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Compost of peanuts residue and rice straw compost on soil Nitrogen forms and upland rice yield

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ABSTRACT

This study provides an innovation in making compost from rice straw (low quality) mixed with peanut residue (high quality) to improve the quality of rice straw compost. The purpose of this research was to discover the optimum composition of a mixture of peanut residue and straw for mineralization, absorption, and Nitrogen Use Efficiency (NUE) and its effect on upland rice plants. The study was conducted in three stages. The first stage determined the quality of five compost mixtures: C1, C2, C3, C4, and C5. The second phase of testing for cumulative N minerals was performed after 1, 2, 4, and 8 weeks of incubation. The third stage examined the impact of the compost mixture on the growth and yield of upland rice in comparison with two treatments, namely the control and NPK fertilizer. The results showed a similarity in the forms of mineralization, where the cumulative N mineral increased with the addition of peanut residue to the compost mixture. The use of a mixture of peanut residue and rice straw compost increased net mineralization by 37.27% (C5) to 59.48% (C1), N uptake by 49.19% (C5) to 62.95% (C3), and NUE by 15.04% (C4) to 51.48% (C3). A strong relationship was detected between the quality of the compost and the forms of N in the soil, particularly the nitrate content, total N minerals, and N microbial biomass, with correlation coefficients of 0.92, 0.88, and 0.94, respectively. A strong to very strong relationship was detected between N form and N uptake (r = 0.84), plant height (r = 0.79), number of tillers (r = 0.78), yield of rice plants (r = 0.93 (plant total dry weight), and r = 0.76 (grain weight). The optimum N uptake, NUE, and yield of upland rice were shown by C3 treatment of 405.28 mg pot^{-1}, 42.21%, and 6.19 tons ha^{-1}, respectively.

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1. INTRODUCTION

In many developing countries, such as Indonesia, high production costs and scarcity of chemical fertilizers are major problems in agricultural production systems. The growth and production of food crops is dependent on the input of chemical fertilizers to maintain productivity and supply the food demands of an ever-increasing population. Reduced usage of inorganic fertilizers in agricultural production is therefore urgently needed because of the declining quality of agricultural soil and other negative effects on the environment, such as increased greenhouse gases and soil and water pollution (Savci, 2012; Sharma & Singhvi, 2017). Plants can only use 30%–50% of chemical fertilizers; therefore, large amounts of the elements used are lost in the soil, poisoning groundwater (Mózner et al., 2012; Wang et al., 2018). Therefore, farmers currently rely on usage of organic materials, such as agricultural waste and animal feces, either as substitutes for chemical fertilizer stocks or to supplement their stocks. However, this practice has not been successful. Many obstacles are faced by farmers in utilizing agricultural waste as an organic fertilizer, including the slow rate of decomposition and mineralization of agricultural residues, such as rice straw.

Rice is the most widely consumed food crop worldwide, ranking third in Indonesia. Consequently, straw production in Indonesia is high. The return of rice straw to the soil is an important nutrient management strategy for maintaining soil fertility. This method improves the carbon and nitrogen cycles, raises the amount of organic C in the soil, reduces the use of chemical fertilizers (Hansen et al., 2017; Lehtinen et al., 2014; Liu et al., 2014; Zhou et al., 2020), increases crop yields, and improves fertilization efficiency (Xie et al., 2018). The repeatable of straw not only enhances the physical qualities of the soil but also minimizes N losses owing to immobilization and leaching and improves the synchronization of N release with crop N requirements (Yang et al., 2023). Returning rice straw to paddy soils is a common practice. However, in crop cultivation systems, the addition of rice straw can lower crop yields during first planting (Sun et al., 2020) and has no impact on N uptake and rice seeds (Kaleeem Abbasi et al., 2015; Yang et al., 2023). Straw treatment as well has a detrimental effect on future rice planting (Wang et al., 2015; Xu et al., 2020; Zhu et al., 2014).

Rice straw is classified as low-quality organic matter because of its high C/N ratio and low N content (Sholihah & Sugianto, 2022). This is because rice straw contains high amounts of crude fiber, lignin, cellulose, and hemicellulose, and little protein; thus, the decomposition and mineralization processes take a long time, which results in a greater amount of N being retained in plant residues during the mineralization process (Han et al., 2020; Talbot & Treseder, 2012; Wang et al., 2015). The decrease in rice yield owing to straw application is also caused by N immobilization, which often occurs in young rice to prevent this by decreasing the soil water content and increasing the dose of N fertilizer required by rice plants during their initial growth (Dhaliwal et al., 2023; Yang et al., 2023).

Low-quality organic materials, such as straw, can be supported in variety of ways, one of which is the mixing of high-quality organic matter, such as legume residue. The mixing of low and high-quality organic matter is needed to improve the organization of nutrient release from organic matter and plant nutrient uptake so that the efficiency of nutrient uptake increases. Zhou et al. (2020) reported that mixing straw and green manure derived from several types of legumes, namely *Hairy vetch* and *vicia villosa Roth*, at a ratio of 1:1 and a C/N ratio of 25 reduced the immobilization of N and loss of C and N. However, the greatest yield was obtained in the treatment with a C/N ratio of 35.

