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Impact of Goat Manure, Dolomite, Zeolite, and Decomposer *Trichoderma sp.* Amendments on the Chemical Characteristics of Inceptisol, Growth and Production of Shallot

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ABSTRACT

Inceptisol is a type of young soil with low NPK nutrient content, which affects the yield of shallot. Efforts to improve the fertility of Inceptisol involve the application of soil amendments. The objective of this study to evaluate the most effective amendments for improving the chemical characteristics, enhancing the growth and yield of shallot. The research was conducted at the Tropical Horticulture Study Center (PKHT), IPB University, Bogor. The method used a two-factor Randomized Block Design (RALF). The first factor the type and combination of amendments (P), is P0 (Control), P1 (Dolomite), P2 (Goat Manure), P3 (Dolomite + Goat Manure), P4 (Dolomite + Goat Manure + Zeolite), P5 (Dolomite + Goat Manure + Trichoderma sp.), and P6 (Dolomite + Goat Manure + Zeolite + Trichoderma sp.). The second factor the variety of shallot (J), which included J1 (Tajuk Variety) and J2 (Sakato Variety). The results showed that the application of amendments and decomposers significantly influenced the chemical characteristics of Inceptisol. Treatment P6 (dolomite, goat manure, zeolite, and Trichoderma sp.,) produced the best results compared to other treatments. Meanwhile, the variety of shallot plants did not have a direct impact on the chemical characteristics of Inceptisol.

1. INTRODUCTION

Inceptisols are young and developing or immature soils and still have properties resembling those of their parent material with weaker profile development compared to mature soils (Jusman *et al*., 2017). Some common problems associated with inceptisols include: 1) Low nutrient content: This is due to lack of soil development. Inceptisols tend to have low fertility and nutrient content, such as low levels of N, P and K nutrients in the soil. So it requires soil improvement by providing intensive soil amendments and decomposers to maintain soil fertility (Nelvia, 2012); 2) Prone to erosion: Unstable inceptisols can be easily eroded by wind and water, which can remove fertile soil layers and cause environmental damage; 3) pH instability: inceptisols can also have variable pH, which can affect plant growth. Soil pH management may be required to suit the needs of specific crops (Ketaren *et al*., 2014).

One commodity that is suitable for planting on inceptisol land is shallots. Shallots can be cultivated on inceptisol. However, in the cultivation of shallot plants, it is necessary to pay attention to the availability of macronutrients in it, especially the availability of K nutrients. According to Triadiawarman *et al.* (2022) planting shallots on inceptisol must be accompanied by improvements in inceptisol characteristics, especially the availability of K nutrients in the soil. Giving goat manure amendments, dolomite, zeolite and decomposer *Trichoderma sp.* on inceptisol is one way that can be done in improving the characteristics of inceptisol and can increase the content of nutrients in the soil.

Improvement efforts to increase inceptisol soil fertility by providing soil amendments, which can increase soil pH because the pH in inceptisol is in the acid to neutral category. Dolomite amendment is a calcium-containing material that can be given to the soil to raise the pH. Goat manure can be used as an amendment because it functions in loosening the soil, improving soil structure and texture, increasing soil porosity, improving soil aeration, increasing the composition of soil organisms and facilitating plant root growth (Rukmana, 2007 in Muflih *et al*., 2023). The use of zeolite is usually mixed with the use of other organic materials such as animal manure or chemical fertilizers, this is because the active ingredients of zeolite will be more optimal if its use is combined with other organic materials, due to the nature of zeolite which has a high CEC and its ability to absorb ammonium ions. *Trichoderma sp.* can act as an auxiliary agent in increasing and accelerating decomposition so that soil fertility is maintained (Setyadi *et al*., 2017).

Providing amendments can increase the solubility of soil nutrients into available forms, and increase soil CEC. The improvement of these properties also depends on the type of amendment added. Soil amendments are used to improve the chemical, physical or biological properties of soil and increase the availability of low nutrients. The addition of amendments is done to streamline the use of inorganic fertilizers by minimizing inorganic fertilizer losses due to evaporation or leaching by rain (Rosmarkam & Yuwono, 2012). In accordance with research conducted by Benauli, (2021) the need for N elements in inceptisol is relatively high, because the N element in inceptisol is relatively low, namely 0.13%. So this research was conducted with the aim of examining the combination of goat manure amendments, dolomite, zeolite and decomposer *Trichoderma sp.* to find out which treatment is most effective in improving the chemical characteristics of inceptisol. Analyze the level of nutrient availability, especially potassium (K) due to the application of amendments. Assess the improvement of inceptisol chemical characteristics on shallot growth and production.

2. RESEARCH MATERIALS AND METHODS

2.1. Time and Place of Research

This research was conducted from November 2022 to March 2023 and was conducted in three places, namely planting activities carried out in the experimental garden of the Center for Tropical Horticulture Studies (PKHT), Bogor Agricultural University (IPB) located at RT.05/RW.05, Pakuan, South Bogor District, Bogor City, West Java. Analytical activities were carried out at the Laboratory of the Center for Tropical Horticulture Studies (PKHT), Bogor Agricultural University (IPB) and the Land Resources Laboratory, Faculty of Agriculture, UPN "Veteran" East Java.

