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Effectiveness of Organic Fertilizer Enriched with Humic Acid on Soil Chemical Quality, Nutrient Uptake, and Shallot Yield in Calcareous Soils

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ABSTRACT

Calcareous soils have great potential for the development of food crops and horticulture, but they are constrained by high pH, low organic matter content, and less than optimal cation exchange capacity, thus affecting the availability of nutrients. This study aims to evaluate the effectiveness of organic fertilizer enriched with humic acid on soil chemical quality, nutrient uptake, and yield of shallots on calcareous soils. The study was designed with two factors, namely type of organic fertilizer (manure and bokashi) and concentration of humic acid (0%, 10%, and 20%) added to the organic fertilizer. The results of the study showed that the application of organic fertilizers, both manure and bokasih, had a similar effect on soil quality and shallot yields. However, the addition of humic acid at a concentration of 20% significantly improved the chemical properties of the soil, nutrient uptake (especially nitrogen and potassium), as well as the yield component of shallots when compared to the concentration of 10% and control. The addition of humic acid has been proven to be effective in improving nutrient availability and supporting plant growth. This innovation can be an effective solution to improve the quality of calcareous soils and agricultural products, especially shallots, which supports sustainable and environmentally friendly agriculture.

1. INTRODUCTION

Calcareous soil is one type of soil that is often found in areas with low rainfall, especially in dry and semi-arid areas such as in the Timor island region of East Nusa Tenggara. The characteristics of calcareous soil are relatively high pH (alkaline), low organic matter content, and less than optimal cation exchange capacity, so it is often less than ideal to support optimal plant growth. Therefore, management of calcareous soil is key to maintaining its productivity (Song *et al*., 2017; Alikhani *et al*., 2023). One type of horticultural plant whose growth and production are greatly influenced by soil quality is shallots (*Allium ascalonicum* L.). Shallots are a promising strategic commodity and have good market prospects so that they are included in the national superior horticultural commodities (Saragih *et al*., 2022). As one of the strategic horticultural commodities, shallots receive special attention from all parties because they have significant economic value (Susanti *et al*., 2018). Shallot productivity in East Nusa Tenggara is still low with an average of 5.9 ton/ha (BPS NTT) and is below the national average production of 9.24 ton/ha, or far below the production potential of above 20 ton/ha (Kementerian Pertanian, 2024). The low productivity of shallots in NTT is caused by various factors, including soil factors and supporting technology. Shallots require a good balance of nutrients and soil moisture to achieve maximum productivity (Sumarni *et al*., 2013). Calcareous soil has great potential in the development of shallots and other horticultural crops, because it is quite widespread in the Timor - East Nusa Tenggara region. However, calcareous soil has constraints in plant development because it has a slightly alkaline pH (base), due to the high lime content ($CaCO_3$ content). This condition will affect the availability and absorption of essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K), and other micronutrients such as iron (Fe) and zinc (Zn) (Brownrigg *et al*., 2022; Przygocka-Cyna *et al*., 2020; Taalab *et al*., 2019), thus reducing the yield of shallots. Along with the development of science and technology, various efforts have been made to improve the quality of calcareous soil. One approach that is now widely discussed is the use of organic fertilizers enriched with active acids such as humic acid. Manure and bokashi are two types of organic fertilizers that are quite well-known and widely used by farmers as soil conditioners (Luta *et al*., 2020). Both types of fertilizers have been shown to be able to significantly increase soil fertility, especially in degraded soils. However, both types of fertilizers have limitations in terms of the speed of organic matter decomposition and their ability to increase nutrient availability in the soil. A study conducted by Alikhani *et al*. (2023) stated that although the use of organic fertilizers significantly increased soil fertility in general, its effect on calcareous land was still less than optimal without the addition of nutrient carrier agents.