In Indonesia, crop rotation is generally applied to monocultured planting systems. After rice cultivation, farmers typically grow a single legume crop. The legume crop commonly grown in paddy fields is soybean (*Glycine max* L.). Soybean plant residue consists of leaves and stems that are left on the land after the soybean are harvested. Like other legume crops, soybean residue can be used as high-quality compost (Sholihah & Sugianto, 2022). Soybeans are commercial crops that give N to the soil naturally through N fixation. Bradyrhizobium strain USDA 110 infected soybean plants cultivated in fertisoil-fertilized soil increased the number of nodules by 65% compared to Anon-inoculated plants (Tortosa et al., 2023), Nitrogen fixation was the greatest in the maize/soybean intercropping systems treatment (Cheng et al., 2023), and a part of it will mineralize for subsequent crops (Mulvaney et al., 2017). Mixing rice straw and legume crops to obtain high N uptake efficiency has not been widely studied. Therefore, it is necessary to study the mixing of straw and peanuts to control the C and N cycles in a plant rotation system within one year of planting, so that the use of N fertilizers can be more efficient. The purpose of this research was to discover the optimum composition of a residue mixture of peanuts and straw for mineralization, uptake, and efficiency of nitrogen use, and its effect on upland rice crops.

Jani et al. (2020) found that when comparing with soil-only controls, peanut leaves made a net contribution to the soil N pool, whereas N contributions from stems and residue mixtures were not detected. The strong correlation between residual N content, C/N ratio, and C mineralization is a major factor controlling nutrient decomposition and release (Duarte et al., 2013; Jin et al., 2013; Schütt et al., 2014; Wang et al., 2013). Legumes can fix N_2 biologically to generate high-quality decomposable residues more quickly and increase soil fertility, notably in nutrient-deficient soils. This is supported by Tripolskaja et al. (2023) that stated that legume plants play an important role in N supply, thereby restoring soil fertility by decomposing high-quality residues and increasing the overall productivity of the system, after legume residue incorporation, the effect of residues on nitrate content and N leaching decreased and did not differ significantly from that of barley residues. By increasing crop productivity, legume plants can also increase soil fertility by improving organic matter through their residues (Jani et al., 2020; Zhou et al., 2020).

2. MATERIAL AND METHODS

This study was carried out from February to July 2020 in the agricultural faculty's greenhouse, the Islamic University of Malang at 7.5 ˚ LS and 137.35 ˚ LU North Latitude ± 500 m above sea level, day and night temperatures were 24–28 and 16–21 °C, respectively. Day and night relative humidities during the study were 69% and up to 85%, respectively. Composting was conducted in the biocompost agricultural faculty's laboratory, Islamic University of Malang.

The research was carried out in three stages:

Stage 1. Production of Compost from Peanut residue and Rice Straw

The composts tested in this study consisted of C1 (100% peanut residue), C2 (75% peanut residue + 25% rice straw), C3 (50% peanut residue + 50% rice straw), C4 (25% peanut residue + 75% rice straw), and C5 (100% rice straw). Rice straw and peanut residue were cut into pieces of similar size and placed in sacks. Each residue mixture was composted using a microorganism inoculant at a concentration of 2.5%, or an equivalent of 10 mL/400 g dry matter. The composting process was maintained at a moisture content of 30%–40%. Every day, the temperature, humidity, and pH were controlled. Composting at this stage required 20 days. The compost obtained was tested for the quality parameters, including total N (%) using the Kjeldahl method (Keeney & Nelson, 1983; Walker et al., 2001), C-organic (%) (Meinander et al., 2020). C/N ratio, lignin content (%) (Maceda & Terrazas, 2022), polyphenol content (%) using Folin-Denis method (Negi et al., 2012), cellulose content (%), the ratio of polyphenols : N and lignin : N, P_2O_5 (g 100^{-1}) using the spectrophotometer method (Abubakar et al., 2016), K_2O (g 100^{-1}) using the flame photometer method (Abubakar et al., 2016).

Stage 2. The Unleached Incubation Experiment

This stage aimed to test the rate of N mineralization. A 250-mL plastic cup was filled with 400 g of Inceptisol soil (Soil

Survey Staff, 2022) and 4 g of compost mixture that were produced from stage 1 (similar to 20 tons ha^{-1} dosage), and aquadest was filled into the cup until field capacity conditions. The treatments tested included C0 (soil without compost), C1, C2, C3, C4, C5, and treatment with NPK fertilizer (C6), according to the recommended dosage (300 kg ha^{-1}) for rice plants. Soil moisture was maintained by adding aquadest to the field capacity conditions, and each glass was covered with aluminum foil to prevent evaporation. Three times each treatment was taken. The incubation experiment used a simple and completely randomized design. Ammonium and nitrate (cumulative N minerals) levels were measured at 1, 2, 4, and 8 weeks (Rakhmad et al., 2019). After the observation period, the N mineralization rate constant (kN, $week^{-1}$) was determinated using the method (Kader et al., 2013) with the Equation 1.

$$N(t) = N_0 + k_0 t \quad [1]$$

N(t) s is the amount of mineral N at time *t*, N_0 is the initial amount of mineral N (mg N kg^{-1}), and k_0 is the rate of zero-order N mineralization (mg N kg-1). The best model to explain the anaerobic N mineralization data was a first-order model (Eq. 2):

$$N(t) = N_A(1 - \exp(-k_1 t)) \quad [2]$$

with k_1 being a first-order rate parameter and N_A being the mineralizable N. Because we believed that all of the NO_3^- that was initially present would be denitrified within the first two weeks of incubation, the initial $N0_3^-$ level was not taken into account when estimating the N mineralization rate for the anaerobic incubations.

