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Utilization of *Trichoderma* sp. and compost to increase nitrogen in specific soil types as planting media

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Abstract

Nitrogen deficiency dramatically affected plant growth, development, and productivity. This study aimed to determine the effects of *Trichoderma* sp. and compost on increasing the nitrogen content in several types of soil used as planting media. The research was conducted using an experimental method arranged in a factorial completely randomized design (CRD). The first factor was the soil types, consisting of Alfisol, Inceptisol, and Vertisol. The second factor was the dose of compost, consisting of four levels, namely K1 (0 tons ha^{-1} or no compost), K2 (10 tons ha^{-1}), K3 (20 tons ha^{-1}), and K4 (30 tons ha^{-1}). The third factor was the concentration of *Trichoderma* sp., which consisted of four levels, namely T1 (0 CFU ml^{-1}), T2 (10^6 CFU ml^{-1}), T3 (10^8 CFU ml^{-1}), and T4 (10^{10} CFU ml^{-1}). The results showed that the combination of compost and *Trichoderma* sp. naturally increased the N content of each soil type. Total N content in Inceptisol, Alfisol, and Vertisol was 0.384%, 0.243%, and 0.230%, respectively. The combination of compost and *Trichoderma* sp. increased sustainable nitrogen availability and was more environmentally friendly.

INTRODUCTION

Nitrogen (N) is an essential element in agricultural systems, crucial for producing plant and animal products to meet the needs of the growing world population (Follett and Hatfield, 2001). It occurs in various forms and vital for all living things. Nitrogen is the nutrient required by plants in the largest amount. It is an essential component of organic molecules, such as amino acids, nucleic acids, and proteins (Walworth, 2013). Nitrogen plays a critical role in the vegetative growth phase of plants and is necessary for the formation of chlorophyll, the green pigment that enables photosynthesis (Rahmawati, 2017). Therefore, nitrogen deficiency can severely affect plant growth, development, and productivity.

Managing N inputs is essential to balancing optimal crop production with environmentally tolerable levels of N-NO_3^-, particularly in water supply (Lamb et al., 2014). Mineralization processes release nitrogen in the form of ammonium (NH_4). In the soil, some of this ammonium is absorbed by plants through their roots, and the majority is converted by soil bacteria into nitrate (NO_3^-). Nitrate, being highly mobile, quickly moves through the soil water and is readily absorbed by plants. Within the plant, nitrate (or ammonium) is transformed into protein. Additionally, nitrate can be converted back into nitrogen gas (N_2), allowing it to return to the atmosphere. The process is known as denitrification, which is carried out by bacteria in soil and water.

Twelve soil orders that are frequently utilized as growth medium were created by classifying different types of soil according to their distinct properties. Inceptisol, Alfisol, and Vertisol are some of the most common soil types found on Indonesian agricultural land. Inceptisols cover 70.52 million hectares in

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Indonesia (Azmi et al., 2022), Vertisols cover around 2.1 million hectares (Masria et al., 2024), and Alfisols cover 12.74 million hectares in East Java (Safitri et al., 2018). These soil types do, however, have a number of drawbacks that may affect soil fertility, especially in relation to their chemical composition.

Chemical characteristics of soil are essential for assessing soil fertility. Recognizing these qualities is crucial for assessing soil fertility potential and underpins good soil management, including fertilization strategies. Analyzing soil chemical characteristics helps ascertain nutrient content. Nusan et al. (2018) state that the production and quality of farmed plants are affected by the nutrients available in the soil. An imbalance of nutrients may result in atypical growth and developmental problems in plants. Consequently, it is essential to evaluate the nutritional composition of a particular soil type or growing medium and understand how to rectify any shortfalls or imbalances.

The surge in agricultural output with population expansion necessitates a suitable approach to enhance agricultural productivity (Kowsari & Eslahi, 2024). Chemical fertilizers and pesticides effectively enhance agricultural yields; nevertheless, prolonged and excessive usage of inorganic substances may lead to soil acidification and nutrient loss (Islam et al., 2024). Consequently, it is imperative to embrace alternate strategies, particularly those that harness the function of soil microbes.

Compost is an organic material that enhances the chemical characteristics of soil. It comprises nutrients, including nitrogen and phosphate, in complex forms that are challenging for plants to assimilate. The incorporation of microorganisms, such as *Trichoderma* species, is essential for the mineralization of nutrients. *Trichoderma* fungus synthesize bioactive substances, including enzymes capable of degrading cell walls and several secondary metabolites. This capability enables *Trichoderma* sp. to decompose organic materials into macro and micro nutrients that are readily absorbed by plants (Latif, 2019). Microorganisms are crucial for sustaining the equilibrium of soil ecosystems, especially fungus and bacteria, which are necessary for supplying plant nutrients, strengthening soil structure, and augmenting soil fertility (Moreira & Bomfim, 2024). This study aimed to determine the utilization of *Trichoderma* sp. and compost to increase the nitrogen content in several types of soil used as planting media.