To overcome these limitations, enrichment of manure and bokashi with humic acid has been proposed as one of the new innovations that can increase their effectiveness. According to (Roulia, 2024; Bhatt & Singh, 2022; Dariah & Nurida, 2011), humic acid can function as a chelating agent that helps increase nutrient availability in the soil, accelerates the mineralization process, and increases the cation exchange capacity of the soil. Thus, the combination of manure, bokashi, and humic acid has the potential to increase nutrient availability for shallot plants in calcareous soil.

Humic acid is an organic acid derived from the decomposition of organic materials. This acid has extraordinary ability to improve soil structure, improve cation exchange capacity, and increase nutrient availability for (Firda *et al*., 2016; Newcomb, 2015). Several studies have shown that enrichment of organic fertilizer with humic acid (Newcomb, 2015) can accelerate the decomposition of organic matter, so that nutrients in the soil are more quickly available to plants. In addition, humic acid can also increase the absorption of macro and micro nutrients by plants, which in turn can increase plant productivity (Roulia, 2024). This study aims to examine in depth how enrichment of organic fertilizer with humic acid can change the dynamics of calcareous soil fertility, especially in relation to increasing nutrient absorption and shallot yields. This study is expected to provide a significant contribution to the management of calcareous soil, which is a major challenge in agricultural cultivation in various regions in Indonesia.

2. MATERIALS AND METHODS

2.1. Research Location

This research was conducted in the experimental field of the Agriculture Service of Kupang Regency located at the Oelnasi Agricultural Extension Center (BPP), District of Central Kupang, Kupang Regency, East Nusa Tenggara. The location of this research was located at the coordinates 10º 09" north latitude and 123º 45" south latitude. The research took place from April to August 2024. Initial soil chemical analysis, it was found that the characteristics of the soil at the research location were: pH value 7.83 (slightly alkaline), C-organic 1.68% (very low), N-total of 0.11% (low), P-available (Bray) 6.8 ppm (low), and K-available 0.46 me/100 g soil (moderate), CEC 19.85 me/100 g soil (moderate) (Sulaeman *et al*., 2009).

2.2. Experimental Design

This study was designed to evaluate the effects of organic fertilizer types and humic acid concentrations on the productivity of calcareous soils that have many problems. The study used a randomized block design with a factorial pattern with two factors, namely the type of organic fertilizer, consisting of two treatments, namely manure and bokashi. The second factor was the concentration of humic acid, with 3 levels, namely: 0%, 10%, and 20% humic acid. The dose of organic fertilizer applied in this study was 5 tons/ha. In addition, Urea, SP36 and KCL fertilizers were also given at 50% of the recommended dose, namely: 75 kg urea/ha, 50 kg SP36/ha, and 35 kg KCL/ha.

2.3. Stages of Research Implementation

This study began with the extraction of humic acid from water hyacinth compost. Mature water hyacinth compost (age of 3 months) was dried until the water content <20% to facilitate the process of extracting humic acid. The dry compost was mixed with NaOH solution at a ratio of 1:10 (1 part compost, 10 parts 0.1M NaOH solution). The mixture was stirred until homogeneus and let stand for 48 h to dissolve the humic acid from the compost. The solution was then filtered to separate the humic acid from the solid residue. The humic acid was precipitated by filtration and the solution was acidified by adding HCl solution to pH 1-2, the aim is to precipitate humic acid. The humic acid precipitate was separated from the solution through a centrifugation process. Furthermore, the humic acid precipitate was dried to become pure humic acid powder. This powder was then used to enrich organic fertilizers.