Stage 3. A Pot Experiment using Upland Rice Plants

The pot contained 16 kg of air-dried soil and a mixture of peanut and straw residue compost, as determined in Step 2. Before the rice was planted, basic soil analysis was carried out. During the maximum vegetative phase, soil analysis was carried out together with N uptake analysis. The planting medium in the pot was watered to 60% of the field capacity before planting and maintained during the pot experiment. Upland rice seedlings of the Ciherang variety, which were 21 days old, were planted in a 5-cm hole, in which each pot contained five rice seeds.

The third-stage experiment used a simple randomized group design with the five treatments of compost mixture in stage 2 plus a control and treatment using NPK fertilizer for comparison. Each treatment was repeated three times, and each replicate contained three plant samples.

The growth variables observed from 1 to 8 weeks after transplanting included plant length, number of leaves, number of tillers, and leaf area, as measured by a Leaf Area Meter (LAM); N uptake; NUE; and rice yield variables, including total plant dry weight, grain weight per pot, and per hectare. The formulas used to calculate N uptake and NUE were Equation 3 and 4.

N uptake (mg pot^{-1}) = (% N in leaves and roots) × total plant dry weight ....[3]

NUE (%) = (N uptake/N available in the soil) × 100% ....[4]

The collected data were analyzed for variance (F-test) at a 5% level to test the impact of the treatment. If the results of the F-test showed a significant effect, 5% Tukey's test was used to determine the differences between treatments. The SPSS 16 version was used to conduct statistical analysis.

3. RESULTS

3.1. Peanut and Rice Straw Compost Quality

The N, P_2O_5, and K_2O contents decreased with the decreasing content of the peanut residue in the compost mixture. Conversely, the C/N, lignin, polyphenol, cellulose, polyphenol/N, and lignin/N ratios increased with decreasing peanut residue content in the compost mixture (Table 1). The results showed that the quality of the compost mixtures varied. An increase in the content of N, P_2O_5, and K_2O occurred with the decrease in rice straw in the mixture by 23%, 60%, and 180%, respectively. The contents of lignin, polyphenols, C/N ratio, lignin/N ratio, and polyphenol/N decreased by 74%, 67%, 9%, 79%, and 73%, respectively, with the decrease in rice straw.

3.2. Nitrogen Mineralization of Compost

In the incubation experiment, the quantity of N releasing into the soil by the compost mixture increased as the amount of peanut residue in the compost mixture increased (Figure 1). At eight weeks after incubation, treatment C1 had the greatest released N compared to those of other treatments, 1457.78 mg kg^{-1}, followed by treatments C6, C3, C2, and C4 at 1229.75, 1164.07, 1132.10, 987.57, and 941.57 mg kg^{-1}, respectively. This is consistent with the mineralization rates shown in Figure 2. The lowest amount of released nitrogen (590.66 mg kg^{-1}) was observed in C0 during the final stage of incubation (8 weeks). This shows that the amount of nitrogen released into the soil depends on the compost nitrogen level and that the compost nitrogen content increases as more peanut stover is added to the soil.

A C/N ratio of 97.75%, which is indicated by equation of quadratic regression model Y = 0.0008x2 - 0.0488x + 0.7599 (Figure 3), has a significant correlation (P = 0.01) with the quality of the compost mixture, which influences the rate of mineralization (kN value).

Table 1. Quality of peanut and rice straw mixed compost

Compost mix	N total (%)	C/N ratio	P_2O_5 (g 100^{-1})	K_2O (g 100^{-1})	Polyphenols (%)	Lignin (%)	Cellulose (%)	Polyphenolsl/N	Lignin/N
C_1	2.34	23.18	0.61	1.03	0.85	8.93	15.79	0.36	3.82
C2	2.12	24.96	0.56	0.98	0.93	9.87	20.42	0.44	4.66
C3	1.98	25.33	0.47	0.87	2.11	10.28	24.21	1.07	5.19
C4	1.83	26.68	0.39	0.74	2.67	26.76	27.42	1.46	14.62
C5	1.73	27.49	0.35	0.35	2.82	37.82	38.40	1.63	21.86

