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REVIEW ARTICLE **Open Access**

Interaction of Humic Acid and NPK 16:16:16 in Nature on Increased Shallot Production (*Allium cepa* L. var. aggregatum)

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Abstract
Shallot productivity is frequently constrained by low nutrient use efficiency and declining soil quality caused by continuous application of inorganic fertilizers. This study aimed to evaluate the effects of humic acid and NPK 16:16:16 fertilizer, as well as their interaction, on the growth and yield of shallot (Allium ascalonicum L.). The experiment was arranged in a factorial Randomized Block Design with two treatment factors and three replications. The first factor was humic acid dosage consisting of 0, 1.5, 3, and 4.5 g plant $^{-1}$, while the second factor was NPK 16:16:16 dosage consisting of 0, 15, 30, and 45 g plant $^{-1}$. The results revealed that both humic acid and NPK 16:16:16 significantly affected several physiological and yield parameters of shallot plants. Significant interactions were observed on plant height at 3 weeks after planting, leaf nitrogen uptake, leaf area index, and fresh bulb weight. The combination of 45 g plant $^{-1}$ NPK and 4.5 g plant $^{-1}$ humic acid produced the highest fresh bulb weight of 74.76 g plant $^{-1}$. Humic acid application enhanced nutrient uptake efficiency, improved soil nutrient availability, and stimulated plant physiological activity, while NPK fertilizer supplied essential macronutrients required for optimal bulb development. The novelty of this study lies in demonstrating the synergistic interaction between humic acid and NPK 16:16:16 in improving shallot productivity under low-organic-matter soil conditions. Therefore, the combined application of 45 g plant $^{-1}$ NPK 16:16:16 and 4.5 g plant $^{-1}$ humic acid is recommended as an effective and sustainable fertilization strategy for shallot cultivation.

Keywords: Bulb Formation, Leaf Area Index, Nutrient Efficiency, Soil Fertility, Sustainable Cultivation

1. Introduction

Onion red (*Allium ascalonicum* L.) is a strategic commodity in horticulture with an important role nationally, serving as a commodity for consumption and controlling food inflation. Onion red productivity in Indonesia still faces various obstacles, especially land degradation and low fertilization efficiency. The continuous use of inorganic fertilizers without balanced organic materials causes a decline in the physical and chemical properties of the land, so that the ability of the land to provide nutrients becomes lower (Sari, 2021).

The North Sumatra region has a big potential for the development of red onion cultivation, but it is generally dominated by acidic soil with low organic matter content. This condition causesnutrients to be easily washed and not optimally available for plants. Using NPK 16:16:16 fertilizer is indeed capable of providingmacronutrients in a fast way. However, absorption efficiency is still low if there is no supporting land improver that is capable of repairing growing media conditions (Lubis, 2023).

Sour humate is one of the functionalorganic materials that repair physical, chemical, and biological soil characteristics. Acid humate is capable of increasing cation exchange capacity, repairing soil structure, and increasing nutrient availability for plants. The combination of sour humate with NPK fertilizer is suspected to give a synergistic effect on growth and production of red through improved nutrient absorption efficiency and physiological activity in plants (Haryadi, 2023).

According to Nainggolan (2010), the combination of sour humate and NPK fertilizers provides better results than single treatments. A combination of NPK fertilizer 300

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kg/ha and acid 40 mL humate is capable of increasing wet tuber weight by 25–30% compared to the control. Although NPK fertilizer and acid humate are used separately and in combination, they have been reported to increase onion red growth and yield; however, fundamental problems that still exist are low nutrient utilization efficiency in sour soil with low organic matter content. The cause is that nutrients provided through inorganic fertilizers are easily washed away, fixed, or not optimally available to the plant, so the productivity of red onions has not yet reached its maximum potential.

This study has a novelty in evaluating the interaction between various doses of sour humate and NPK fertilizer 16:16:16 in a more comprehensive way on red onion plants in North Sumatra soil, not only on tuber results but also on physiological parameters such as leaf N uptake and leaf width index. Research also determines the optimal combination and effective dose to sustainably increase the productivity of red onions.