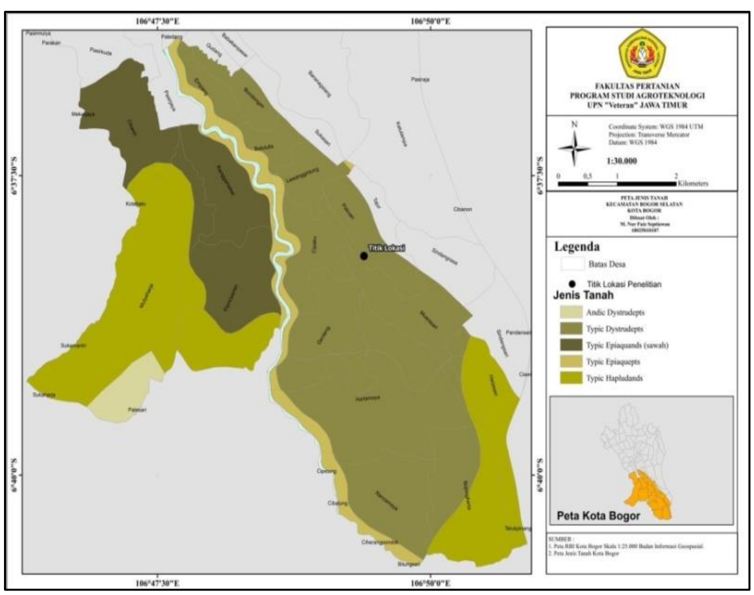

Figure 1. Soil type map

2.2. Research Tools and Materials

The tools used include hoes, shovels and shallot sprayers. Materials used include shallot bulbs, goat manure, dolomite, zeolite, *Trichodherma sp*., pesticides, polybags and soil media.

2.3. Research Method

The method used was a completely randomized factorial design (CRD) with two factors. The first factor is the type and combination of goat manure amendments, dolomite, zeolite, and decomposer *Trichoderma sp.* and the second factor is the use of shallot plant varieties. The first factor of Type and Combination of Amendments (P) consists of 7 levels, namely P0 (Control), P1 (Dolomite 2 tons/ha), P2 (Goat Manure 10 tons/ha), P3 (Dolomite 2 tons/ha + Goat Manure 10 tons/ha), P4 (Dolomite 2 tons/ha + Goat Manure 10 tons/ha + Zeolite 2 tons/ha), P5 (Dolomite 2 tons/ha + Goat Manure 10 tons/ha + *Trichoderma sp.* 20 kg/ha), P6 (Dolomite 2 tons/ha + Goat Manure 10 tons/ha + Zeolite 2 tons/ha + *Trichoderma sp.* 20 kg/ha). The second factor of Shallot Plant Variety (J) consists of 2 levels, namely J1 (Tajuk Variety), J2 (Sakato Variety), and J2 (Sakato Variety).

2.4. Observation Parameters

Observation parameters include pH Conductometry method, C-organic Walkey and Black method, ammonium (NH_4^+), nitrate (NO_3^-) titrimetric destillator method, P-available using P-Olsen method, K-exchangeable using SSA method, CEC using colorimetric method, and bacterial population using Total Plate Count (TPC) method.

2.5. Data Analysis

Observation data comes from laboratory analysis, after the data is collected, ANOVA or variance test is carried out, 5% least significant difference (HSD) test, and T test on K-exc and total microbial population analysis because there are no replicates in the two analyses.

3. RESULTS AND DISCUSSION

3.1. Soil Characteristics

Inceptisol from the experimental garden of the Center for Tropical Horticulture Studies (PKHT), Bogor Agricultural University (IPB) located at RT.05/RW.05, Pakuan, South Bogor Sub-district, Bogor City, West Java is presented in (Table 1). The physical properties of soil texture parameters with a percentage of sand 28%, dust 51%, and clay 17% based on these results the soil in the experimental garden of the Center for Tropical Horticulture Studies (PKHT), Bogor Agricultural University (IPB) is included in the dusty loam soil texture class. The characteristics of dusty loam soil have the ability to retain water and physical and chemical reactions in it, but the disadvantage of this soil is that it has a minimal surface area, making it difficult to retain water and absorb elements in the soil (Liana *et al*., 2022). This is in accordance with the results of the analysis of soil chemical properties of C-Organic value of 1.89% which is classified as low.

Table 1. Characteristics of Inceptisol before treatment

No.	Parameters	Unit	Result	Criteria (*)
1.	Texture	%	Sand 28%, Silt 51 %, Clay 21 %	Silty loam
2.	pH H_2O	-	5.62	Slightly acidic
3.	C-organic	%	1.89	Low
4.	N-NH_4^+	ppm	193.83	High
5.	N-NO_3^-	ppm	77.85	High
6.	P-Olsen	ppm	81.54	Very high
7.	K-dd	ppm	4.29	Very low
8.	CEC	Cmol/kg	22.32	Medium
9.	Microbial Population	CFU/ml	80×10^{-4}	Medium

Notes (*): Criteria sourced from Sulaeman *et al*. (2009)

The pH value is 5.62 with slightly acidic criteria. This condition is because inceptisol soils tend to contain high levels of Fe and Al, both of these elements can cause acidity in the soil. The soil pH increases when the concentration of Al and Fe is reduced, (Swanda *et al*., 2015). Ammonium (NH_4^+) content in the soil before treatment amounted to 193.83 ppm and nitrate (NH_3^{-1}) amounted to 77.85 ppm, the content of ammonium and nitrate is high. The P content in the soil characteristic analysis of 81.54 ppm is classified as very high and the K-dd content of 4.29 ppm is included in the very low criteria. The content of nitrogen (N), phosphorus (P) and potassium (K) in Inceptisol at different altitudes can vary and nutrient content is also influenced by environmental factors and land use (Ketaren *et al.*, 2014).