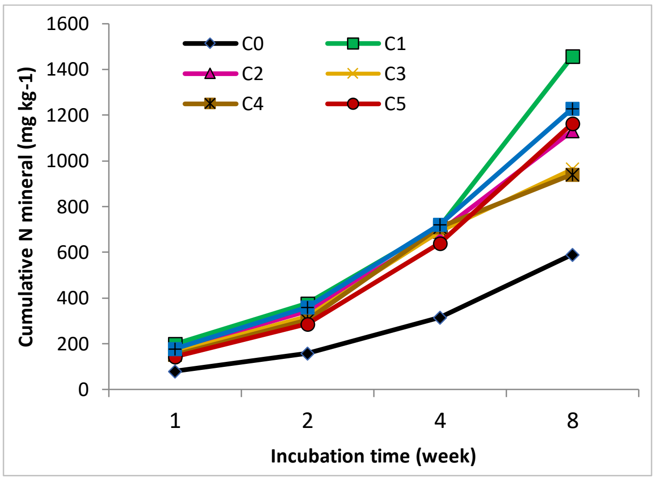

Figure 1. Cumulative mineral N released by compost

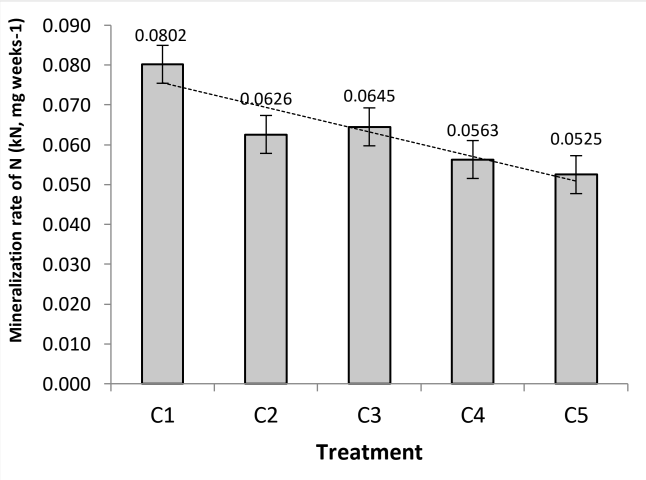

Figure 2. Value of mineralization rate of N (kN, mg weeks^{-1}) of various compost mixures

3.3. Growth Variables

Observations of growth variables at 8 weeks after transplanting showed that plant height, number of leaves, and number of tillers in the treatments using compost with either single or mixed compost showed better growth than that in the control (without compost application). However, the difference in the residue composition was not significant. Nevertheless, peanut residue compost tended to have better growth than those of the other treatments, whereas the control (C0) and NPK fertilizer treatments provided the lowest growth (Table 2).

3.4. N Uptake and Nitrogen Use Efficiency (NUE) in Upland Rice Plants

Treatments with peanut residue and rice straw compost had a significant effect on N uptake and NUE at harvest (Table 3). Optimum N uptake and NUE were found in the C3 treatment of 405.28 mg kg^{-1}, but were not significantly different from those in the C2 treatment, with an N uptake value of 395.25 mg kg^{-1}. All treatments showed significantly higher N uptake than that of the control. The optimum NUE was also shown by the C3 treatment at 42.21%, which was significantly different from those of the other treatments. The lowest N uptake was found in the control treatment of 162.46 mg kg^{-1}, and the NUE was 23.40%.

The C3 treatment (a mixture of 50% peanut residue + 50% rice straw) gave the optimum N uptake and NUE, which was different from what happened with the growth variable, where the treatment that gave the highest growth was found in the C1 treatment (100% peanut residue). This shows that low-quality organic matter (rice straw) releases more N over time, whereas N uptake observations were carried out before harvest.

Table 2. The average plant growth in various treatments

Treatments	Leaf Area (cm^2)	Plant Height (cm)	Number of Leaves	Number of Tillers
C0	8224.70	92.80 a	106.83 a	23.00 a
C1	9982.74	104.05 b	181.50 b	37.33 b
C2	9697.72	102.82 b	164.17 ab	35.67 b
C3	9975.95	101.60 ab	160.67 ab	36.33 b
C4	9764.30	99.12 ab	155.83 ab	36.00 b
C5	9561.67	96.97 ab	141.00 ab	30.00 ab
C6	10193.69	97.08 ab	151.00 ab	29.17 ab
Tukey 5%	ns	9.85	66.11	9.12

Remarks: Numbers accompanied by the same letter in the same column indicate no significant differences in the 5% Tukey test

Table 3. Uptake and nitrogen use effciency in upland rice plants

Treatment	N Uptake (mg kg^{-1})	The Nitrogen Use Effciency (%)
C0	164.46 a	23.40 a
C1	364.15 de	25.23 a
C2	395.25 ef	34.94 b
C3	405.28 f	42.21 c
C4	329.36 cd	35.03 b
C5	310.83 cd	26.71 a
C6	260.03 b	23.50 a
Tukey 5%	38.95	4.70

Remarks: NUE is the nitrogen use efficiency. Numbers accompanied by the same letter in the same column indicate no significant differences in the 5% Tukey test.