This study aims to evaluate the influence of giving sour humate and NPK 16:16:16 fertilizer, as well as their interaction, on the growth and production of red onion plants.

2. Material and Methods

This study was implemented on the Test Field of the Faculty of Agriculture, University of North Sumatra, Medan, North Sumatra, Indonesia, which is located at coordinates 3.561° N and 98.656° E with a height of ± 32 m above sea level (masl). The study used a two-factor randomized factorial design (RAK) with three treatments.

The first factor in the study is the dose of sour humate, applied at 0 g, 1.5 g, 3 g, and 4.5 g per plant. The second factor is the dose of NPK 16:16:16 fertilizer, applied at 0 g, 15 g, 30 g, and 45 g per plant. These factors resulted in 16 treatment combinations, each replicated three times, yielding a total of 48 research plots. Each plot measures 1 m × 1 m, with plants spaced 20 cm × 20 cm apart. The observed parameters include plant height, leaf nitrogen uptake, leaf area index, fresh tuber weight, and other physiological parameters. The study data were analyzed using Analysis of Variance (ANOVA) to determine the influence of the treatment on the observed parameters. If the results analysis shows a real influence, then further testing with the Duncan Multiple Range Test (DMRT) at the 5% level will be conducted. The data analysis process was carried out using the IBM SPSS Statistics software version 25.0.

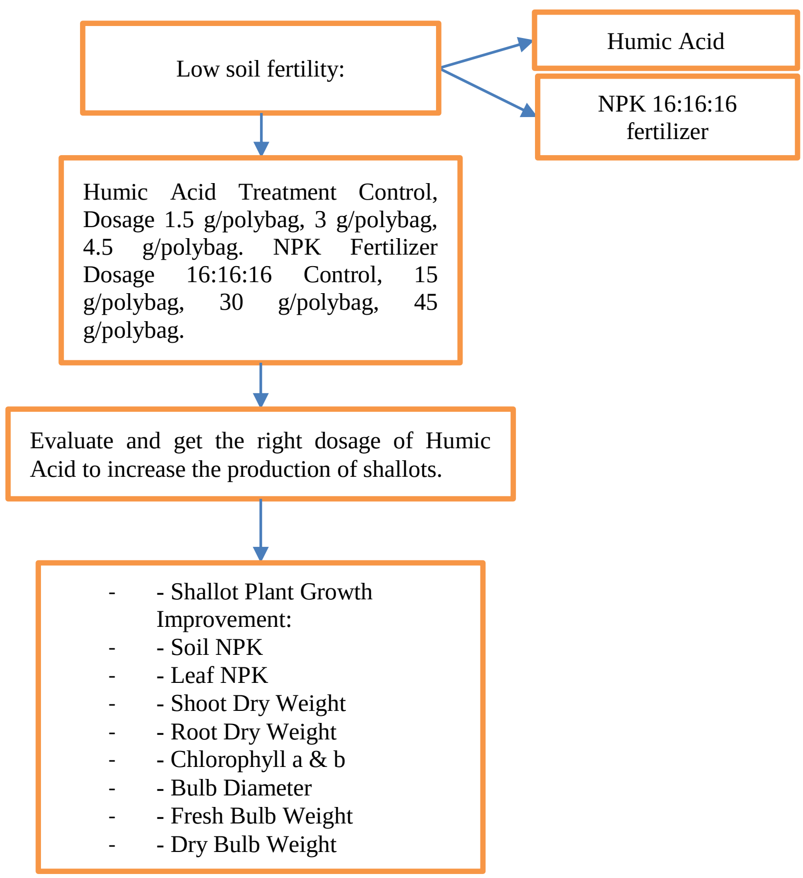

Figure 1. Research flow diagram

3. Results and Discussion

3.1. Plant Length

Research results show that the treatment of sour humate and NPK 16:16:16 fertilizer has a real influence on the length of red onion plants. The second treatment interaction is influential at 3 MST. The H2N0 treatment produces the highest plant length, namely 20.07 cm, while the H0N3 treatment produces the lowest plant length, which is 14.25 cm.