3.2. Effect of Treatments on Soil Characteristics

The effects of single factors on soil properties are presented in Tables 2 and 3, respectively for data collected at 35 DAP and 60 DAP. Whereas, the effects of treatment combinations are detailed in Tables 4 and 5, respectively for data collected at 35 DAP and 60 DAP. The effects of treatments are discussed as the following.

Table 2. Effect of single factors on soil properties at 35 DAP

Treatments	pH	C-organic	Nitrate (NO_3^-)	P-Olsen	CEC
	(--)	(%)	(ppm)	(ppm)	(cmol/kg)
Amendments and Decomposers					
P0	6.65^{a}	1.60^{a}	41.10^{a}	82.04^{b}	22.50^{a}
P1	7.26^{c}	1.74^{ab}	75.70^{b}	82.35^{bc}	25.64^{b}
P2	6.84^{b}	1.85^{b}	69.81^{ab}	76.08^{a}	25.31^{b}
P3	7.29^{c}	1.88^{b}	60.86^{a}	78.70^{ab}	25.29^{b}
P4	7.35^{c}	1.91^{bc}	91.98^{bc}	87.44^{c}	27.33^{cd}
P5	7.37^{cd}	2.00^{cd}	91.74^{b}	100.88^{d}	25.93^{bc}
P6	7.45^{d}	2.18^{d}	115.39^{c}	104.63^{d}	29.02^{d}
HSD 5%	0.12	**0.17**	**32.00**	**5.83**	**2.02**
Shallot Varieties					
J1	7.19	1.83^{a}	70.22	86.96	25.42
J2	7.16	1.93^{b}	85.94	87.94	26.29
HSD 5%	**NS**	**0.09**	**NS**	**NS**	**NS**

Note : Numbers followed by the same letter in the same column indicate not significantly different in the HSD test at α = 5%. NS = not significant. P0 (Control), P1 (Dolomite 2 ton/ha), P2 (Goat Manure 10 ton/ha), P3 (Dolomite 2 ton/ha + Goat Manure 10 ton/ha), P4 (Dolomite 2 ton/ha + Goat Manure 10 ton/ha + Zeolite 2 ton/ha), P5 (Dolomite 2 ton/ha + Goat Manure 10 ton/ha + *Trichoderma sp.* 20 kg/ha), P6 (Dolomite 2 ton/ha + Goat Manure 10 ton/ha + Zeolite 2 ton/ha + *Trichoderma sp.* 20 kg/ha), J1 (Tajuk variety), J2 (Sakato variety).

Table 3. Effect of single factors on soil properties at 60 DAP

Treatments	pH	C-organic	Nitrate (NO_3^-)	P-Olsen	CEC
	(--)	(%)	(ppm)	(ppm)	(cmol/kg)
Amendments and Decomposers					
P0	6.06^{a}	1.76^{a}	20.76^{a}	103.91^{a}	26.12^{a}
P1	6.55^{c}	1.87^{a}	47.96^{a}	108.36^{a}	25.54^{a}
P2	6.02^{a}	1.95^{a}	62.85^{ab}	108.21^{a}	24.25^{a}
P3	6.30^{b}	1.96^{ab}	54.36^{a}	111.63^{ab}	26.03^{a}
P4	6.18^{ab}	2.02^{b}	93.59^{b}	118.42^{b}	27.75^{a}
P5	6.11^{a}	2.07^{bc}	86.89^{b}	124.67^{bc}	25.78^{a}
P6	6.14^{a}	2.33^{c}	106.47^{b}	132.71^{c}	31.93^{b}
HSD 5%	**0.20**	**0.28**	**50.03**	**13.55**	**3.78**
Shallot Varieties					
J1	6.27^{b}	2.01	62.65	111.74^{a}	26.93
J2	6.11^{a}	1.98	72.46	119.09^{b}	26.62
HSD 5%	**0.11**	**NS**	**NS**	**7.24**	**NS**

Note : Numbers followed by the same letter in the same column indicate not significantly different in the HSD test at α = 5%. NS = not significant. P0 (Control), P1 (Dolomite 2 ton/ha), P2 (Goat Manure 10 ton/ha), P3 (Dolomite 2 ton/ha + Goat Manure 10 ton/ha), P4 (Dolomite 2 ton/ha + Goat Manure 10 ton/ha + Zeolite 2 ton/ha), P5 (Dolomite 2 ton/ha + Goat Manure 10 ton/ha + *Trichoderma sp.* 20 kg/ha), P6 (Dolomite 2 ton/ha + Goat Manure 10 ton/ha + Zeolite 2 ton/ha + *Trichoderma sp.* 20 kg/ha), J1 (Tajuk variety), J2 (Sakato variety).