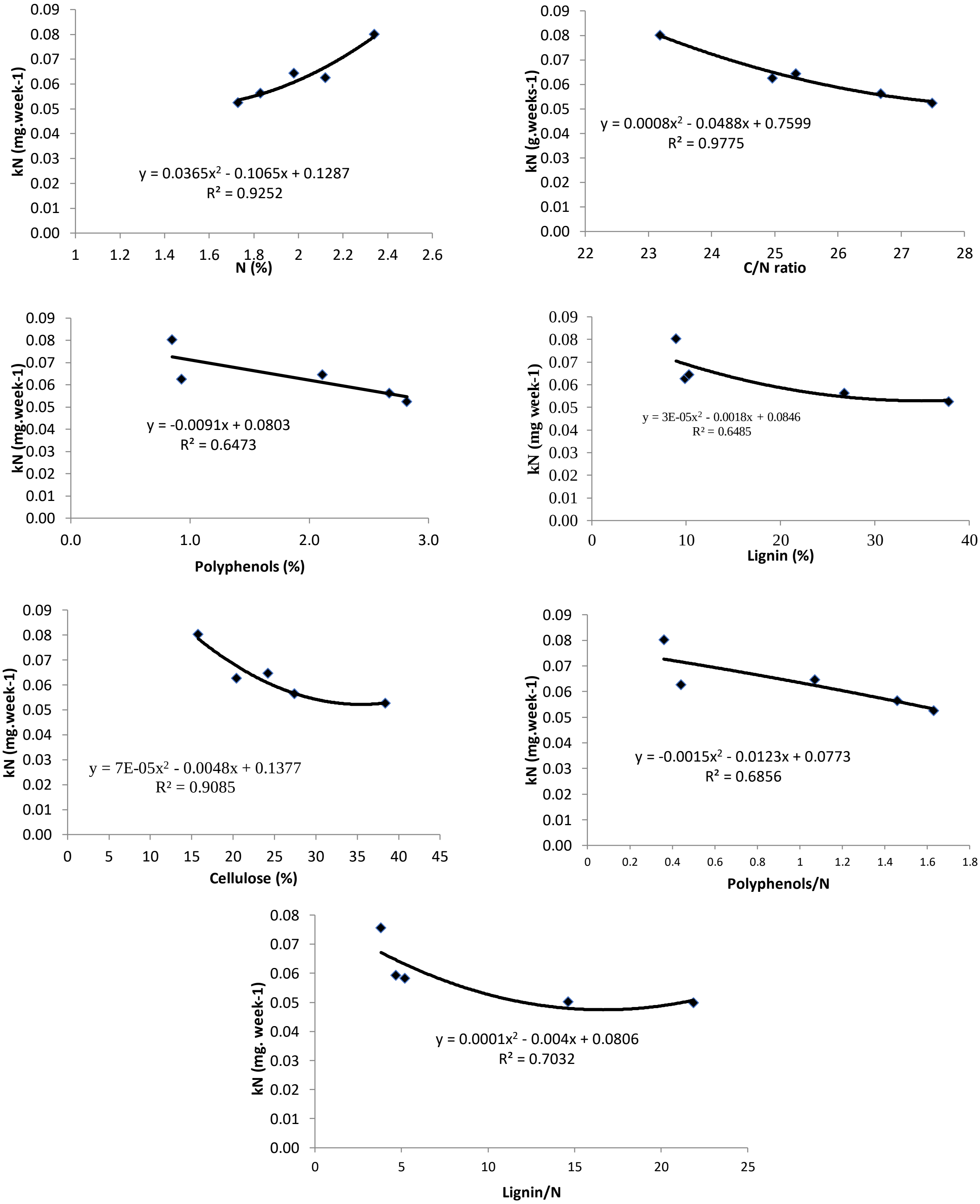

Figure 3. The relationship between the compost mixture quality and the kN value of the compost mixture for 8 weeks incubation

3.5. Yield Variable of Upland Rice Plant

The mixed compost residue of peanut and rice straw had a significant effect on yield variables, including total plant dry weight, grain weight per pot, and grain weight per hectare (Table 4). Treatment C3 showed that the total plant dry weight and grain weight per hectare were better than those of the other treatments by 235.50 g pot^{-1} and 6.19 ton ha^{-1}, respectively. This showed that C3 was the optimum peanut-rice straw compost combination for supporting the growth and yield of rice plants. During the growth period, nutrients are mostly supplied by high-quality organic matter (peanut residue), and before the generative period, many of the nutrients are supplied by low-quality organic material derived from rice straw with a slow mineralization rate so that nutrient availability is slower.

Table 4. The average upland rice yield variables in variety treatments

Treatments	Total plant dry weight (g pot^{-1})	Grain weight (g pot^{-1})	Grain weight (ton ha^{-1})
C0	106.83 a	47,67 a	3.81 a
C1	215.00 ab	76,00 ab	6.08 ab
C2	217.83 ab	76,83 ab	6.15 ab
C3	235.50 b	77,33 b	6.19 b
C4	196.17 ab	76,17 ab	6.09 ab
C5	182.00 ab	72.50 ab	5.80 ab
C6	134.83ab	64,83 ab	5.19 ab
Tukey 5%	120.98	4.95	2.37

Remarks: Numbers accompanied by the same letter in the same column indicate no significant differences in the 5% Tukey test.

Table 5. Initial and final soil analysis

Parameters	Initial soil analysis	final soil analysis are made per treatment						
		C0	C1	C2	C3	C4	C5	C6
pH H_2O (1:1)	6.20	6.22	6.53	6.55	6.68	6.30	6.45	6.28
N content (%)	0.20	0.21	0.87	0.65	0.67	0.43	0.38	0.25
C - organic (%)	1.91	1.95	2.76	2.70	2.69	2.58	2.55	2.22
CEC (meq/100g)	28.95	29.07	29.56	29.98	30.25	28.43	27.03	26.65
C/N ratio	10.00	9.28	3.17	4.15	4.72	6.00	6.71	8.88
K (meq/100g)	0.50	0.53	0.68	0.66	0.65	0.54	0.57	0.62
Ca (meq/100g)	8.70	8.72	9.23	9.16	9.13	8.65	8.76	8.21
Mg (meq/100g)	1.53	1.53	1.63	1.67	1.75	1.69	1.68	1.45
Na (meq/100g)	0.28	0.29	0.32	0.43	0.38	0.31	0.29	0.26
Amount Base (meq/100g)	11.02	11,07	11,86	11,92	11,92	11,19	11,30	10,54
Saturation Base (%)	38.00	38.08	40.12	39.76	39.40	39.36	41.81	39.55
Microbial biomass N (mg.Kg^{-1})	0.00355	0.03735	735,70	755,99	885,27	565,34	487,42	164,96
NH_4^+ (mg.Kg^{-1})	0.0112	115,62	712,01	691,14	790,97	611,02	638,97	121,66

Remarks: (Chemistry, Biology, and Soil Physics Laboratory, Brawijaya University).