Table 1. Average length of plants aged 3 - 5 MST with treatment NPK 16-16-16 fertilizer and humic acid

MST	NPK 16-16-16 (g/plant)	Humic Acid (g/plant)				
		H 0 (0)	H 1 (1, 5)	H2 (3)	H3 (4, 5)	Average
3	N 0 (0)	14.48 ± 1.29[bc]	19.58 ± 1.27[ab]	20.07 ± 1.69[a]	19.90 ± 1.41[a]	18.51
	N 1 (15)	20.53 ± 0.51[a]	19.15 ± 1.18[ab]	18.37 ± 0.77[ab]	18.12 ± 0.83[ab]	19.04
	N 2 (3 0)	15.97 ± 1.43[bc]	15.52 ± 1.05[bc]	15.33 ± 1.49[bc]	17.58 ± 1.06[abc]	16.10
	N 3 (45)	14.25 ± 1.12[c]	15.65 ± 0.15[bc]	17.75 ± 0.91[abc]	17.15 ± 1.66[abc]	16.20
	Average	16.31	17.48	17.88	18,19	
4	N 0 (0)	21.57 ± 1.10	25.93 ± 0.47	24.72 ±2.21	26.73 ± 1.22	24.74 [a]
	N 1 (15)	25.23 ±0.62	24.83 ± 2.11	24.77 ± 0.81	24.17 ± 1.65	24.75 [a]
	N 2 (3 0)	21.67 ± 1.29	22.10 ± 0.88	20.40 ± 1.97	23.38 ± 1.59	21.89 [b]
	N 3 (45)	18.32 ±0.96	21.30 ± 0.91	24.15 ± 1.10	24.58 ±2.64	22.09 [b]
	Average	21.70 [b]	23.54 [a]	23.51 [a]	24.72 [a]	
5	N 0 (0)	23.05 ±1.07	27.50 ± 0.49	26.21 ± 2.29	28.35 ± 1.25	26.28 [a]
	N 1 (15)	26.58 ±0.67	26.50 ± 2.11	26.60 ± 0.67	25.96 ± 0.79	26.41 [a]
	N 2 (3 0)	22.98 ±1.36	23.44 ± 0.94	21.64 ± 2.07	24.80 ± 1.67	23.21 [b]
	N 3 (45)	19.43 ±1.00	22.59 ± 1.04	25.61 ± 1.18	26.07 ± 2.77	23.43 [b]
	Average	23.01 [b]	25.01 [a]	25.02 [a]	26.30 [a]	

Description: Numbers followed by the same letter indicate no significant difference based on the Duncan test (DMRT) at the 5% level.

Improvement in plant growth is allegedly related to the increased availability of nutrients and the restoration of growing media conditions as a result of applying sour humic acid humate. This substance enhances the soil's capacity to retain nutrients, making nutrient absorption by roots more efficient.

3.2. Leaf N Uptake

Interaction of NPK 16-16-16 fertilizer and acid humate is influential on leaf N uptake in red onion. N0H2 treatment produces the highest N absorption, namely 3.74 mg of plant $^{-1}$, whereas N2H1 treatment produces the lowest N uptake: 1.60 mg plants $^{-1}$. The highest average N uptake was found in the treatment of sour humate H3, namely 3.38 mg plant $^{-1}$, whereas the lowest was in H1, namely 2.19 mg plant $^{-1}$. Increased N absorption occurs because sour humate is capable of increasing cation exchange capacity, repairing microorganism activity in the soil, and improving nitrogen absorption efficiency by plant roots.

Research results show that giving sour humate can increase N absorption up to 54.34% compared to the lowest treatment. The results are higher than those of Wahyuni et al. (2022), who reported an improvement in nitrogen absorption efficiency of 20–35% in onion plants due to the application of humate. Putri's research (2020) also reported that the combination of NPK fertilizer and acid humate increased plant nitrogen uptake in horticulture by 28.6% compared to without acid humate. The height of nitrogen uptake in this research shows that the combination of NPK 16-16-16 fertilizer and acid humate can increase nitrogen availability and optimally support vegetative plant growth.

