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Shallot cultivation originated from True Shallot Seed (TSS) on Andisols enriched with various ameliorants

Abstract. Application of soil ameliorants is important to improve Andisols properties and increase shallot productivity. The research objective is to determine the kind of ameliorant which the best effect on the growth and productivity of shallots originating from TSS in Andisols Lembang, West Java. The experiment was conducted in Margahayu Research Station, Lembang, West Java from January to May 2021. A randomized block design (RBD) with 6 treatments and 5 replications was set up in the field. Treatments include control (no ameliorant), 20 tons/ha of horse manure, 10 tons/ha of rice straw compost, 10 tons/ha of bamboo leaf compost, 10 tons/ha of husk biochar, and 5 kg/ha humic acid. The results showed that vegetative performance and yield of true shallot seed-based shallot variety of Trisula in Andisols enriched with rice straw compost was higher than in other ameliorant treatments. Additionally, nutrient uptake in rice straw compost treatment was also higher than in other ameliorant treatments.

Keywords: Andisols · Bamboo leaf compost · Humic acid · Husk biochar · Rice straw compost

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Introduction

In the last 10 years, shallot production in Indonesia has continually increased and reached twice from 964,221 tons in 2012 to 1,982,360 tons in 2022. The area of shallot production has also continued to increase in the last 10 years, from 99,519 ha in 2012 to 184,386 ha in 2022, meanwhile, the productivity slightly increased from 9,7 tons per ha in 2012 to 10,7 tons per ha in 2022 (Ministry of Agriculture, 2022). The increase in shallot production and productivity could be attributed to the highly intensive level of shallot cultivation. For instance, farmers commonly use exceeded dosages of N and P fertilizers that is higher than recommended doses (Basuki, 2014). Excessive use of chemical fertilizers and without regard to conservation principles could cause land degradation.

Since the 1990s, the Indonesian Vegetable Research Institute (IVEGRI) (since 2022 it transformed into the Indonesian Institute for Testing Instrument Standard of Vegetable Crop) has conducted various studies related to the use of botanical shallot seeds (TSS, True Shallot Seed) as an alternative planting material. The research mainly focused on the use of TSS as planting material, developing cultivation techniques to produce consumable bulbs and TSS production (Sumarni et al., 2012), and producing bulb planting materials from TSS (Sopha et al., 2015). There was significant difference of the cultivation techniques and varieties used in producing shallots from bulbs and TSS. However, botanical shallot seeds were considered technically and economically feasible to be used as alternative planting materials. TSS gives several advantages such as less seed needed, easy storage, long-term storage, and relatively virus-free seeds (Prahardini & Sudaryono, 2018).

Shallot production in the highlands is commonly cultivated on Andisols. The characteristics of Andic soil are highly related to the presence of non-crystalline minerals such as allophane, imogolite, ferrihiphrit, or humus allophane complex in the soil (Rachim & Arifin, 2011). Andisols has several unique properties that can affect the productivity of agricultural commodity, includes high P fixation, organic matter content, bulk density, porosity and mesopores, and has a pH-dependent charge. In addition, high P retention (>85%) in Andisolss can lessen agricultural productivity because it could limit the availability of P in the soil (Anda & Dahlgren, 2020). With such limitations of Andisols, specific improvement should be implemented to increase the productivity of shallot cultivation on that certain soil type.

Ameliorant is a soil enhancer that can be used to improve soil properties. It is suggested that the use of various ameliorants could improve soil properties (Avifah et al., 2022). Application of ameliorants can improve soil physical properties, such as its water holding capacity, pore aeration, and infiltration rate. In addition, the provision of ameliorants can increase nutrients, soil pH and CEC, and reduce Al-dd (Dariah et al., 2015). Ameliorants can also be a source of energy and food for soil microbes, as well as provide a conducive environment for soil organisms that play significant roles in increasing nutrient availability in the soil (Rusdi et al., 2019).

Organic materials could be used to increase the availability of P in the soil (Sari et al., 2017). Organic acids from organic material decomposition could trigger the release of P that is commonly bound by the amorphous fraction in Andisols. This process increases the availability P and reduce P retention in Andisols (Irawan et al., 2016). In addition, the provision of organic matter could also add the P nutrients and consequently could increase the amount of P in the soil.

Bamboo leaf and rice straw-based compost that contains high silica contents i.e. 58.3% and 4-20%, respectively could be used to improve Andisols properties (Nugraha et al., 2017). Silicate is one of the anions that could release P from the huge affinity of adsorption complex and push the adsorbed phosphate anion. The addition of Si into the soil can reduce the activity of Al, Fe and Mn. Silicate anions could replace P anions at adsorption sites, and make them available for plants (Mariana et al., 2015).