The next stage is the enrichment stage of organic fertilizers with humic acid. The prepared manure and bokashi fertilizers were dried first. Manure and bokashi were added with humic acid with a concentration of 10% of the total weight of the fertilizer. Fertilizer and humic acid were stirred until evenly mixed. Next, organic fertilizer enriched with humic acid was applied to the experimental land with main characteristic is calcareous soil. The experimental land was prepared and divided according to the number of treatment plots. The size of each treatment unit is 1.2x3 m. The distance between replications was 1 m and the distance between plots in each replication was 0.5 m. The total land area used in this experiment was 175.2 m^2 with size 14.6m × 12m. Shallot seeds was local Sabu variety. Planting was carried out after treatment application, with a planting distance of 20x10 cm, so that a population of 180 plants per plot was obtained. Sample plants were taken in the middle of the plot and determined randomly, as many as 20 plants per plot. Inorganic fertilizers in the form of SP-36, Urea, and KCL, were given evenly to all experimental units. Each amounted to 50 kg SP36/ha, 75 kg urea/ha, and 35 kg KCL/ha. SP-36 fertilizer as a source of P was given together with the application of treatment, namely one day before planting Shallots by means of a line. Urea and KCL fertilizers were given when the shallot plants were two weeks old. Figure 1 shows experiment plot for this experiment.

2.4. Observation Variables

The variables observed in this study were: chemical properties at the end of the experiment which included: pH, N-total (Kjeldhal), P-available (Bray-2), K-exchangeable and CEC (ammonium acetate extract 1N pH 7), and C-organic (Walkey and Black method). Soil samples at the end of the experiment were taken when the plants were 80 days after planting or approaching harvest. Observations on Shallot plants included N and P nutrient absorption and dry Shallot yields. For analysis of plant nutrient absorption, plant samples were carried out destructively during the maximum vegetative phase, namely plants aged 45 days after planting.

2.5. Data Analysis

The data were subjected to a two-way ANOVA. If a significant effect was obtained, it was continued with the Duncan Multiple Range Test (DMRT) at a level of 5% to determine the differences between treatments.

Figure 1. Experimental plot to study the effect of organic fertilizer and humic acid addition

RESULTS AND DISCUSSION

3.1. Soil chemical characteristics

The results of the variance analysis showed no interaction between the type of organic fertilizer and the concentration of humic acid, but each factor showed a significant effect ($p<0.05$) on the chemical properties of calcareous soil at the end of the experiment. The chemical characteristics of the soil on the influence of single factors of manure and bokashi enriched with humic acid are presented in Table 1.

3.1.1. Soil pH

Soil pH is one of the important indicators of soil chemistry because it is related to the availability of nutrients for plants. pH in calcareous soil is a major problem because it generally has a pH above neutral or slightly alkaline which affects nutrient availability. The results of the DMRT test (Table 1) showed that the manure and bokashi fertilizer treatments gave relatively similar pH values, namely 7.50 and 7.44, respectively. Both treatments showed a pH that was relatively neutral, which means that both types of organic fertilizers tend not to disrupt the acid-base balance of the soil, so they can support the survival of shallot plants well. According to several studies, neutral or slightly alkaline soil pH generally strongly supports the availability of nutrients for (Ferrarezi *et al*., 2022; Duddigan *et al*., 2021). The

Table 1. Effect of manure and bokashi enriched with humic acid on the average chemical characteristics of calcareous soil at the end of the experiment

Treatment Factor	pH	C-organic (%)	N-Total (%)	P-available (ppm)	K-exchangeable (me/100g soil)	CEC (me/100g soil)
Fertilizer type:						
Manure	7.50a	2.73a	0.15a	7.26a	0.31a	27.04a
Bokashi	7.44a	2.71a	0.16a	7.31a	0.32a	27.86a
Humic Acid Concentration:						
0%	7.58b	2.64c	0.12c	5.79c	0.27c	25.02c
10%	7.46a	2.70b	0.16b	7.58b	0.31b	27.84b
20%	7.38a	2.82a	0.18a	8.48a	0.37a	29.50a

Note: mean values followed by the same letter in the same column shows no significant difference according to the DMRT test at the 5% level.