According to Santi (2019), acid humate plays a role in increasing the efficiency of nitrogen fertilization by binding nutrients in the root zone, thereby reducing nitrogen loss due to leaching. Additionally, nitrogen is a key element in the formation of chlorophyll and plant proteins, so improved nitrogen uptake directly influences the photosynthesis process and the growth of red onion plants.

3.3. Leaf Area Index

Giving NPK 16-16-16 fertilizer and acid humate is influential on the wide leaf onion index. The N0H3 treatment produced the highest leaf area index, namely 3.97, whereas the lowest was in the N2H1 treatment, which was 2.02. The highest average index wide leaf was found in the treatment of sour humate H3, namely 3.30, while the lowest was in H0 at 2.53. This result shows that the application of sour humate can increase leaf growth through improved nutrient availability and efficient absorption by plants.

This study shows an improvement in leaf width of 30.43% between the highest and lowest treatments. The results are higher than those of Khoir (2023), who reported that the combination of sour humate and NPK fertilizers increased onion red leaf growth by 19.6% compared to the control. Research by Hidayat et al. (2023) also shows that the application of sour humate and NPK 16:16:16 increases vegetative growth of red onion by 23.1% compared to without treatment. The wide leaf index in this research is allegedly because sour humate is capable of repairing growing media conditions, increasing root activity, and increasing nitrogen absorption, which plays a role in chlorophyll formation and leaf network development.

According to Abdelrasheed (2021), the application of humate material is capable of increasing nutrient utilization efficiency and plant photosynthesis activity in onion, so that leaf area and plant productivity become more optimal. High leaf area increases the plant's ability to catch sunlight, so that the formation of photosynthates for onion red growth becomes better.

Table 2. Average leaf N uptake (mg plant $^{-1}$) with NPK 16-16-16 fertilizer treatment and sour humate

NPK 16-16-16 (g /plant)	Sour Humate (g/ plant)				Average
	H0 (0)	H1 (1.5)	H2 (3)	H3 (4.5)	
N0 (0)	1.85 ± 0.64 ^{de}	1.87 ± 0.33 ^{de}	3.74 ± 0.61 ^{a}	3.32 ± 1.18 ^{ab}	2.70 ^{b}
N1 (15)	3.09 ± 0.76 ^{abc}	2.90 ± 0.64 ^{abcd}	3.01 ± 0.90 ^{abcd}	3.71 ± 0.49 ^{a}	3.18 ^{a}
N2 (30)	3.14 ± 1.08 ^{abc}	1.60 ± 0.18 ^{e}	3.23 ± 0.83 ^{abc}	3.19 ± 0.65 ^{abc}	2.79 ^{b}
N3 (45)	1.72 ± 0.28 ^{e}	2.40 ± 0.66 ^{bcde}	2.46 ± 1.14 ^{bcde}	3.29 ± 0.75 ^{ab}	2.47 ^{b}
Average	2.45 ^{b}	2.19 ^{b}	3.11 ^{a}	3.38 ^{a}	

Description: Numbers followed by the same letter indicate no significant difference based on the Duncan test (DMRT) at the 5% level.

Table 3. Average leaf area index with NPK 16-16-16 fertilizer treatment and sour humate

NPK 16-16-16 (g /plant)	Humic acid (g /plant)				Average
	H0 (0)	H1 (1.5)	H2 (3)	H3 (4.5)	
N0 (0)	2.06 ± 0.62 ^{c}	3.35 ± 1.08 ^{bc}	3.61 ± 0.94 ^{ab}	3.97 ± 1.39 ^{a}	3.25 ^{a}
N1 (15)	3.66 ± 1.05 ^{ab}	3.58 ± 1.14 ^{abc}	3.15 ± 0.86 ^{bc}	2.86 ± 0.99 ^{bc}	3.31 ^{a}
N2 (30)	2.33 ± 0.78 ^{c}	2.02 ± 0.65 ^{c}	2.20 ± 0.72 ^{c}	2.90 ± 0.92 ^{bc}	2.36 ^{b}
N3 (45)	2.07 ± 0.64 ^{c}	2.48 ± 0.82 ^{c}	3.21 ± 1.12 ^{bc}	3.46 ± 1.28 ^{abc}	2.81 ^{b}
Average	2.53 $^{(b)}$	2.86 $^{(b)}$	3.04 $^{(a)}$	3.30 $^{(a)}$	