The results of the initial and final soil analyses for each treatment are shown in Table 5. In general, all soil analysis parameters increased, with the exception of the C/N ratio, which decreased. This shows that the peanut residue-rice straw compost that was applied settled better in the soil ecosystem, and is therefore referred to as "better soil settlement." The C3 treatment had the greatest content of N, ammonium (NH_4^+), and nitrate (NO_3^-) microbial biomass compared to those of the other treatments and the lowest concentration of urea (C6) compared to that of the control (C0).

3.6. The Relationship Of the Correlation Coefficient Between Compost Quality and Forms of N, Upland Rice Growth, and Final Soil Conditions

The relationship between compost quality, form of N in the soil, growth, and yield of rice plants is indicated by the correlation coefficients (r) illustrated in Table 6. Table 6 indicates the relationship between compost quality and dynamics of N is very strong in the content of nitrate (NO_3^-) in all compost quality parameters (r = 0.86 – 0.96), followed by N total minerals and N microbial biomass. In ammonium content (NH_4^+), the correlation was weak (cellulose content, r=0.24) to strong (polyphenol content, r=0.74). In upland rice plant growth, the correlation was very strong for all compost quality parameters with plant height, followed by the number of leaves, number of tillers, and leaf area; the correlation was moderate to strong. For upland rice yields, the correlation was strong for all compost quality parameters except for cellulose (total plant dry weight) and polyphenols (grain weight). When the two observed variables have a r value near to 1, this means there is a significant correlation between them.

As shown in Table 7, compost quality was strongly correlated with soil property parameters in terms of N, C-organic content, CEC, K, and Ca content (except for the cellulose parameter). Soil pH has a strong correlation with polyphenol and lignin contents, whereas other parameters are weakly correlated. The number of bases strongly correlated with the polyphenol, lignin, polyphenol/N, and lignin/N ratios, whereas base saturation strongly correlated with the lignin, cellulose, and lignin/N ratios.

N form in the presence of compost addition strongly to very strongly correlated with N uptake by rice plants, and all parameters of growth and yield of rice plants (Table 8), except for the number of leaves, number of tillers (NH_4^+), and seed weight in the parameter of nitrate content (NO_3^-), which were moderately correlated (r = 0.58).

Table 6. The correlation coefficient (r) between compost quality and dynamics of N, rice growth and yield

Compost quality	Forms of N				Growth Variables				Yield Variable	
	NH_4^+ (mg kg^{-1})	NO_3^- (mg kg^{-1})	N mineral (NH_4^+ + NO_3^-) (mg kg^{-1})	Microbial biomass N (mg kg^{-1})	Leaf Area (cm^2)	Plant Height (cm)	Number of Leaves	Number of Tillers	Total plant dry weight (g pot^{-1})	Grain weight (ton ha^{-1})
N total (%)	0.43	0.91	0.73	0.79	0.48	0.99	0.94	0.70	0.81	0.87
C/N	0.48	0.96	0.81	0.84	0.60	0.99	0.95	0.76	0.85	0.91
Polyphenols (%)	0.79	0.86	0.86	0.99	0.58	0.96	0.76	0.60	0.99	0.78
Lignin (%)	0.66	0.91	0.89	0.84	0.60	0.93	0.73	0.94	0.83	0.95
Cellulose (%)	0.24	0.88	0.62	0.59	0.57	0.96	0.97	0.94	0.64	0.97
Polyphenols/N	0.66	0.86	0.81	0.94	0.57	0.97	0.79	0.70	0.97	0.89
Lignin/N	0.61	0.92	0.88	0.82	0.60	0.95	0.75	0.94	0.81	0.96

=0,80-1,00 (very strong); =0,60-0,79 (strong =0,40-0,59 (moderate) ; =0,20-0,39 (weak); =0,00-0,19 (very weak);

Table 7. The Correlation coefficient (r) between quality and final soil conditions

Compost quality	Final soil conditions										
	pH H_2O	N content (%)	C - organic (%)	CEC (meq/ 100g)	C/N	K (meq/ 100g)	Ca (meq/100g)	Mg (meq/ 100g)	Na (meq/ 100g)	Amount Base (meq/ 100g)	Saturation Base (%)
N total (%)	0.36	0.94	0.96	0.96	0.99	0.80	0.80	0.69	0.84	0.78	0.65
C/N	0.38	0.98	0.98	0.98	0.99	0.80	0.81	0.61	0.80	0.78	0.69
Polyphenols (%)	0.63	0.83	0.93	0.98	0.94	0.88	0.89	0.95	0.61	0.91	0.52
Lignin (%)	0.74	0.86	0.94	0.96	0.89	0.99	0.99	0.32	0.51	0.97	0.97
Cellulose (%)	0.15	0.86	0.90	0.83	0.97	0.70	0.68	0.64	0.42	0.56	0.98
Polyphenols/N	0.49	0.84	0.93	0.99	0.95	0.86	0.84	0.92	0.61	0.84	0.68
Lignin/N	0.70	0.88	0.96	0.95	0.91	0.99	0.99	0.12	0.49	0.95	0.98

=0,80-1,00 (very strong); =0,60-0,79 (strong); =0,40-0,59 (moderate) ; =0,20-0,39 (weak); =0,00-0,19 (very weak);

4. DISCUSSION

The findings of this research showed that the inclusion of peanut compost improves the quality of rice straw compost. Compost made from peanut residue can accelerate straw compost mineralization. Variation was observed in the quality of the compost mixture, as shown in Table 1. Under unwashed conditions, the compost quality was the best indicator of N release control. N is slowly released from plant residues with high lignin, polyphenol, and C/N ratios (Lestari et al., 2022; Zhang et al., 2022).