provision of manure containing high organic matter can function as a buffer that maintains the stability of soil pH, while bokashi fertilizer is also known to contain ingredients that have the effect of increasing pH in calcareous soils (Chen *et al*., 2023). Meanwhile, the results of the DMRT test of the humic acid concentration factor on soil pH showed a significant difference between the different humic acid concentration treatments. The administration of humic acid with a concentration of 10% (pH 7.46) and 20% (pH 7.38) caused a decrease in soil pH compared to a concentration of 0% (without humic acid), but between the treatments of 10% and 20% humic acid, no statistically significant difference was found. This shows that the addition of humic acid has a real impact on lowering soil pH. This decrease in pH may be due to the influence of humic acid which is acidic, which can help neutralize alkaline conditions in calcareous soils. Humic acid as a fertilizer enrichment material contributes to reducing the amount of base cations in the soil solution so that there is a gradual decrease in soil pH (Alsudays *et al*., 2024). In addition, humic acid also increases the activity of soil microorganisms that produce organic acids during the decomposition process, which also plays a role in lowering soil pH (Yang *et al*., 2021). These findings support previous studies showing that humic acid is effective in improving the chemical properties of calcareous or alkaline soils by increasing CEC and facilitating nutrient release (Nuraini & Zahro, 2020).

3.1.2. C-organic

The treatment of fertilizer types, manure and bokashi fertilizer (Table 1) showed no different soil C-organic content, respectively 2.73% and 2.71% C-organic. Both types of fertilizers effectively increased the soil C-organic content. This is in line with many studies showing that manure and bokashi fertilizers can increase the soil C-organic content, because both fertilizers contain organic matter that can be decomposed into humus, which functions as a provider of carbon reserves for soil microorganisms (Swarnam & Velmurugan, 2014; Chen *et al*., 2023).

The results of the DMRT test also showed that the soil C-organic content at the end of the experiment increased along with the increase in humic acid concentration (Table 1). Treatment with 20% humic acid had significantly higher C-organic content (2.82%) compared to treatments of 10% (2.70%) and 0% (2.64%). This shows that humic acid at a higher dose has a greater effect on increasing the C-organic content of calcareous soil. This increase indicates that humic acid plays a role in increasing the C-organic content of the soil, which can increase the activity of soil microorganisms and improve the structure of calcareous soil. This increase in C-organic will support water retention and the availability of nutrients for plants. Conversely, treatment without humic acid produced lower C-organic levels, indicating that without the addition of humic acid, organic fertilizers have a more limited effect on increasing the organic matter content of the soil. It is further explained that humic acid consists of a complex polymer structure and is resistant to microbial decomposition. When added to organic fertilizers, humic acid helps maintain more stable organic matter in the soil, thereby increasing the overall C-organic content (Roulia, 2024). Humic acid is also known to stimulate microbial activity in the soil. These microorganisms play a role in the process of decomposing organic matter into more stable acids, such as humus, which contributes to increase C-organic in the soil (Jindo *et al*., 2020).

3.1.3. Total N Content

The results of the analysis presented in Table 1, found that the type of organic fertilizer enriched with humic acid had a significant effect on increasing total nitrogen levels in calcareous soil. The treatment of fertilizer types, both manure and bokashi fertilizer produced total N levels that were not significantly different, respectively by 0.15% and 0.16%. Both types of organic fertilizers can significantly increase soil total N levels compared to the initial conditions of calcareous soil, which usually have low N content. Manure and bokashi contain nitrogen in the form of organic compounds that can be released gradually through the mineralization process by soil microorganisms (Swarnam & Velmurugan, 2014; Matheus *et al*., 2024), so that consistent application of manure and bokashi can increase the nitrogen content in the soil, which supports the availability of nitrogen nutrients for plants. Table 1 shows that treatment with a concentration of 20% humic acid provided the highest increase in soil N-total levels (0.18%) and was significantly different from other treatments. The treatment of 10% humic acid produced a total N content of 0.16% and the lowest gross total N, which was 0.12%, was obtained in the 0% treatment (without humic acid). This indicates that a higher dose of humic acid can accelerate the process of nitrogen mineralization from organic matter contained in the soil. Increasing the total N content also plays an important role in supporting plant growth, considering that nitrogen is the main nutrient needed for protein synthesis and chlorophyll formation in plants (Živčák *et al*., 2014).