Biochar is an active charcoal that can be used as a soil ameliorant. Biochar could improve soil chemical properties, increase soil pH and CEC (Zhu et al., 2014), increase nutrient ion absorption and reduce P retention in Andisols (Yuliana, 2018). Biochar application can increase nutrient availability through three mechanisms i.e., provision of nutrient supply, retaining nutrients, and triggering the dynamics of microorganisms in the soil (Yu et al., 2019). A combination of biochar and dolomite could increase shallot production in the highland areas (Haryati & Erfandi, 2019), while combination of biochar and Trichoderma could reduce the application of chemical fertilizers by 50%, increase the diameter and height of shallot bulbs (Adnyana & Rahayu, 2016).

Humic acid could be used as a soil ameliorant since it can reduce P retention and increase available P in the Andisols. Phosphor retention decreased through a chelating mechanism or the formation of complexes with Al and Fe (Sandrawati et al., 2018). The release of phosphate retention occurs due to negative charge of soil colloid because of the addition of huge quantities of negatively charged ameliorants to the soil that block the positive charge on the soil colloid and fill the exchange sites (Devnita, 2010).

Numerous studies have been conducted to determine the effect of various ameliorants on shallot productivity, however limited studies have been conducted on true shallot seeds-based shallot cultivations in Andisols. Therefore, this study was conducted to determine the effect of ameliorants includes manure, rice straw compost, bamboo leaf compost, husk charcoal, and commercial humic acid on the productivity of shallots from TSS in Andisols Lembang, West Java.

Materials and Methods

The experiment was conducted from January to May 2021 at Margahayu Research Station of IVEGRI, Lembang, West Java, Indonesia. The soil in this experiment site was categorized as Andisols order with class texture of loamy clay (28% sand, 41% dust and 32% clay). Additionally, soil analysis was performed in the Integrated Laboratory of IVEGRI. A shallot variety of Trisula was used in this study.

The study was arranged using a randomized block design (RBD) with 6 treatments and 5 replications, i.e., control (without ameliorant, A), 20 tons/ha of horse manure (B), 10 tons/ha of rice straw compost (C), 10 tons/ha of bamboo leaf compost (D), 10 tons/ha of husk charcoal (E), and 5 kg/ha humic acid (F). Ameliorants were applied 2 weeks prior to transplanting. TSS seedlings aged three weeks were moved to experimental plots size 5m x 1m. The plant spacing used was 20 x 20 cm, so there were 125 plants in each experimental plot.

Observations of vegetative growth parameters, i.e., plant height and number of tillers were carried out to the 15 randomly selected sample plants on the 2, 4, 6 and 8 weeks after transplanting. The plant P uptake analysis was carried out at the maximum vegetative growth phase (on 45 days after transplanting). One plant sample in each treatment plot was collected for this laboratory analysis. On the harvesting day, the number of bulbs per plant and the weight of fresh bulbs was recorded. Additionally, dry weight and askip dry weight per plot were recorded after drying process. Chemical properties of the experiment site soil before planting and each experiment plot after harvesting time were analyzed in the laboratory. The effect of ameliorant on plant growth and yield productivity was analyzed using the ANOVA test at the 5% level and was tested further with the DMRT advanced test at the 5% level.

Results and Discussion

Andisols in Lembang made from Andesite, has an acidic pH, and has a high to very high (but less than 25%) organic C content in the topsoil layer (Devnita, 2010). Chemical analysis of the experimental site' soil (Table 1) shows that the soil had a slightly acidic H_2O pH of 5.8 and a KCl pH of 4.9. The pH KCl suggested the low exchangeable Al content, thus it cannot be measured by the titration method (Rosalina & Maipuw, 2019). C Organic and Total N content in the soil was high i.e., 5.72 and 0.59% respectively. The available P and K content was high i.e., 122.7 and 302.4 ppm respectively. The content of potential P and K was also considered high i.e., 503.04 and 42.43 mg/100g, respectively.

