Jurnal Agronomi Indonesia
(Indonesian Journal of Agronomy)

ISSN 2085-2916 | e-ISSN 2337-3652
April 2024, *52*(1), 1-9
DOI: https://dx.doi.org/10.24831/jai.v51i1.50768

Research Article

Responses of shallot to ameliorant and actinobacteria applications in water-saturated system on tidal land

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ABSTRACT

Tidal areas are believed as future land for many commodities in Indonesia. Here, shallot growing was evaluated on tidal land supplemented with soil conditioners. The research aimed to evaluate the adaptive response of shallot varieties for growing on tidal land with a water-saturated system indicating Fe and Al stress by applying soil ameliorant and actinobacterial. The study used a completely randomized factorial design with three replications. The first factor was shallot variety (Bima Brebes, Batu Ijo, and SS Sakato) and the second factor was soil conditioners (no ameliorant, actinobacteria, ameliorant+actinobacteria, and actinobacteria+ameliorant+dolomite). Bima Brebes and Batu Ijo cultivars had the highest growth percentage, age at shoot emergence, plant height, and number of leaves, while the SS Sakato variety had the slowest growth. Shallot production variable had a significant interaction with soil conditioners. Bima Brebes variety demonstrated high suitability for a water-saturated system in tidal land, and actinobacteria+ameliorant+dolomite was a more promising conditioner than other treatments.

Keywords: pyrite, saturated soil culture, tidal swamps, growth, yield, marginal land

Edited by:
Siti Marwiyah
IPB University

Received:
12 October 2023
Accepted:
2 April 2024
Published online:
29 April 2024

Citation:
Haitami, A., Ghulamahdi, M., Sopandie, D., Susila, A. D., & Lestari, Y. (2024). Response of shallot to ameliorant and actinobacteria applications on water-saturated system in tidal land. *Jurnal Agronomi Indonesia (Indonesian Journal of Agronomy)*, *52*(1), 1-9

INTRODUCTION

Shallot (*Allium ascalonicum* L) is an important commodity for Indonesians. The increase in shallot prices due to fluctuations in national production can cause economic inflation. Shallot productivity is around 9-10 tons ha^{-1} (Susanti & Supriyatna, 2020). Statistic Bureau (BPS, 2022) noted five provinces as shallot production centers in Indonesia, i.e., Central Java, East Java, West Nusa Tenggara, West Java, and West Sumatra contribute 91.90% of Indonesian production, and Central Java province contributes the highest. However, domestic supply is still shortage.

Tidal land can be used for new agricultural production, especially shallot. Utilization of tidal land, which is suboptimal land, is a viable alternative (Saputra & Sari, 2021). Tidal land in Indonesia is estimated at 20.12 million ha, around 16.19% of the total agricultural land in Indonesia which covers an area of 124.25 million ha, with details of potential land at 2.07 million ha, acid sulfate land 6.72 million ha, peat land at 10.89 million ha, and saline land 0.33 million ha, the area land that has the potential to be used as agricultural land reaches 8.536 million ha, of which 2.834 million ha have been reclaimed and 5.702 million ha have not been reclaimed (Sahuri et al., 2023).

Soil and water management are the primary keys to agricultural cultivation on tidal land. Water-saturated cultivation technology can reduce levels of oxidized pyrite (Ghulamahdi, 2017; Toyip et al., 2019). Providing ameliorants and actinobacteria, fertilizing, and adding macro and micronutrients to improve soil nutrient status and soil pH. Actinobacteria are nitrogen-fixing bacteria that can fix nitrogen from the air and convert it into a form that plants can absorb. This water-saturated cultivation system will eliminate the negative influence of excess water on plant growth. It will acclimatize for two weeks after planting. Then, the plant will improve its growth by allocating photosynthesis results to the bottom of the plant for root growth and root nodules for 2-4 weeks after implementation. Irrigation begins (Ghulamahdi et al., 2016). This system can suppress pyrite oxidation, prevent a decrease in pH, reduce Al and Fe, and increase nutrient availability (Sagala et al., 2018).