3.1.4. P-available content

The P-available content of calcareous soil at the end of the experiment showed a significant effect ($p<0.05$) of organic fertilizer and humic acid treatments on the availability of phosphorus (P) in the soil. In the fertilizer type treatment, both manure and bokashi fertilizer provided available P levels that were not significantly different, at 7.26 ppm and 7.31 ppm, respectively. Both types of organic fertilizers are able to increase the available P content of the soil compared to calcareous soil conditions which tend to be low in phosphorus content. Manure and bokashi contain phosphorus elements derived from organic materials that can be decomposed and released into a form of phosphorus that is more available to plants, either through the mineralization process or by forming complex organic compounds that bind phosphorus (Swarnam & Velmurugan, 2014).

Meanwhile, the concentration factor of humic acid has a significantly different effect on the available P content of the soil. Treatment with a concentration of 0% (without humic acid) produced the lowest available P levels (5.79 ppm), followed by treatment with 10% humic acid (7.58 ppm). Treatment with a concentration of 20% humic acid gave the highest available P levels (8.48%) significantly compared to other treatments. This increase in available P levels can be caused by the role of humic acid in increasing the solubility of phosphorus bound in the form of unavailable compounds. In addition, humic acid can also increase the activity of decomposing microorganisms in the soil, which play a role in the process of mineralization of organic matter and the release of phosphorus from unavailable compounds into forms that are more easily accessible to plants (Yang *et al*., 2019).

3.1.5. Exchangeable K levels

Exchangeable potassium (K-ex) levels in calcareous soil are influenced by the type of organic fertilizer and the concentration of humic acid. Manure and bokashi have been shown to be effective in increasing K-ex although the differences are not significant with K-ex levels of 0.31 and 0.32 me/100g soil, respectively. Both of these fertilizers, through the process of decomposition of organic matter, can increase the soil's capacity to store and provide potassium that is more readily available to plants, especially in calcareous soils that have lower cation exchange capacity (Hsu & Lai, 2022). In addition, the concentration of humic acid also has a positive effect on K-ex. The treatments of 10% and 20% humic acid produced K-ex of 0.31 and 0.37 me/100g of soil, respectively, higher than without humic acid (0.27 me/100g of soil). This indicates that a higher dose of humic acid has a greater impact on increasing the availability of potassium in the soil. The increase in K-ex levels is closely related to the ability of humic acid to increase the cation exchange capacity (CEC) of the soil. Humic acid has carboxyl and phenol groups that can interact with cations such as K^+, thereby increasing the availability of K in the soil. Humic acid also helps bind cations in the soil, which increases K retention and prevents K leaching from the soil, especially in soils with high permeability levels (Newcomb, 2015).

3.1.6. Soil CEC

The results of the experiment showed that the cation exchange capacity (CEC) of calcareous soil at the end of the experiment was significantly influenced by the type of fertilizer and the concentration of humic acid given. Based on the data obtained, both manure and bokashi fertilizer showed CEC values that were not significantly different, respectively 27.04 and 27.86 me/100g of soil. Both types of organic fertilizers are able to increase the cation exchange capacity of calcareous soil which basically has a low CEC, so that it can increase the ability of calcareous soil to maintain and provide nutrients for plants. Manure and bokashi contain organic matter that can improve soil structure and increase the activity of soil microorganisms, which play a role in the process of decomposing organic matter into humus. This humus functions as a provider of a place for the exchange of cations in the soil, which in turn increases the soil CEC (Matheus *et al*., 2024). In addition, these two types of fertilizers also contain cations such as calcium, magnesium, and potassium which can contribute directly to increasing soil CEC. The concentration of humic acid also affects CEC. Increasing the concentration of humic acid at doses of 10% and 20% significantly increased the CEC by 27.84 and 29.50 me/100g of soil, respectively, higher than without humic acid. Humic acid increases the soil's capacity to retain cations by forming cation complexes with organic matter and soil minerals, as well as improving soil structure, increasing aeration, and supporting microorganism activity. This increase in CEC is very important for increasing the availability of nutrients for plants. These results indicate that the addition of humic acid plays an important role in increasing the soil's ability to absorb and retain cations, which is one indicator of soil fertility. This study is also in line with studies stating that the addition of humic acid can improve soil fertility by increasing CEC and facilitating the release of nutrients (Nuraini & Zahro, 2020; Roulia, 2024).