The mineralization rate decreased as the C/N ratio of the compost mixture increased. The C/N ratio is the most widely used parameter for controlling the mineralization and immobilization of N (Herviyanti et al., 2023; Heuck & Spohn, 2016; Santrum et al., 2021), in addition to other factors, such as N content (Talbot & Treseder, 2012; Tripolskaja et al., 2023; Wang et al., 2015), polyphenols (Kaleeem Abbasi et al., 2015; Lestari et al., 2022; Sun et al., 2020), and lignin (Gaitanis et al., 2023; Talbot & Treseder, 2012).

Mineralization of N from plant residues is controlled by the N and C/N contents in the residual content ratio. The N content's critical value was 1.75%, and for the C/N ratio, the critical value was 20, to allow for occur the mineralization of organic substances. A C/N ratio greater than 25 has the potential to increase N immobilization in the soil (Abera et al., 2012; Sholihah et al., 2012; Stallings et al., 2017). Investigations demonstrated that all plant residues had an N content greater than 1.70%, whereas all compost mixtures had a C/N ratio below 30 (Table 1).

Concerning the quality of the peanut residue, as shown in Table 1, C1 contained high N, low C/N ratio, and low polyphenol, cellulose, and lignin contents compared to those of other compost mixtures, such that the mineralization speed was high (Figure 2) and ultimately released the highest level of mineral N (Figure 1) compared to those of other treatments. Mixing peanut residue with rice straw can improve the quality of organic matter. Compost derived from peanut residue alone is of high quality, but this has the disadvantage of a very high mineralization rate, so that too much N mineral is released into the soil, risking a very large loss of N, considering that N is very mobile. With the rice straw mixture, the speed of mineralization can be reduced, which will ultimately reduce the amount of N released into the soil, thereby increasing nutrient synchronization. N is an element that is easily transformed into a form that is not available to plants, but its presence can be used as an indicator of soil quality (Kang et al., 2016; Su et al., 2023; Wang et al., 2015).

According to regression analysis, there is a substantial correlation between the compost variables N content, polyphenols, lignin, C/N ratio, polyphenols/N, lignin/N, and (lignin+polyphenols)/N and the N release rate constant (kN) (Figure 3). This demonstrates how crucial these factors are for calculating the release of N from compost. The release rate constant and correlation coefficient showed the best results, N (kN), and C/N ratio. The chemical composition of the plant residue, namely the concentration of N-organics, C-organics, C/N ratio, lignin, polyphenols, lignin/N ratio, polyphenol/N ratio, and (lignin + polyphenol)/N ratio, determines the rate of N mineralization (Kaleeem Abbasi et al., 2015; Rahmonov et al., 2023).

The addition of compost to soil modifies the microbial activity, which plays an important role in the decomposition of soil organic matter and nutrient release. Therefore, plants can employ them to help their growth (Chen et al., 2014; Kasifah et al., 2014; Nguyen-Sy et al., 2023; Zhu et al., 2014).

Table 8. The correlation coefficient between Forms of N with N uptake, upland rice growth and yield

Forms of N	N Uptake	Growth Variables				Yield Variable	
		Leaf Area (cm^2)	Plant Height (cm)	Number of Leaves	Number of Tillers	Total plant dry weight	Grain weight
NH_4^+	0.73	0.23	0.67	0.49	0.73	0.95	0.78
NO_3^-	0.87	0.24	0.85	0.66	0.73	0.85	0.58
N mineral (NH_4^+ + NO_3^-)	0.84	0.24	0.81	0.60	0.77	0.94	0.73
Microbial biomass N	0.94	0.49	0.82	0.71	0.89	0.99	0.96

=0,80-1,00 (very strong); =0,60-0,79 (strong); =0,40-0,59 (moderate) ; =0,20-0,39 weak); =0,00-0,19 (very weak);

This shows that plant nutrients were widely available from the mineralization of high-quality organic matter from peanut residues. A significant difference was detected in the amount of N minerals released in the various compositions of peanut and straw residue mixtures. Based on the results of using wheat straw with two types of moisture content (dry and wet), Rahmonov et al. (2023) showed that the morphology of plant tissue (small diameter of the stem and the thickness of the thin wall of the stem) determines the differences in the structure of organic matter's/rice straw composition (total C, total N, hemicellulose, cellulose, and lignin) and ultimately determines the amount of decomposition under the same environmental conditions, namely moisture content.