The shallot crop commodity also has the potential to be developed on tidal areas by using appropriate technology, one of which is the use of adaptive varieties and by applying the concept of water-saturated cultivation. The findings of the research (Haitami et al., 2023), show that the tolerant shallot variety is Bima Brebes with a water table depth of 20 cm. One method of planting shallots in tidal land with adequate irrigation can be done with a water-saturated cultivation system (WSCS), namely planting by providing ongoing irrigation and ensuring the water level remains constant for the layer below the roots to be saturated with water.

Research on shallots in tidal areas has been conducted by testing six varieties at various water level depths. After successfully researching shallots at different water table depths (Haitami et al., 2023) the weakness is that it is necessary to add ameliorant input, such as manure, dolomite, and actinobacteria are growth-promoting hormones and can chelate Fe in tidal fields (Retnowati et al., 2018). Therefore, it is required to implement the use of manure, dolomite, and actinobacterial ameliorant for shallot plants in tidal fields that are saturated with water so that it is hoped that they will be able to evaluate the growth response and yield of several varieties of shallots cultivated in tidal fields which are saturated with water. The research aimed to evaluate the adaptive response of shallot varieties for growing on tidal land with a water-saturated system indicating Fe and Al stress by applying soil ameliorant and actinobacterial.

MATERIALS AND METHODS

Research design

The research was carried out in type B tidal fields in plastic houses in Mulyasari village, Tanjung Lago subdistrict, Banyuasin regency, South Sumatera province, from April to June 2023. Water level of type B tidal field was influenced by high tides. The soil was flooded by freshwater 50-100 cm for 3-6 months, soil pH of 3.5-4.5 (acid), had fairly thick layer of pyrite, moderate organic content (2-4%), low N and P contents, and medium K content.

Red shallot of the Bima Brebes, Batu Ijo, and SS Sakato varieties were used. The ameliorant used chicken manure 20 t ha^{-1}, and actinobacterial inoculant derived from selected isolates. Fertilizers used urea, ZA, SP-36, and KCl, and dolomite 2 t ha^{-1}.

This experiment used a completely randomized factorial design with the first factor of shallot variety and the second factor of ameliorant and actinobacteria (control [no ameliorant, no actinobacteria], actinobacteria, actinobacteria+ameliorant=AA, and actinobacteria+ ameliorant+ dolomite=AAD). In total, the experiment consisted of 12 treatment combinations with three replications or 36 experimental units.

Rejuvenation of actinobacteria

Six actinobacterial isolates were rejuvenated (Cal31t, Cal24h, Car21t, Crc32t, Dbi28t, and PS4-16) on ISP-4 liquid media (*International Streptomyces Project*). Rejuvenated isolates were incubated at 28 °C for 14 days (Fitriandini et al., 2017). The concentration of actinobacterial at least 10^6 CFU mL^{-1} was added 0.05% Tween-80 and 5% Arabic gum. The solution was poured into a sterile ISP-4 medium (autoclaved at 121 °C for 15 min).

The working formulation of actinobacteria was made of 1 L actinobacteria culture in production media plus 20% starter culture, then shaked and incubated at room temperature for 14 days. Sterile peat media was added as bacterial culture (2:1, m/m), and used as an inoculant. Shallot bulbs were treated with inoculant by soaking them in an actinobacterial media of 200 g kg^{-1} seed, according to treatments.

Fertilizer application

Shallot bulbs were planted in plastic polybags sized 30 cm in height. The polybag was placed in water and the water level was maintained at 20 cm in depth to coop with the water-saturated system.

Manure (20 tons ha^{-1}) as an ameliorant and dolomite (2 t $ha^{-1)}$ were applied 2 weeks before planting. Fertilizers were applied three times: pre-planting (Urea 47 kg ha^{-1}, ZA 100 kg ha^{-1}, SP-36 311 kg ha^{-1}, and KCl 56 kg ha^{-1}), at 2 week after planting (WAP) (Urea 93 kg ha^{-1}, ZA 200 kg ha^{-1}, and KCL 112 kg ha^{-1}) and at 5 WAP (Urea 47 kg ha^{-1}, ZA 100 kg ha^{-1}, and KCL 56 kg $ha^{-1)}$ followed Susila (2006).

Data analysis

Research data were analyzed using analysis of variance (ANOVA). Further DMRT test was carried out for any treatments that had a significant effect. All analysis was conducted using SAS 9.0 and Minitab software.