Table 4. Effect of treatment combinations on soil properties at 35 DAP

Treatments	Ammonium (NH_4^+) (ppm)	K-exc (ppm)	Total Microbial Population (CFU/ml)
P0J1	172.00	4.29	112
P0J2	175.54	4.25	98
P1J1	277.93	4.58	92
P1J2	245.56	4.51	66
P2J1	320.21	4.66	142
P2J2	303.94	4.57	168
P3J1	283.67	4.45	60
P3J2	268.34	4.56	78
P4J1	201.56	**5.05**	153
P4J2	**360.52**	4.92	102
P5J1	233.92	4.07	340
P5J2	270.13	4.59	240
P6J1	297.27	4.66	**368**
P6J2	349.40	4.66	363
HSD 5%	NS		

Table 5. Effect of treatment combinations on soil properties at 60 DAP

Treatments	Ammonium (NH_4^+) (ppm)	K-exc (ppm)	Total Microbial Population (CFU/ml)
P0J1	181.84[a]	5.99	153
P0J2	193.80[ab]	5.69	180
P1J1	252.35[b]	5.42	180
P1J2	180.38[a]	5.49	152
P2J1	248.13[b]	5.09	201
P2J2	188.76[a]	5.90	160
P3J1	139.18[a]	5.64	166
P3J2	268.24[b]	5.30	182
P4J1	255.62[b]	6.07	178
P4J2	269.38[bc]	5.82	205
P5J1	316.18[c]	6.14	378
P5J2	233.70[b]	5.95	380
P6J1	**329.69[c]**	6.31	430
P6J2	297.98[c]	**6.60**	**472**
HSD 5%	86.70		

3.2.1. Effect of Treatments on pH

Soil pH is the level of acidity that has a relationship with the availability of nutrients and chemical processes in the soil. The treatment of providing amendments (goat manure, dolomite, zeolite and decomposer *Trichoderma sp.*) and the use of different types of shallot varieties on inceptisol had no significant effect on the interval of 35 DAP and the interval of 60 DAP, but the provision of amendments and decomposers was able to increase the pH of inceptisol which was initially acidic to neutral. The best increase in soil pH value was at interval 60 DAP with an average value of 6.19 with a neutral category. The increase in pH value occurred due to the provision of lime amendments so that lime can increase soil pH by producing OH- (hydroxide) ions which are alkaline. When lime is dissolved in the soil, OH- ions interact with acidic H^+ (hydrogen ion), this reaction reduces the concentration of H^+ ions, so the soil pH increases (Zahrah, 2009).

At the 35 DAP interval, the increase in pH value was due to the provision of lime amendments that had just been made so that the amendments had not been completely decomposed in the soil, while at the 60 DAP interval the amendments had been decomposed and had been absorbed by plants so that the pH value was lower. In addition, the provision of lime in the soil can increase the pH value of the soil because lime is alkaline so that the pH of the soil which was originally acidic becomes neutral (Krisnawati & Bowo, 2019).

The results of the analysis of variance of each factor, the provision of a combination of amendments significantly affects the pH value. This is due to the alkaline nature of the lime added to the soil, while the use of different types of shallot varieties shows the results of the analysis of variance have no significant effect, this is because shallot varieties have no effect on the pH value in the soil. In the P2 treatment, the 35 DAP interval shows the results of the analysis of variance different from the other treatments, this is because P2 is the only treatment that does not have a combination of dolomite amendments so that it has the lowest pH value compared to the other treatments (Rinawati & Rusmawan, 2015).

3.2.2. Effect of Treatments on C-organic

C-Organic is the total carbon element contained in the soil and plays an important role in improving the chemical, biological and physical properties of soil, such as increasing the availability of nutrients for plants that can support plant growth (Maryam & Yusmah, 2023). The results of the analysis of variance showed that the provision of amendments (goat manure, dolomite, zeolite and decomposer *Trichoderma sp.*) gave significantly different results and the value of C-Organic increased along with the increase in the incubation period, this is because the longer incubation period causes C-organic in the soil to increase significantly so that ameliorants can be absorbed by plants, this is in accordance with the statement of Siregar (2017). Siregar (2017) the increase in C-Organic content in the soil depends on the incubation period after the addition of amendments in the soil, this is because C-organic amendments need to undergo a decomposition process before nutrients and carbon can be available to plants. If decomposition does not take place properly, the increase in organic carbon may not occur.

The results of analysis of variance on each treatment factor showed that the combination of amendments had a significant effect on soil C-Organic at intervals of 35 DAP and 60 DAP. This is in accordance with the statement (Afandi *et al*., 2015) that the increase in C-Organic value is directly proportional to the provision of soil amendments, the more complete the provision of amendments added, the C-Organic value also increases. Providing soil amendments can increase the availability of nutrients needed by plants so that the availability of C-organic can increase. Providing amendments such as goat manure and zeolite can increase organic carbon content which is a source of energy for microorganisms such as *Trichoderma sp.* in composting (Pakpahan *et al*., 2015).