Appropriate provision of nutrients is still being achieved through improved synchronization between the release of nutrients by organic matter when plants need them. The release of nutrients from organic matter is determined by the rate of decomposition and net mineralization of the organic material. The higher the amount of nutrients released, the more nutrients can be taken up by plants, indicating high synchronization. Synchronization is related to the need for plant nutrients to support growth and development through photosynthesis in plant leaves (Liang et al., 2022; Zhou et al., 2023). Additionally, plants have the ability to influence soil organic matter, which will decompose (Liu et al., 2023; Liu et al., 2022). Plants produce labile carbon molecules through root exudates, which alter the soil's composition and encourage the activity of soil microbes (Cheng et al., 2014; Meier et al., 2017).

The quality of the compost mixture had a significant impact on the rice plants' NUE and uptake N. Compost's level of mineralization and decomposition depends on its quality (Policastro & Cesaro, 2023; Sakiah et al., 2021). The total N uptake by rice plants was significantly impacted by the variation in compost content. As N fertilizers are applied more frequently, the amount of nitrogen in plant tissues increases. High levels of N in organic matter stimulate microbial activity, which in turn increases mineralization and the amount of N released, ultimately increasing the N uptake of rice plants (Musyoka et al., 2017; Zhou et al., 2020).

This C3 treatment (50% peanuts + 50% rice straw) showed the best synchronization between the release of nutrients and the need for plants to meet nutrient needs, starting from the vegetative phase until before harvest, with an NUE value of 42.21%. Sholihah and Sugianto (2015) reported that mixing rice straw and green manure derived from legume residues may improve the synchronization between N release and demand, thereby contributing to increased yields and reduced N losses from soil-crop systems.

The results of the correlation analysis demonstrated very strong relationship between compost quality and the dynamics of N in the soil (Table 6), especially the parameters of nitrate content, total N minerals, and microbial biomass N. Furthermore, the dynamics of N in the soil determined the N uptake, growth, and yield of rice plants, as shown in Table 8. The quality of the compost also strongly correlated with the final soil properties (Table 7); treatment C3 showed the highest total soil mineral N and biomass N content compared to those of other treatments (Table 5). Element N is the most needed mineral in the process of plant growth besides the elements P and K. Proteins are composed of N-containing compounds, which are very important compounds in many plant organs, such as the seeds (Quilichini et al., 2022). The amount of N available for tall plants will increase the uptake and efficiency of N, which shows the highest level in C3 treatment compared to those of other compost treatments. Then, the highest growth and yield of rice plants shows the C3 treatment of 6.19 ton.ha^{-1} grain weight. Treatment C1 had a higher amount of N minerals than that of treatment C3, but N C3 uptake was higher than that in C1. This can be explained by the nature of C1 from the high quality group (100% peanut stover compost) without any mixture of low quality (rice straw), so that mineralization quickly occurs and accelerates the content of N minerals in the soil; however, the need of the plant for N is still low, so that low nutrient synchronization occurs, along with the very mobile nature of N. This is similar to other studies that found that adding fertilizers to the soil boosts plant uptake, which in turn leads to increased yields. (La Habi et al., 2018; Recena et al., 2015; Spohn & Kuzyakov, 2013; Sun et al., 2020).

Compared to the treatment with inorganic fertilizers (C6), the application of the compost mixture resulted in rice yields that were not significantly different. Accordingly, farmers' usage of inorganic fertilizers might be replaced with a mixed compost made from leftover rice straw and peanut residue (Darby et al., 2016; Hossain et al., 2017; Sakiah et al., 2021). Compared with the control, the application of the compost mixture increased rice yields by 34.31%–38.45% (Wang et al., 2015). It has been suggested that using N fertilizers with controlled N release could increase rice grain production (Klotzbücher et al., 2015).

The addition of organic matter to soil increases microbial activity as an agent of decomposition and mineralization, thereby increasing the release of nutrients (Duarte et al., 2013). However, soil animals have been found to influence litter decomposition and change litter variety in litter mixtures in addition to climate and litter quality, both directly by processing dead plant material in a specific way and indirectly by regulating microbial activity (Santonja et al., 2017). The present study, however, did not include soil animals in order to concentrate on microbially driven litter decomposition. This exclusion may account for the present experiment's low importance of plant community features. An earlier investigation at the Jena Experiment Field Site showed that anecic earthworms and legumes had a considerable impact on leaf litter mass loss. (Patoine et al., 2020). Other research has found that the addition of organic matter to the soil can increase wheat yield by 32% compared with controls (Debiase et al., 2016). Xu et al. (2020) concluded that the application of organic matter can affect soil properties, N availability, and efficiency of nutrient uptake by plants (Han et al., 2020; Musyoka et al., 2017; Nguyen-Sy et al., 2023).

5. CONCLUSION

Peanut residue and rice straw compost showed an increase in cumulative N mineral with an increase in peanut residue composition during the incubation periods of 1, 2, 4, and 8 weeks, with an increase in net mineralization from 37.27% to 59.48%. C3 treatment was the best one by increasing N mineralization by 62.95%. N uptake, NUE, and upland rice yields were 405.28 mg pot^{-1}, 42.21%, and 6.19 tons ha^{-1}, respectively. A strong to very strong relationship was detected between the N form and N uptake (r = 0.84), plant height (r = 0.79), number of tillers (r = 0.78), and yield of rice plants r = 0.93 (total plant dry weight), and r = 0.76 (grain weight).

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Declaration of Competing Interest

The authors declare that no competing financial or personal interests that may appear and influence the work reported in this paper.

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