RESULTS AND DISCUSSION

Soil and water qualities

The soil analysis before the experiment showed high organic matter content, very high P_2O_5, low K_2O, pH H_2O of 4.35, and a high exchangeable Al (Table 1). Cation exchange capacity values with high criteria and base saturation with low criteria. The water source for saturated water cultivation in this research originated from secondary drainage channels connecting to tidal water. Water quality during low and high tides is presented in Table 2. The electrical conductivity is not too high, namely, 0.630 dS m^{-1} at high tide and 0.546 dS m^{-1} at low tide, and it also has a low pH, namely 4.00 at high tide and 3.97 at low tide.

Table 1. Soil analysis before the experiment and its status.

Variables	Initial soil analysis	Status*
pH H_2O	4.35	Very acid
pH KCl	3.81	Very acid
C-org (%)	3.30	Very high
N total (%)	0.23	Moderate
P_2O_5 Bray I (ppm)	38.0	Very high
K (cmol(+) kg^{-1})	0.29	Low
CEC (cmol(+) kg^{-1})	27.36	High
Saturated base (%)	15.56	Low
Al-exc (cmol(+) kg^{-1})	6.57	High
Fe (ppm)	389	Very high
Cu (ppm)	1.32	Low
Zn (ppm)	1.88	Low
Mn (ppm)	8.20	Low

Note: *According to the criteria of Balittanah (2005).

Table 2. Water quality during high and low tides.

Water parameters	High tide	Low tide
DHL (dS m^{-1})	0.630	0.546
pH	4.00	3.97
N-total (%)	0.72	0.96
P-total (mg L^{-1})	0.23	0.16
K-total (mg L^{-1})	6.62	4.46
Fe-total (mg L^{-1})	nd*	nd

Note: *nd: not detected

Actinobacterial inoculant content

Inoculants of actinobacterial contained macro and micronutrients (Table 3). The high organic C content in the inoculant could be due to the mixing effect with peat soil. Blanco-Canqui et al. (2013) stated that increasing organic C can increase soil aggregate stability, water storage capacity, water infiltration, biomass, soil microbial activity, and cation-anion exchange. Increasing organic C takes time (Hu et al., 2018) stated that providing organic fertilizer from crop residues increases C input by 0.9 Mg C/ha/year, and the average increase in C-organic over 4 years is 0.4 Mg C/ha /year.

Table 3. Analysis of actinobacterial inoculant.

Variables	Value	Measurement method
pH H_20	7.22	pH meter
pH KCl	7.06	pH meter
C-org (%)	32.27	Spectrophotometry
N-total (%)	0.65	Kjeldahl
P-available (ppm)	498.80	Spektrofotometry (Olsen)
CEC (cmol /kg)	30.86	Titrimetry
Mg-exc (cmol /kg)	10.76	AAS
Ca- exc (cmol /kg)	36.23	AAS
K- exc (cmol /kg)	9.76	AAS
Na- exc (cmol /kg)	9.74	AAS
P_2O_5 total (%	0.55	Spektrofotometry
K_2O total (%)	0.68	AAS

Note: Analysis results at the AGH IPB Laboratory 2023.

Plant emergence

The variety influenced the percentage of growth and emergence of shoots (Table 4). The Bima Brebes variety had a higher percentage of growth and shoot emergence ($P>0.05$) than the Batu Ijo and SS Sakato varieties. The growth and shoot emergence of the Bima Brebes variety was higher when treated with Actinobacteria+Ameliorant+Dolomite. It is probable that the Bima Brebes variety is more adaptive to lowland tidal fields as compared to SS Sakato and Batu Ijo. According to Nabilah et al. (2023), the Sakato variety is more suitable for planting in the highlands with a production of about 27.62-29.44 t ha-1. Varieties showed different abilities on bulb formation during the vegetative phase of 0-7 days after planting (DAP) and 14-21 DAP.

The shallot's variety and the application of actinobacteria significantly affected the growth percentage and the age at which shoots emerged. Shoot growth was influenced by varietal variations (Table 4). The fastest shoot growth was found in the Bima Brebes and Batu Ijo varieties, while the slowest was in the SS Sakato variety ($P>0.05$). All shallot varieties have pretty good growth patterns, but the growth of the SS Sakato variety is relatively slow compared to other varieties.

Table 4. Percentage growing bulb and shoot emergence of shallot varieties after planting.