MATERIALS AND METHODS

This research was conducted in the Greenhouse and Land Resources Laboratory at the Faculty of Agriculture, Universitas Pembangunan Nasional "Veteran" Jawa Timur. The study was conducted in factorial completely randomized design (CRD). The first factor was soil types, consisting of Alfisol, Inceptisol, and Vertisol. The second factor involved four levels of compost doses, including K1 (0 tons ha^{-1} or no compost), K2 (10 tons ha^{-1}), K3 (20 tons ha^{-1}), and K4 (30 tons ha^{-1}). The third factor was the concentration of *Trichoderma* sp., divided into four levels, consisting of T1 (0 CFU ml^{-1}), T2 (10^6 CFU ml^{-1}), T3 (10^8 CFU ml^{-1}), and T4 (10^{10} CFU ml^{-1}). A total of 48 treatment combinations were constructed from the aforementioned treatments, with each combination replicated three times, yielding 144 experimental units overall. Soil sampling conducted four times during the 56-day incubation period, with samples collected biweekly.

The soil samples were then analyzed for total nitrogen using the Kjeldahl Method. A 0.5 g soil sample was measured and deposited in a test tube. Subsequently, 1 g of a selenium combination and 5 ml of concentrated sulfuric acid were added (the addition must occur inside a fume hood), followed by digestion at a temperature of 350°C for 3 to 4 hours. Digestion was considered complete with the emergence of white vapors and the acquisition of a clear extract (about 4 hours). Upon completion of digestion, the test tube was extracted, let to cool, and then diluted with deionized water to a final volume of 100 ml in a 100 ml volumetric flask. The extract was then used for nitrogen (N) quantification using a colorimetric method.

Soil sample preparation

The soil samples used in the study consisted of Alfisol, Inceptisol, and Vertisol. The soil samples were sieved with a 2-mm sieve and put into 20 × 20 cm polybags with a total weight of 4.4 kg.

Provision of *Trichoderma* sp. and compost

Trichoderma sp. was prepared by propagating pure *Trichoderma* sp. using sugar potato extract. *Trichoderma* sp. was obtained from the Microbiology Laboratory, Universitas Pembangunan Nasional "Veteran" Jawa Timur. The compost was made from dry leaves that had been decomposed and ready to use. The compost in the research was a compost product of Universitas Pembangunan Nasional "Veteran" Jawa Timur.

Preparation of Planting Media

Planting media prepared were combinations of *Trichoderma* sp. and compost homogenized according to the treatment combinations. The combinations were then mixed evenly with the prepared soil.

Statistical Analysis

Data from analysis in laboratories were gathered from 14 DAI to 56 DAI. Subsequent to tabulation, the data were subjected to analysis of variance (ANOVA). Additionally, to assess the impact of the treatments, the data conducted the Honest Significant Difference (HSD) test at a significance threshold of 5%.

RESULTS AND DISCUSSION

Soil before treatment, compost and *Trichoderma* sp. were analyzed in laboratory, and the results are presented in Table 1. The results of basic analysis showed that the Total N content (%) of Alfisol soil used was 0.17, respectively, which are in the low category. This condition follows the chemical properties of Alfisol in East Java as stated by Taufiq (2001) that Alfisols have low content of organic C. In Inceptisols, the total N contents was 0.31%, respectively, which are in the medium category. The nutrient content of Inceptisol soils is categorized as low to high, with varying fertility depending on the parent material. In Vertisols, the total N contents was 0.16%, respectively, which are in the low category. According to Matheus and Kantur (2022), Vertisols chemically have weaknesses, including low organic C, available K, and available P and moderate total N. Based on the results of basic soil analysis before treatment, the total N content of each type of soil was categorized as low to medium. Therefore, it is necessary to add compost as a source of organic matter to increase soil nitrogen content and soil microorganisms, such as *Trichoderma* sp., to accelerate the decomposition process of organic matter.