3.2. Nutrient Uptake and Yield of Shallots

Based on the results of the analysis of variance, it shows that the treatment of organic fertilizer enriched with humic acid provides an insignificant interaction ($p>0.05$), but each factor has a significant effect ($p<0.05$) on nutrient uptake (N and P), and components of Shallot yields on calcareous soil. The results of the DRMT test on the average plant nutrient uptake (N and P) and components of shallot yields on calcareous soil are presented in Table 2.

Table 2. Effect of organic fertilizer treatment enriched with humic acid on N- and P-uptake and shallot yields on calcareous soil

Treatment Factor	N uptake (mg/plant)	P uptake (mg/ plant)	Number of Bulbs per clump	Bulbs diameter (cm)	Yield (ton/ha)
Fertilizer type:					
Manure	33.72a	26.27a	9.57a	2.76a	9.06a
Bokashi	34.50a	25.53a	9.31a	2.72a	9.74a
Humic Acid Concentration:					
0%	27.84c	21.78c	6.65c	2.42c	11.40c
10%	35.15b	25.76b	9.65b	2.82b	13.74b
20%	39.35a	30.16a	12.02a	2.97a	14.18a

Note: mean values followed by the same letter in the same column shows no significant difference according to the DMRT test at the 5% level.

3.2.1. Nitrogen (N) Uptake

Nitrogen is one of the macronutrients that is very important for plants. The results of the analysis (Table 1) show that the treatment of the types of organic fertilizers has similar effectiveness in increasing nitrogen absorption by plants. Manure and bokashi not only provide nitrogen, but also increase the organic matter content of the soil, which can directly improve soil structure and increase cation exchange capacity (CEC), so that more nutrients such as nitrogen can be absorbed by plants (Nuraini & Zahro, 2020; Roulia, 2024).

In addition, it can be seen that the treatment of humic acid concentration on N absorption of shallot plants also shows a significant increasing trend. treatment with 20% humic acid provides the highest N absorption significantly compared to other treatments. This shows that increasing the dose of humic acid not only increases nitrogen availability but also improves the efficiency of nitrogen absorption by plants. The addition of humic acid can improve soil structure, enlarge pore space, and increase soil resistance to erosion, which in turn allows plants to obtain more nitrogen that can be utilized for vegetative growth and onion bulb formation (Gemin *et al*., 2021). This increase in nitrogen uptake is in line with previous studies showing that humic acid can increase fertilizer efficiency and nutrient availability in marginal soils, such as calcareous soils (Roulia, 2024). According to Aylaj *et al*., (2023) the application of humic acid improves soil chemical properties, increases nutrient retention, and encourages healthier plant growth, and has the potential to reduce dependence on synthetic fertilizers.