3.2.3. Effect of Treatments on Ammonium (NH_4^+)

Based on the results of the ANOVA test, the provision of 2 treatment factors, namely the combination of amendments and types of shallots, has a significant effect on Ammonium (NH_4^+) content at 60 DAP interval. These results were followed by Test (HSD) at the 5% level. Based on the results of ANOVA, it shows that the provision of ameliorant has no significant effect at the interval of 35 DAP (Table 4) and is significantly different at the interval of 60 DAP (Table 5). This is because the provision of amendments at the interval of 60 DAP has undergone more complete decomposition so that the availability of ammonium in the soil increases. In addition, the provision of amendments such as goat manure can increase ammonium in the soil through a fermentation process that breaks down ammonia into nitrogen that can be absorbed by plants. (Maula, 2023). While the provision of zeolite plays a role in increasing soil ammonium by inhibiting the conversion of NH_4^+ into nitra (Suwardi, 2009). According to research conducted by Astuti *et al*. (2022), *Trichoderma sp.* isolate acts as a decomposer that can accelerate the decomposition of goat manure and zeolite used as soil amendments.

3.2.4. Effect of Treatments on Nitrate (NO_3^-)

Analysis of variance on each treatment factor showed that the provision of amendments had a significant effect on soil nitrate content at 35 DAP (Table 4) and 60 DAP (Table 5), while the use of shallot varieties had no significant effect on nitrate content at 35 DAP and 60 DAP intervals. This is because soil nitrate content is more influenced by factors such as soil fertility, soil pH, and the availability of other nutrients such as phosphorus and potassium. In addition, the use of different varieties does not directly affect soil nitrate content. Plant varieties affect plant growth and productivity, but do not directly affect plant nutrient content (Asri & Arma, 2019).

The decrease in nitrate value at 60 DAP interval is due to the binding of nutrients by plants, including shallots, absorbing nitrogen for growth. If the absorbed nitrogen exceeds the available supply, the nitrogen content in the soil can decrease. This is in accordance with the statement of Herwanda *et al*. (2017) that nitrogen nutrients play an important role in the growth and yield of shallots, including bulb size and number of leaves, the content of available nitrogen absorbed by plants will affect the level of available nitrogen in the soil, so that the availability of soil nitrogen will decrease.

3.2.5. Effect of Treatments on P-Olsen

The results of the analysis of variance in each treatment showed that the provision of amendments had a very significant effect on the availability of phosphorus in the soil, while the treatment of the use of varieas showed results that were not significantly different at the interval of 35 DAP (Table 4) and significantly different at the interval of 60 DAP (Table 5). Dolomite application can increase phosphorus availability because dolomite contains CaO and MgO nutrients that can neutralize soil pH. If the soil lacks calcium and magnesium, the plants will be less productive. With the addition of dolomite, the soil pH will increase, so dolomite can help increase the availability of soluble phosphorus in the soil. Giving goat manure can increase phosphorus content in the soil because goat manure contains various nutrients and microorganisms that can break down phosphorus so that phosphorus content increases.

In research conducted by Kurniawati (2016), that the provision of zeolite can increase the content of nutrients Nitrogen and Forfor, as well as increase the vegetative growth of plants. While the provision of *Trichoderma sp.* is used as a decomposer that helps in understanding the nutrients and amendments given to the soil so that the amendments can be maximally available for soil and plants. There is an increase in the value of P at the interval of 60 DAP this is due to a longer incubation period. In each treatment, the average increase from the 35 DAP interval to the 60 DAP interval is because the amendments given to the soil have undergone more complete decomposition so that the availability of phosphorus in the soil increases and is available to plants (Pakpahan *et.al*., 2015).

3.2.6. Effect of Treatments on K-exchangeable

Potassium in shallots plays a role in the fruit ripening process, through the synthesis of lycopene, the pigment responsible for the red color of the fruit. In addition, K ions can also encourage high acid content in plants, which plays a role in making the fruit taste good. The following K-exc analysis results are presented in Table 6. The results of the K-exc analysis showed that the highest value was in the 60 DAP interval of the P6J2 treatment with a value of 6.60 ppm. This is because in the P6J2 treatment, dolomite, goat manure, zeolite and *Trichoderma sp.* amendments were given so that the addition of these various amendments can increase the maximum K-dd value compared to other treatments. Dolomite plays a role in neutralizing soil pH so that it affects the availability of potassium, goat manure contains macro and micro nutrients, including potassium so that it can increase the availability of soil potassium. The addition of zeolite can control the rate of potassium release from KCl fertilizer, thus allowing more efficient and cost-saving fertilizer use. Zeolites can temporarily bind potassium from cation exchange, thus inhibiting the process of too rapid K release and allowing plants to absorb potassium effectively (Suwardi, 2009). *Trichoderma sp.* plays a role in helping convert decomposed organic matter into simple compounds that plants can absorb as nutrients, including potassium (Amalia *et al*., 2019).

Based on the results of the T test of K-exc value on the provision of amendments shown in Table 6, it states that there is a significant difference in the average of K-exc values between treatment P0 and P6, and between treatment P3

Table 6. T-test Matrix of 0.05 treatment application on K-exc

Treatment	P0	P1	P2	P3	P4	P5	P6
P0	0.000						
P1	0.178	0.000					
P2	-0.021	-1.000	0.000				
P3	0.357	0.130	0.285	0.000			
P4	-2.305	-3.012	-1.883	**-9.281**	0.000		
P5	-1.083	-0.698	-0.386	-0.847	1.075	0.000	
P6	**-3.674**	-2.123	-1.745	-2.079	-0.341	-2.496	0.000
T-table	**3.182**						

and P4, while the other treatments do not show significant results. This is because the P0 treatment is acontrol treatment that has the lowest K-exc value while the P6 treatment is the treatment with the most complete amendment so that it shows the highest K-exc value, therefore the two treatments show a significant average difference between the control and the plants treated with amendments.