Table 1. Results of basic analysis of soil and compost

Basic Analysis	Property	
	N (%)	Category
Soil types		
Alfisol	0.17	L
Inceptisol	0.31	M
Vertisol	0.16	L
Compost	12.10	(*)

Remarks: (*) = meets the requirements of Permentan 2019; M = Medium, L = Low

The results (Table 2) showed that in Alfisol, the combination of compost at a dose of 30 tons ha^{-1} and *Trichoderma* sp. at a concentration of 10^6 CFU ml^{-1} increased total N content to 0.243%, which is in the moderate category. This shows that the greater the dose of compost given, the greater the total N content. This result is in line with the opinion of Nenobesi et al. (2017), stating that the higher the dose of compost applied to the soil, the higher the nitrogen nutrient content in the soil. The lowest total N content in Alfisol (0.106%) was observed in the treatment combination of Alfisol soil + compost 10 tons ha^{-1} + *Trichoderma* sp. 10^6 CFU ml^{-1}.

In Inceptisol, the combination of compost at a dose of 20 tons ha^{-1} and *Trichoderma* sp. at a concentration of 10^8 CFU ml^{-1} increased soil total N to 0.384% from the initial total N content of 0.31%. The combination of compost and *Trichoderma* sp. had not been able to significantly increase the total N content. It can be seen that the total N content remained in the medium category before and after treatments. The application of compost at a dose of 20 tons ha^{-1} gave a higher total N content value compared to that of 30 tons ha^{-1}. It is suspected that 20 tons ha^{-1} is the optimal compost dose for Inceptisol. The results of research by Sihite et al. (2016) showed that manure treatment at a dose of 20 tons ha^{-1} on Inceptisol increased total N content up to 0.24% compared to a dose of 30 tons ha^{-1} with a value of 0.22%.

The highest total N content in Vertisol was found in the combination of compost at a dose of 10 tons ha^{-1} and *Trichoderma* sp. at a concentration of 10^{10} CFU msl^{-1}, with a value of 0.230% (medium). This proves that the combination of compost and *Trichoderma* sp. increased the total N content, which was previously 0.16% (low). The highest total N content was 0.384%, which was in Inceptisol. Inceptisol soil has a slightly acidic pH, making it suitable for the metabolism of *Trichoderma* sp. This is in agreement with Uruilal et al. (2012), mentioning that the fungus prefers a low pH, and its optimum

Table 2. Effects of compost and *Trichoderma* sp. combination on total nitrogen (%) content

Combi-nation	14 DAI			28 DAI			42 DAI			56 DAI		
	J1	J2	J3	J1	J2	J3	J1	J2	J3	J1	J2	J3
K1T1	0.110[a]	0.183[b-j]	0.193[e-k]	0.205[b-g]	0.255[d-j]	0.160[abc]	0.193	0.280	0.207	0.180[b-f]	0.260[jkl]	0.150[abcd]
K1T2	0.116[abc]	0.167[a-i]	0.193[e-k]	0.214[b-h]	0.278[g-k]	0.189[abcd]	0.180	0.220	0.190	0.170[a-g]	0.263[jkl]	0.157[a-e]
K1T3	0.132[a-f]	0.247[j-p]	0.183[a-j]	0.193[a-e]	0.290[hijk]	0.180[abcd]	0.193	0.143	0.163	0.173[b-f]	0.258[ijkl]	0.183[c-h]
K1T4	0.136[a-g]	0.257[k-p]	0.190[d-k]	0.234[c-i]	0.292[hijk]	0.174[abcd]	0.180	0.163	0.187	0.190[efgh]	0.270[jkl]	0.177[b-f]
K2T1	0.121[abcd]	0.257[k-p]	0.133[a-g]	0.166[abc]	0.277[f-k]	0.120[a]	0.227	0.180	0.183	0.167[a-g]	0.247[ijk]	0.133[a]
K2T2	0.106[a]	0.257[k-p]	0.190[d-k]	0.168[abc]	0.305[ijkl]	0.142[ab]	0.223	0.223	0.163	0.170[a-g]	0.263[jkl]	0.147[abc]
K2T3	0.153[a-h]	0.240[j-o]	0.193[e-k]	0.170[abc]	0.229[c-i]	0.162[abc]	0.210	0.263	0.167	0.180[b-f]	0.283[klm]	0.134[a]
K2T4	0.151[a-h]	0.310[opq]	0.167[a-i]	0.152[abc]	0.205[b-g]	0.199[a-g]	0.227	0.243	0.157	0.180[b-f]	0.267[jkl]	0.163[a-f]
K3T1	0.139[a-g]	0.300[nopq]	0.227[i-m]	0.160[abc]	0.350[kl]	0.186[abcd]	0.223	0.277	0.173	0.187[d-f]	0.263[jkl]	0.160[a-f]
K3T2	0.133[a-g]	0.317[pq]	0.203[g-l]	0.168[abc]	0.335[jkl]	0.198[a-g]	0.210	0.283	0.197	0.183[c-h]	0.288[lm]	0.160[a-f]
K3T3	0.118[abcd]	0.333[q]	0.177[a-j]	0.165[abc]	0.384[l]	0.202[a-g]	0.230	0.260	0.190	0.203[gh]	0.318[m]	0.143[ab]
K3T4	0.114[ab]	0.303[opq]	0.197[e-k]	0.193[a-e]	0.325[ikl]	0.175[abcd]	0.227	0.290	0.203	0.193[efgh]	0.270[jkl]	0.187[d-h]
K4T1	0.128[a-e]	0.300[nopq]	0.187[c-k]	0.209[b-h]	0.299[ijk]	0.193[a-f]	0.233	0.197	0.210	0.163[a-f]	0.243[ij]	0.197[fgh]
K4T2	0.151[a-h]	0.270[l-q]	0.213[h-m]	0.211[b-h]	0.290[hijk]	0.213[b-h]	0.243	0.237	0.190	0.167[a-g]	0.220[hi]	0.203[gh]
K4T3	0.135[a-g]	0.300[nopq]	0.230[i-n]	0.183[abcd]	0.273[e-k]	0.193[a-e]	0.233	0.250	0.197	0.170[a-g]	0.290[lm]	0.187[d-h]
K4T4	0.145[a-h]	0.280[m-q]	0.200[f-l]	0.167[abc]	0.256[d-j]	0.186[abcd]	0.237	0.273	0.183	0.177[b-f]	0.270[jkl]	0.197[fgh]
Tukey 5%		0.06			0.07			NS			0.03	
F value		3.281			2.881			1.777			4.117	
P value		0			0			0.039			0	