Description: Numbers followed by the same letter indicate no significant difference based on Duncan's test (DMRT) at the 5% level.

3.4. Fresh Weight of Tubers

Giving NPK 16-16-16 fertilizer and acid humate was influential on the fresh weight of red onion tubers. N3H3 treatment resulted in the highest fresh weight of tubers, namely 74.76 g, whereas the lowest was the N0H1 treatment, which was 49.85 g. The highest average fresh tuber weight was found in the treatment of sour humate H3 at 64.05 g, while the lowest was in H1 at 56.57 g. The increase in fresh tuber weight is allegedly because the combination of NPK fertilizer and acid humate is capable of increasing nutrient availability, especially nitrogen, phosphorus, and potassium, which play an important role in tuber formation and enlargement.

The greatest improvement in fresh weight of tubers was observed in this research. This reached 49.97% compared to the lowest treatment. This result is higher than the study by Rizki (2019), who reported an improvement in onion red tuber weight by 25–30% due to a combination of NPK fertilizer and acid humate. According to Saputra (2021), application of acid humate also increases the fresh weight of tubers by 22.4% compared to without acid humate. The research results show that the combination of NPK 16-16-16 fertilizer and acid humate used is capable of increasing nutrient absorption efficiency and the photosynthesis process, so that accumulation of photosynthesis in tubers becomes taller.

According to Wahyuni (2022), humate material can increase root activity and fertilization efficiency, so that nutrient absorption takes place more optimally. The potassium element plays a role in the translocation of photosynthesis results to tubers, while phosphorus supports energy formation and tuber network development, so that fresh weight of tubers increases.

Figure 2. Comparison of Research Results Quality. A = H0N0 x HON3, B = H0N0 x H2N2, C = H0N0 x H0N1, D =

H0N0 x H0N3, E = H0N0 x H2N0, F = H0N0 x H0N3.

Table 4. Average fresh weight of tubers (g) by treatment: NPK 16-16-16 fertilizer and sour humate

NPK 16-16-16 (g /plant)	**Humic acid (g /plant)**				**Average**
	H0 (Control)	**H1 (1.5)**	**H2 (3)**	**H3 (4.5)**	
N0 (Control)	53.93 ± 0.12 c	49.85 ± 0.17 c	71.72 ± 0.19 ab	59.49 ± 0.12 bc	58.74
N1 (15)	52.25 ± 0.20 c	59.34 ± 0.14 bc	60.07 ± 0.15 bc	63.99 ± 0.20 abc	58.91
N2 (30)	60.90 ± 0.22 abc	58.37 ± 0.06 bc	55.48 ± 0.11 c	57.94 ± 0.22 bc	58.17
N3 (45)	64.12 ± 0.22 abc	58.71 ± 0.15 bc	56.06 ± 0.10 c	74.76 ± 0.22 a	63.41
Average	57.80	56.57	60.83	64.05	

Description: Numbers followed by the same letter indicate no significant difference based on the Duncan test (DMRT) at the 5% level.

4. Conclusion

Giving NPK 16:16:16 fertilizer and acid humate can increase growth and yield of red onion, especially in long plants, leaf N uptake, index wide leaves, and tuber weight. The second treatment shows the best response to plant growth and production, so it is recommended for increasing fertilization efficiency and red onion yield.

The best combination was obtained in the treatment of NPK fertilizer 16:16:16 at a dose of 45 g plant $^{-1}$ and acid humate at a dose of 4.5 g plant ^{1}, which produced the highest fresh tuber weight of 74.76 g.

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