This is because in the P6 treatment, dolomite, goat manure, zeolite and *Trichoderma sp.* amendments were given so that the addition of this combination of amendments can increase the maximum K-exc value compared to other treatments. Dolomite plays a role in neutralizing soil pH content so that it affects the availability of potassium, goat manure contains macro and micro nutrients, including potassium so that it can increase the availability of soil potassium. The addition of zeolite can control the rate of potassium release from KCl fertilizer, thus allowing more efficient and cost-saving fertilizer use. Zeolites can temporarily bind potassium from cation exchange, thus inhibiting the process of too rapid K release and allowing plants to absorb potassium effectively (Suwardi, 2009). *Trichoderma sp.* plays a role in helping to convert decomposed organic matter into simple compounds that plants can absorb as nutrients, including potassium (Amalia *et al*., 2019).

3.2.7. Effect of Treatments on Cation Exchange Capacity (CEC)

Cation Exchange Capacity (CEC) is defined as the capacity of a soil to exchange cations (positively charged ions) with other cations in the soil solution. Cation exchange capacity is also defined as the level of clay's ability to absorb and exchange cations. Cations have the ability to absorb anions (negatively charged ions) or organic and inorganic particles (Saputri, 2020). Soil cation exchange capacity is one of the important soil chemical properties because it affects the ease and availability of nutrients for plant roots.

The results of the analysis of variance on the treatment factors showed that the provision of amendments had a real effect at intervals of 35 DAP (Table 4) and 60 DAP (Table 5), while the use of different shallot varieties showed no real effect. Soil amendments such as dolomite, goat manure, zeolite and *Trichoderma sp.* can increase the CEC value of soil dolomite contains basic cations such as CaO as much as 35.7% which can increase soil CEC (Syaputra *et al*., 2015), goat manure contains nutrients such as nitrogen, phosphorus, and potassium, so that these elements can be bound by soil particles. The increase in CEC occurs because the soil can absorb and provide nutrients better. Zeolite as a natural mineral has an important role in improving soil properties and increasing CEC. Zeolite has a very high cation exchange capacity, which is between 120 to 180 meq per 100 grams. This means that zeolite is able to absorb and store metal ions such as potassium (K), calcium (Ca), and magnesium (Mg) in large quantities (Setiawan *et al*., 2023) and the addition of *Trichoderma sp.* can improve the availability of nutrients in the soil. By decomposing organic matter, *Trichoderma sp.* releases nutrients that can be absorbed by plants, thus contributing to an increase in soil CEC.

3.2.8. Effect of Treatments on Microbial Population

Microbial population is the number of microbial cells contained in the soil, the presence of microorganisms has an important role in soil and plants such as increasing the availability of nutrients, soil microbes can help convert decomposed organic matter into simple compounds that can be absorbed by plants as nutrients (Napitupulu *et al*., 2023). The results of the analysis of the total microbial population are presented in Table 7, the results of the analysis show that the total microbial population at the interval of 60 DAP has increased compared to the total microbial population at the interval of 35 DAP, the highest microbial population value is at the interval of 60 DAP treatment P6J2 with a value of 472×10^{-4} CFU/ml and the total microbial population value in the initial soil characteristics analysis of 80×10^{-4} CFU/ml. The increase in total microbial population was due to the addition of *Trichoderma sp.* decomposer in the soil. *Trichoderma sp.* can increase the number of microbes in the soil by activating microbes to accelerate the decomposition of organic matter. This allows microbes to grow and develop faster, thus increasing the soil microbial population (Palealu & Baideng, 2018).

The results of the T test of microbial populations on the provision of amendments are shown in Table 11. There were significant differences in the average results of microbial population analysis in the P0-P4 treatment with P5 and P0-P5 treatment with P6, while the other treatments did not show significant results. This is because the P5 and P6 treatments are the treatments with the most complete combination so that the two treatments show the best value compared to the other treatments so it can be concluded that the P5 and P6 treatments are the best treatments on the results of the analysis of the total soil microbial population. The increase in total microbial population is due to the addition of *Trichoderma sp.* decomposer in the soil. *Trichoderma sp.* can increase the number of microbes in the soil by activating microbes to accelerate the decomposition of organic matter. This allows microbes to grow and develop faster, thus increasing the soil microbial population (Suanda *et al*., 2020).