Remarks : Values followed by the same letters in the same column indicate no significant difference based on the HSD Tukey test at 5%; DAI: Days After Incubation; NS: No Significant

ranges from 4 - 6. In addition, the total N content in Inceptisol soil before treatment was higher than that in the other three soil types.

Compost is a source of organic matter that can provide nutrient availability for plant growth and development. Based on the study of Mcgrath et al. (2020), soil restoration method using one-time use of compost in conjunction with tillage provides sustained improvements in soil density and organic matter content that will help increase tree growth in unirrigated and unkempt planting sites. The study by Jin-shun et al. (2023) on a 30-year field fertilization experiment shows that synthetic N fertilizer applied over an extended period combined with straw or manure enhances SOC and total nitrogen levels and storage more effectively than synthetic fertilizer applied alone, particularly in the soil layers.

The decomposition of organic matter to provide nutrients, such as nitrogen, can be accelerated by adding decomposing microorganisms, such as *Trichoderma* sp. This is in accordance with Suryani et al. (2022), stating that compost decomposed using *Trichoderma* sp. can increase soil nitrogen content. According to Pratama et al. (2015), *Trichoderma* sp. can produce decomposing enzymes that decompose organic matter. This decomposition will release nutrients bound in complex compounds into plant nutrients.

Total N content in the three soil types experienced fluctuations and erratic increases from 14 DAI to 56 DAI. This is due to the mobile nature of nitrogen and its rapid loss due to various factors. Nitrogen loss in soil is caused by nitrogen leaching in the form of nitrate, evaporation, and the use of nitrogen by microorganisms for metabolism (Setiawati et al., 2022). According to Mayasari et al. (2015), in the metabolism of microorganisms, nitrogen plays an important role in the formation of nucleic acids, proteins, and coenzymes to support microbial proliferation.

The increase in nitrogen content affected by the treatments indicates that *Trichoderma* sp. has the ability to enhance nitrogen content in the soil. This is in line with the findings of Kusuma et al. (2019), mentioning that *Trichoderma* sp. fungi have the ability to increase and improve nitrogen content in the soil. Similarly, Samolski et al. (2012) also reported that *Trichoderma* spp. enhanced nitrogen availability and improved nutrient uptake through the modulation of root architecture.

CONCLUSIONS

The combination of compost and *Trichoderma* sp. has been proven effective in increasing total nitrogen content in Alfisols, Inceptisols and Vertisols. The nitrogen content from the highest to lowest was found in Inceptisol (0.384%), Alfisol (0.243%), and Vertisol (0.230%). The combination of compost and *Trichoderma* sp. is expected to increase the availability of nitrogen nutrients sustainably and to be more environmentally friendly than synthetic fertilizers. In addition to enhancing nutrient availability, compost and *Trichoderma* sp. contribute to maintaining soil health by preserving the diversity of soil microorganisms.

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