaining decreased over time and also followed the daily decay rate trends. Lynch et al. [26] explained that consumption of organic carbon by soil microorganisms, continuous release of carbon in the form of CO_2 into the atmosphere, leaching of water-soluble compounds degraded by the soil microbial population, and increase in temperature and rainfall may have contributed to increasing breakdown and decrease in residue mass overtime. Other studies have also reported faster decomposition of plant residues within a few days of incorporation. This has been attributed to favorable climatic factors (moisture and temperature) to microorganisms [6, 26].

Generally, treating plant residues with NPS results in more mass loss than did LL alone. The higher mass loss of organic inputs at increasing rates of NPS fertilizer under nutrient-depleted soil can also be associated with an external supply of NPS fertilizer and a lower C/N ratio (<11). Such conditions would create enabling environment for soil microbial populations to colonize and easily break down organic residues without nutrient limitations. Thus, the organic input would supply a considerable amount of nutrients through mineralization, and results in a smaller amount of remaining dry matter residue [26]. Rezig et al. [14] illustrated that mineral fertilizer when combined with crop residues results in maximum decomposition and nutrient release compared to non-treated treatments.

Relatively, the lesser weight loss without NPS application may explain the importance of initial soil nutrient concentration in influencing residue decomposition [14], and the need for supplementing mineral fertilizer for enhancing microbial degradation under nutrient-limited soils even though a residue with lower C:N was incorporated. In our study, two-thirds of the residue was prepared from *C. macrostachyus*. Though not measured in this study, the work of Gindaba et al. [4] illustrated that the lignin concentration of green and abscised *C. macrostachyus* leaves varied between 6 and 11%. Palm [27] indicated that if the lignin concentration value of the leaf material is below 15%, higher N mineralization is expected to occur. Such cases would promote faster decomposition and nutrient release into the soil [6].

Mineral NPS application significantly influenced the days taken for 50% of the residue to decompose (t_{50}) over 56 days of incubation (Table 3). It showed the opposite trend with *k*. On average, the lowest percentage of remaining dry mass with a t_{50} of 27.8 days was observed from 150 kg NPS/ha. On the other hand, the highest values of remaining dry mass were observed in the untreated residue, with a half-life (t_{50}) of 38.8 days. Scholars associated that residues with a C/N ratio below 30 are more readily colonized by soil microbial populations since there is more available N to incorporate in their tissues [26]. This may increase decomposition and mineralization within a short period of time. Meanwhile, the soils in the study area do not have an adequate amount of soil nutrients such as N, P, K, S, B, and Cu [12]. Application of 150 kg NPS/ha under nutrient limiting soils, though lower C/N ratio residue was incorporated, would furnish more nutrients to microbial populations. This may explain the rapid decomposition of untreated residues.

Data regarding agronomic performance revealed the highest and lowest common bean values from 150 kg NPS/ha + 2.5 ton LL/ha and sole leaf litter application, respectively. The higher performance may be related to the faster release of nutrients to the soil during residue decomposition, the match between demand and nutrients supply in the growth period, and an increased supply of nutrients from both sources [26]. In the present study, the decomposition rate has a significant ($p < 0.01$) and positive relationship with LAI ($r = 0.63$) and pods per plant ($r = 0.77$). Furthermore, grain yield has shown a significantly positive relationship with daily decay rate (k) ($r = 0.67$), and a negative relationship with mass loss ($r = -0.67$) and half lifetime ($r = -0.66$). The combined effects of these processes consequently promote better growth, yield component, and yield of common bean. Earlier studies have also reported that the integrated use of mineral and organic fertilizer resulted in higher grain yield [7, 15, 28].

5. Conclusion

The soils of the study area were found to have low levels of organic matter, N, P, and S. Thus, the result showed that enriching the narrow C/N ratio leaf litter mixtures that were applied to the depleted soil conditions with mineral fertilizer significantly enhanced the decomposition rates. Application of 150 kg NPS/ha resulted in a faster daily decay rate (k), maximum dry mass loss and earlier time for half of the residues to be decomposed (half-life). This would imply that NPS fertilizer encourages rapid decomposition and furnishes readily available plant nutrients for uptake during the early growth period of the crop. This could be the possible reason for obtaining better growth, yield attributes, and grain yield of common bean. Therefore, to maximize the benefits of organic residues, particularly under nutrient-depleted soils and low-input cropping systems, their integration with mineral nutrients is suggested.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Authors' Contributions

The authors collected, analyzed, interpreted, and prepared the manuscript.

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