Table 7. T-test Matrix of 0.05 treatment application on microbial population

Treatment	P0	P1	P2	P3	P4	P5	P6
P0	0.000						
P1	0.687	0.000					
P2	-1.670	-1.000	0.000				
P3	0.994	0.073	1.794	0.000			
P4	-3.130	-2.642	0.348	-2.050	0.000		
P5	**-9.972**	**-12.999**	**-5.087**	**-8.626**	**-13.111**	0.000	
P6	**-34.962**	**-19.147**	**-9.604**	**-31.686**	**-21.325**	**-3.501**	0.000
T table	**3.182**						

Table 8. Effect of single factors on plant characteristic and yield

Treatments	Leaf Length (cm)			Number of Leaves	Tuber Weight (g)		Number of Bulbs
Amendments and Decomposers	**20 DAP**	**40 DAP**	**60 DAP**	**Interval 3**	**Fresh**	**Dry**	**(--)**
P0	23.75	28.13^{a}	32.58	47.83^{a}	25.22^{a}	19.64^{a}	9.83
P1	24.92	29.38^{a}	33.50	61.67^{b}	31.68^{b}	24.74^{bc}	12.33
P2	24.21	31.33^{b}	36.33	64.33^{b}	34.54^{b}	25.44^{c}	11.67
P3	24.67	31.67^{b}	37.25	66.00^{b}	34.98^{b}	24.43^{b}	12.50
P4	23.54	30.42^{ab}	36.33	56.33^{a}	27.98^{a}	19.45^{a}	10.33
P5	25.58	32.38^{b}	37.92	59.17^{ab}	29.21^{a}	20.88^{a}	11.67
P6	25.50	31.79^{b}	36.79	69.00^{b}	29.72^{ab}	20.99^{ab}	9.17
HSD 5%	**NS**	**2.55**	**NS**	**11.51**	**5.88**	**4.13**	**NS**
Shallot Varieties							
J1	23.56^{a}	30.25	35.57	66.81^{b}	32.00	23.07	13.57^{b}
J2	25.63^{b}	31.20	36.06	54.43^{a}	28.95	21.38	8.57^{a}
HSD 5%	**1.09**	**NS**	**NS**	**6.15**	**NS**	**NS**	**1.42**

Note : Numbers followed by the same letter in the same column indicate not significantly different in the 5% HSD test.
P0 (Control), P1 (Dolomite 2 ton/ha), P2 (Goat Manure 10 ton/ha), P3 (Dolomite 2 ton/ha + Goat Manure 10 ton/ha), P4 (Dolomite 2 ton/ha + Goat Manure 10 ton/ha + Zeolite 2 ton/ha), P5 (Dolomite 2 ton/ha + Goat Manure 10 ton/ha + *Trichoderma sp.* 20 kg/ha), P6 (Dolomite 2 ton/ha + Goat Manure 10 ton/ha + Zeolite 2 ton/ha + *Trichoderma sp.* 20 kg/ha), J1 (Tajuk variety), J2 (Sakato variety).

3.3. Effect of Treatments on Plant Characteristic and Yield

Table 8 summarizes the effect of single factors on the characteristic and yield of shallot including leaf length, number of leaves, bulb weight, and number of bulbs. They are discussed as the following.

3.3.1. Effect of Treatments on the Leaf Length

Leaf length in shallot plants is influenced by several factors, both environmental and genetic, the following leaf length values are presented in Table 8. Based on the results of the analysis of variance of onion leaf length on each treatment factor, the results are not significant. In the treatment of giving various amendments, it is significantly different at the interval of 40 DAP and not significantly different at the interval of 20 DAP and 60 DAP. This is because the effect of soil amendments on the length of shallot leaves can vary depending on the type of amendment, dosage, and soil conditions (Khadijah *et al*., 2021). Meanwhile, the treatment of shallot varieties was significantly different at intervals of 20 DAP and not significantly different at intervals of 40 DAP and 60 DAP. It is suspected that the variety of a plant does not always affect leaf length because leaf length can be influenced by other factors such as the environment, care and the type of soil used as a medium has an important role in the growth of shallot plants (Sitorus *et al*., 2023).

This study used 2 different types of varieties as treatment factors, namely the Tajuk Variety and the SS Sakato Variety. Both varieties have an average leaf length that is not much different, the Tajuk variety has an average leaf length of 29.79 cm and the SS Sakato variety has a higher average leaf length of 30.96 cm. SS Sakato variety is the result of research conducted by the PKHT IPB research team, this variety has several advantages, namely high productivity, suitable for cold areas, large tuber size and fragrant aroma. However, leaf length is not always determined by the type of variety used, but environmental factors, nutrient availability and the maintenance process also affect the growth of shallot plants (Khadijah *et al*., 2021).

3.3.2. Effect of Treatments on the Number of Leaves

The number of leaves on a plant refers to the total number of leaves that grow on a particular plant. The number of leaves can vary depending on several factors such as plant age, older plants tend to have more leaves than younger plants (Kurnianingsih *et al*., 2019). The results of the analysis of variance of the number of leaves of shallot plants on each treatment factor showed significantly different results. In the treatment of giving a combination of amendments significantly different at each interval, this is because soil amendments such as goat manure can increase the content of soil nutrients such as NPK nutrients which play an important role in leaf growth, decomposer Trichodema sp. can also improve the activity of soil microorganisms. Mycorrhizae help decompose organic matter and improve nutrient circulation which will affect leaf growth (Triadiawarman *et al*., 2022). Research conducted by Cataldo *et al*., (2021), states that the provision of zeolite can improve the quality of plant metabolite content, such as anthocyanins which play a role in providing red and purple colors in shallots. Meanwhile, the treatment of shallot varieties has a significant effect on the number of plant leaves (Aryani *et al*., 2024).