Table 1. Characteristics of experimental site' soil prior to transplanting and after harvesting

Parameters	Unit	Prior to Transplant	After harvesting					
			A	B	C	D	E	F
pH H_2O		5.8	5.5	5.5	5.6	5.5	5.5	5.5
pH KCl		4.9	4.8	4.8	4.8	4.8	4.8	4.8
C Organic	%	5.72	5.42	5.71	5.49	5.87	5.79	5.80
N Total		0.59	0.61	0.65	0.61	0.65	0.66	0.61
P Olsen (P_2O_5)	ppm	122.7	205.0	204.8	201.6	194.4	208.8	200.6
K MV		302.4	334.1	376.4	489.5	370.9	351.0	402.0
P HCl (P_2O_5)	mg/100g	503.04	462.15	477.14	463.86	467.28	494.94	472.08
K HCl (K_2O)		42.43	48.15	60.45	66.96	51.13	47.83	60.72
Ca-dd	mol /kg	7.82	7.80	7.64	8.05	8.36	7.46	8.53
Mg-dd		1.88	1.83	1.82	2.02	1.92	1.74	2.03
K-dd		1.01	1.30	1.36	1.71	1.33	1.26	1.47
Na-dd		0.05	0.07	0.08	0.09	0.05	0.09	0.08
CEC		24.23	30.23	29.80	29.87	29.13	29.22	28.64

The results of soil chemical analysis after harvest showed a decrease in pH, both in non-ameliorant and with ameliorant soils (Table 1). The decrease in pH that occurred was still quite acidic (5.5 – 6.5). High rainfall during field activities triggers acid dilution followed by an increase in H+ ions in the topsoil, so that the pH drops (Olojugba, 2018). Organic C content in treatments A (non-ameliorant) and C (rice straw compost) decreased, while in other treatments it increased slightly. The nutrients N and K have increased, which probably comes from other than ameliorant also comes from N and K fertilization given during plant growth. Treatment C (rice straw compost) caused the highest increase in K element, this was due to the high K content in rice straw compost (Kadengkang et al., 2015). While the available P content increased in all treatments, and vice versa, potential P decreased. The results of the decomposition of organic matter in the form of organic acids bind Al and Fe allophan in Andisolss in the form of chelation causing available P to increase (Sari et al., 2017).

Table 2. Precipitation, temperature, and relative humidity during experiment period

Month	Precipitation (mm)	Minimum temperature (°C)	Maximum temperature (°C)	Relative humidity (%)
1	190	16.3	24.9	86.5
2	188	17.7	25.4	88.6
3	235.5	16.2	24.4	80.2
4	181.5	16.7	25.1	88.6
5	128.5	17.1	24.9	77.3

Source: IVEGRI' meteorological station

The ameliorant treatments caused significant differences in plant height measured at 2, 4, 6, 8 weeks after planting (Table 3). At the beginning of growth, bamboo leaf compost ameliorant (D) produced plants with the highest size, which differed significantly from humic acid treatment (F). In the following weeks, the humic acid treatment still produced plants with the shortest size. Until the end of the observation, the ameliorant of rice straw compost seemed to consistently produce the highest shallot plants. Aside from being an ameliorant, organic matter can also function as a source of nutrition for plants. Organic materials, such as manure and compost (bamboo leaves and rice straw) have higher N, P, and K content than biochar, husk charcoal and humic acid, so they have a positive effect on plant growth.

Table 3. Shallot heights in ameliorants treatments

Treatments	Plant (cm) Plant ages (weeks after transplanting)			
	2	4	6	8
A	14.5 ab	16.3 a	27.9 a	39.9 ab
B	14.5 ab	15.9 a	26.5 ab	37.7 ab
C	14.3 ab	16.1 a	28.6 a	41.7 a
D	15.2 a	15.7 ab	25.7 ab	36.9 ab
E	14.7 ab	15.0 b	24.8 b	36.2 b
F	13.4 b	14.5 b	24.7 b	35.9 b

Note: control (without ameliorant, A), 20 tons/ha of horse manure (B), 10 tons/ha of rice straw compost (C), 10 tons/ha of bamboo leaf compost (D), 10 tons/ha of husk charcoal (E), and 5 kg/ha humic acid (F). Mean followed by similar letter was not significantly different based on DMRT advanced test at 0.05.

Table 4. Number of shallot leaves in ameliorants treatments

Treatments	Number of shallot leaves							
	Crop ages (weeks after transplanting)							
	2		4		6		8	
A	2	a	3.2	a	5.8	a	6.2	a
B	2	a	3.2	a	5.5	a	5.9	a
C	2	a	3.5	a	6.5	a	7.0	a
D	2	a	3.4	a	5.4	a	5.7	a
E	2	a	3.1	a	4.9	a	5.1	a
F	2	a	3.4	a	6.0	a	6.3	a

Note: control (without ameliorant, A), 20 tons/ha of horse manure (B), 10 tons/ha of rice straw compost (C), 10 tons/ha of bamboo leaf compost (D), 10 tons/ha of husk charcoal (E), and 5 kg/ha humic acid (F). Mean followed by similar letter was not significantly different based on DMRT advanced test at 0.05.