3.2.2. Phosphorus (P) Uptake

Phosphorus is one of the essential nutrients needed for plant growth, but in calcareous soils, P availability is often limited because it is bound by high calcium (Ca). The results of the DMRT test (Table 2) showed that the treatment of fertilizer types, both manure and bokashi fertilizer, increased P absorption which was not significantly different, namely by 26.27 and 25.53 mg/plant. In addition, the treatment of humic acid concentration significantly increased the absorption of phosphorus by shallot plants, namely by increasing the concentration of humic acid from 20% significantly increasing P absorption by 30.16 mg/plant, higher than other treatments. This shows that increasing the concentration of humic acid can be more effective in dissolving bound phosphorus and increasing its availability to plants. The results are in line with the research of Wahyuningsih *et al*., (2017) that the administration of humic acid to utisols affects P absorption and soybean plant growth. Humic acid also plays a role in improving soil structure and increasing the activity of microorganisms that can help increase the availability of P in the root zone of plants, thereby increasing P absorption by plants. This increase can be explained by the ability of humic acid to increase the solubility of phosphorus bound to the form of unavailable compounds. Humic acid has the ability to form complexes with cations in the soil, including calcium, which can bind phosphorus in a form that is less available in calcareous soils. With the presence of humic acid, phosphorus bound to calcium becomes more soluble and available to plants (Rosan *et al*., 2018). Humic acid not only increases the availability of P by dissolving bound phosphate, but also helps maintain P around the plant root zone so that it is more easily absorbed by plants (Newcomb, 2015).

3.3. Shallot Yield

The results of the experiment showed that the yield components consisting of the number of bulbs per clump, bulb diameter (cm), and shallot yield (tons/ha), were significantly influenced by the type of organic fertilizer and the concentration of humic acid given. The results of the DMTR test in Table 2 show that the number of bulbs per clump, bulb diameter (cm), and shallot yield (tons/ha) in the bokashi and manure fertilizer treatments gave no different results. Both types of organic fertilizers have almost similar effectiveness in increasing soil fertility by providing essential nutrients such as nitrogen, phosphorus, and potassium, which support plant growth and the formation of shallot bulbs (Kumar *et al*., 2017). In addition, the microbial content contained in organic fertilizers can also help in the decomposition process of organic matter in the soil, improve the physical properties of the soil, and increase the soil's capacity to retain water and nutrients (Swarnam & Velmurugan, 2014; Chen *et al*., 2023).

Meanwhile, the treatment of humic acid concentration showed different effects on the number of bulbs per clump, bulb diameter (cm), and shallot yield (tons/ha). The application of humic acid with a higher concentration showed a very significant increase in shallot yield. The results of the DMRT test showed that the treatment of 20% humic acid concentration gave the highest results significantly compared to other treatments. This indicates that a higher dose of humic acid can increase the efficiency of nutrient utilization by plants and improve the physical and chemical conditions of the soil, which ultimately supports increased crop yields. The increase in shallot yield components not only reflects improvements in nutrient availability, but also in soil conditions that better support optimal plant growth. Organic fertilizers, especially those rich in humic acid such as manure and Bokashi, have been shown to significantly increase the productivity of calcareous soils and increase onion yields (Kumar *et al*., 2017). Calcareous soils often have limitations in the availability of nutrients, especially macronutrients that are important for plant growth, including phosphorus and nitrogen, which play a major role in the development of shallot bulbs. The increase in shallot yields can be an indicator that the availability of these nutrients has increased after the addition of humic acid to the fertilizer (Przygocka-Cyna *et al*., 2020; Alsudays *et al*., 2024).

4. CONCLUSION

Based on the results of the research conducted, it can be concluded that the concentration of humic acid added to organic fertilizers has been shown to have a significant effect on improving soil quality and crop yields. The addition of humic acid at a concentration of 20% showed a better increase in soil chemical properties, including pH, nutrient content (especially nitrogen, phosphorus, and potassium), and shallot yield components compared to a concentration of 10% and without the addition of humic acid (0%). The concentration of 20% humic acid was able to increase nutrient availability and affect the efficiency of nutrient absorption by plants, which ultimately contributed to an increase in more optimal shallot yields. This shows that humic acid can play an important role in improving the quality of calcareous soils, which generally have limitations in nutrient availability. The implication is that the use of organic fertilizer enriched with humic acid, especially at a concentration of 20%, can be an alternative to improve soil quality and agricultural yields, especially shallots, in areas with calcareous soil conditions. Thus, the practice of organic-based fertilization with humic acid can be promoted as an effective environmentally friendly method to support sustainable agriculture.

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