This study used 2 different types of varieties as treatment factors, namely the Tajuk Variety and the SS Sakato Variety. The two varieties have an average number of leaves that are not much different, the Tajuk Variety has an average number of leaves of 48 strands and the SS Sakato Variety has a smaller average number of leaves, namely 42 strands. The average number of leaves on the Tajuk variety is more than the SS Sakato variety. The Tajuk variety has the advantage of good varietal quality and has good resistance so that it can grow outside the growing season. However, the number of plant leaves is not always determined by the type of variety used but environmental factors, nutrient availability and the treatment process also affect the growth of shallot plants (Khadijah *et al*., 2021).

3.3.3. Effect of Treatments on Tuber Weight

The weight of shallot bulbs is done by weighing the wet weight and dry weight of the bulbs then the wet weight value is reduced by the dry weight of the bulbs so that the actual weight value of the bulbs is produced. Based on the results of the analysis of variance of the weight of shallot bulbs against each treatment factor, it shows that it is significantly different from the provision of amendments and is not significantly different from the treatment factor of shallot varieties. In the treatment of giving amendments significantly different at each interval, the highest value is in the treatment of P2 (Goat Manure) and P3 (Dolomite + Goat Manure) this is because goat dung contains important nutrients such as NPK, which supports plant growth and the formation of larger bulbs, goat dung is an organic fertilizer that can increase water retention besides goat dung contains natural ZPT which can stimulate bulb growth (Danial *et al*., 2020). Dolomite is an additive used for soil pH adjustment. Soils that are more neutral or slightly alkaline tend to support plant growth better (Manurung & Vindo, 2019). While the treatment of shallot varieties has an insignificant effect on the weight of shallot bulbs, this is thought to be caused by other more dominant factors, although varieties play an important role in agricultural yields, there are other factors that are more dominant in determining the weight of shallot bulbs, such as soil conditions, fertilizers, climate, and cultivation management (Azmi *et al*., 2011).

This study used 2 different types of varieties as treatment factors, namely the Tajuk Variety and the SS Sakato Variety. The two varieties have an average number of leaves that are not much different, the Tajuk Variety has an average wet weight of tubers of 32 g, dry weight of tubers 23.07 and the SS Sakato Variety has a smaller average tuber weight, namely wet tuber weight 28.95 g, dry tuber weight 21.38 g. The average weight of tubers in the Tajuk Variety is greater than the SS Sakato variety. This is because the number of tubers in the Tajuk Variety is more than the SS Sakato Variety so that the tuber weight is also heavier. Tajuk varieties have the advantage of a relatively short harvest age of less than two months, making it easier to care for and maintain (Azmi *et al*., 2011).

3.3.4. Effect of Treatments on the Number of Bulbs

The number of shallot bulbs is the total bulbs produced on each clump. The number of shallot bulbs can vary depending on the variety and growing conditions. Factors that affect the number of shallot bulbs include bulb varieties and the availability of macro nutrients in the soil (Husain *et al*., 2022). Based on the results of the analysis of variance of the number of shallot bulbs against each treatment factor, it shows that it is not significantly different from the provision of amendments and significantly different from the treatment factor of shallot varieties. This is because the provision of amendments does not directly affect the number of shallot bulbs, amendments are more instrumental in the process of tillage to improve soil quality and productivity. While the treatment of shallot varieties has a very significantly different effect on the number of shallot bulbs, this is because varieties that are more productive and more resistant to pests and diseases can produce more bulbs (Azmi *et al*., 2011).

Based on (Table 8) The highest number of shallot bulbs is found in the P3J1 treatment, namely the provision of dolomite + goat manure amendments and the use of crown varieties with a total of 16 pieces. The average number of shallot bulbs is 11 pieces. In this study, 2 types of varieties were used as treatment factors, namely the Tajuk Variety and the SS Sakato Variety. The Tajuk variety has an average number of bulbs of 14 pieces and the SS Sakato variety has an average number of bulbs of 9 pieces. The average number of tubers in the Tajuk variety is greater than the SS Sakato variety. Because the SS Sakato Variety has a larger tuber size, this causes the number of tubers in this variety to be less than the Tajuk Variety. Tajuk tubers can be stored for 3-7 months. The color of the tubers is pink, the weight per tuber ranges from 5-12 g, and the number of tubers per clump ranges from 5-15 bulbs (Marlin *et al*., 2019).

4. CONCLUSIONS

The provision of Dolomite, Goat Manure, Zeolite and *Trichoderma sp.* decomposer (P6) amendment treatment significantly affected the chemical characteristics of inceptisol and gave the best results compared to other treatments. Nutrient elements N-NH_4^+ and K-exc were highest in treatment P6J1, while nutrient elements N-NO_3^- and P-Olsen were highest in treatment P6J2. The treatment of different varieties of shallots gives a real effect on the number of leaves and the number of bulbs. Two varieties of shallots have their respective advantages, the Tajuk variety has more bulbs than the SS Sakato variety so that the weight of the bulbs is also heavier, the harvest age is relatively short which is less than two months, making it easier to care for and maintain. While the SS Sakato variety of shallots has several advantages, including a larger bulb size, which is almost half the size of jumbo onions, fresh red color and a more fragrant aroma.

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