Table 5. Number of shallot tillers cultivated in various ameliorant treatments.

Treatments	Number of tillers				
	Crop ages (weeks after transplanting)				
	2	4	6	8	10
A	1.0 a	1.0 a	1.0 a	1.8 a	1.9 a
B	1.0 a	1.0 a	1.0 a	1.6 a	1.7 a
C	1.0 a	1.0 a	1.0 a	1.8 a	2.0 a
D	1.0 a	1.0 a	1.0 a	1.5 a	1.6 a
E	1.0 a	1.0 a	1.0 a	1.5 a	1.6 a
F	1.0 a	1.0 a	1.0 a	1.7 a	1.8 a

The number of leaves and tillers were not affected by the different types of ameliorants treatments (Table 4 and Table 5). However, there was a tendency for plants treated with rice straw compost to have the highest number of leaves and tillers. Previous study has shown that the genotypic factor greatly influences the variable number of leaves and number of tillers (Waluyo et al., 2021). The number of tillers in this case was very low, ranging from 1.6 to 2. Shallots grown from TSS seedlings commonly grow differently from plants whose seeds were bulbs.

Nutrients uptake in various ameliorant treatments (Table 6) shows that Nitrogen, Phosphor and Potassium in compost rice straw treatment was relatively high compared to other treatments. This high nutrient uptake contributed to relatively high shallot growth and production in this treatment compared to other treatments. The post-harvest parameters include fresh weight, dry weight, and askip dry weight were not affected by the different types of ameliorants used in the experiment (Table 7). High incidence of crops diseases (data is not presented) due to high rainfall and relative humidity during the experiment (Table 2) might contribute to the quite low shallot yield and insignificantly different yields among treatments. However, shallots treated with manure and composts (treatment B, C and D) tended to have higher yield compared to other treatments. While charcoal husk and humate acid functioned only as soil ameliorant, manure and compost could be used as soil ameliorant and nutrient sources for crops. A previous study found that compost had a significant effect on the number of leaves, number of tubers harvested, and fresh weight of bulbs since it provides nutrients needed for shallot growth (Susanti, 2015) and the use of 15 tons/ha rice straw compost could reduce 50% NPK fertilizer (Tarigan et al., 2017).

Table 6. Nitrogen (N), Phosphor (P), and Potassium (K) uptake in various ameliorant treatments

Treatment	Content (%)			Absorption (mg/plant)		
	N	P	K	N	P	K
A	3.48	0.28	3.92	56.46	4.46	63.66
B	2.87	0.26	3.47	66.31	5.99	80.26
C	3.07	0.26	3.41	68.21	5.79	75.59
D	2.73	0.24	2.67	60.13	5.28	58.89
E	2.84	0.24	3.08	60.82	5.04	65.92
F	3.17	0.27	3.61	51.80	4.38	58.93

Note: control (without ameliorant, A), 20 tons/ha of horse manure (B), 10 tons/ha of rice straw compost (C), 10 tons/ha of bamboo leaf compost (D), 10 tons/ha of husk charcoal (E), and 5 kg/ha humic acid (F).

Table 7. Fresh weight (g), dry weight (g), and askip dry weight (g) in various ameliorant treatments

Treatment	Fresh weight (g)		Dry weight (g)		Askip Dry weight (g)	
A	4691.0	a	3355.0	a	1913.0	a
B	6729.6	a	4755.0	a	1635.0	a
C	7028.0	a	5092.6	a	1987.0	a
D	5958.6	a	4176.8	a	1750.0	a
E	5423.0	a	3935.6	a	1636.0	a
F	5083.6	a	3709.8	a	1995.0	a

Note: control (without ameliorant, A), 20 tons/ha of horse manure (B), 10 tons/ha of rice straw compost (C), 10 tons/ha of bamboo leaf compost (D), 10 tons/ha of husk charcoal (E), and 5 kg/ha humic acid (F). Mean followed by similar letter was not significantly different based on DMRT advanced test at 0.05.

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Conclusion

1. Vegetative performance and yield of true shallot seed-based shallot variety of Trisula in Andisols enriched with rice straw compost was slightly higher than in other ameliorant treatments.
2. Nutrient uptake in rice straw compost treatment was also higher than in other ameliorant treatments.

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