Treatment	Growing bulb (%)	Average shoot emergence (day)
Varieties		
Bima Brebes	89.35a	4.40c
Batu Ijo	88.38a	9.44b
SS Sakato	76.75b	10.75a
Ameliorant + Actinobacteria		
Control	80.67c	9.82a
Actinobacteria	84.04b	7.81b
Actinobacteria+ameliorant (AA)	87.22a	7.63b
Actinobacteria+ameliorant+dolomite (AAD)	87.40a	7.54b

Note: Values followed by the same letter in the same column indicate nonsignificant differences according to DMRT at the level of 5%.

Plant height

Plant growth at ages 1, 2, 3, 4, and 5 WAP showed different responses between the varieties tested by providing ameliorant and actinobacteria in water-saturated cultivation in tidal fields (Table 5). The height of shallot plants at 1-5 WAP was significantly influenced by the application of AA and shallot varieties but not by their interaction. The average height of shallot plants given AAD was 32.03 cm, higher than the other treatments. Table 5 shows Bima Brebes variety had a higher plant height than the Batu Ijo and SS Sakato varieties. The Bima Brebes was more responsive by application of manure, dolomite, and AA. It is hypothesized that by applying water-saturated cultivation technology, Fe tends to be in a reductive situation and does not oxidize which may prevent from negative effect on plant growth. The application of AAD can significantly increase plant height and number of leaves. The interaction between plant height and treatments was not significant. It is speculated that the application of AAD can provide a nutrient supply for the growth of shallot plants, where in this study, the pH conditions were very acidic, and Fe and Al stress could result in the soil conditions becoming very acidic. The decrease in pH occurs due to the release of H^+ ions into the soil solution (Sagala et al., 2021).

Table 5. Plant height of shallot varieties.

Treatment	Plant height (cm)				
	1 WAP	2 WAP	3 WAP	4 WAP	5 WAP
Varieties					
Bima Brebes	4.58a	10.55a	17.76a	20.63a	29.12a
Batu Ijo	4.22b	10.05ab	15.68b	19.69b	23.03b
SS Sakato	4.14b	9.72b	15.17b	19.31b	20.85b
Ameliorant + Actinobacteria					
Control	3.48c	8.43d	11.65d	15.50d	18.42d
Actinobacteria	4.17b	9.27c	14.33c	16.26c	20.01c
Actinobacteria+ameliorant (AA)	4.65a	10.69b	18.09b	22.78b	28.60b
Actinobacteria+ameliorant+dolomite (AAD)	4.94a	12.02a	20.75a	24.96a	32.03a

Note: Values followed by the same letter in the same column indicate nonsignificant differences according to DMRT at the level of 5%.

High Fe content can cause iron toxicity in plants and hamper the absorption of nutrients (Zhang et al., 2016). Thus, the application of actinobacterial-enriched ameliorant can increase the height of shallot plants because of the ability of actinobacterial-enriched manure ameliorant to increase soil moisture (Lazcano et al., 2021). An actinobacterial inoculant mixed with peat soil as an effective carrier (Kravets et al., 2021).

Table 6 shows that the addition of AAD increased the number of leaves significantly from 2 to 5 WAP being 26.87 pieces per plant. The Bima Brebes variety produced a large amount of leaves compared to the Batu Ijo and SS Sakato varieties. The number of leaves is very important to determine the growth and development of tubers. It is suspected that the application of AAD can increase nutrient levels, especially N, so the number of leaves is more significant with organic fertilization. Leaf formation requires optimal nitrogen nutrients, which play a role in the rate of photosynthesis and protein synthesis, thereby increasing the growth rate. Nitrogen plays a role in chlorophyll formation, so leaves appear greener (Biru, 2015). Organic fertilizer, especially manure, can increase the vegetative growth of shallots. Andishmand and Noori (2012) reported manure application improves fresh and dry weights in shallot. Manure treatment improves soil structure in favor of root growth.

Table 6. Number of leaves of shallot varieties.

Treatment	Number of leaves				
	1 WAP	2 WAP	3 WAP	4 WAP	5 WAP
Varieties					
Bima Brebes	7.22a	9.95a	12.14a	13.39a	20.20a
Batu Ijo	6.30b	9.23b	10.88b	11.76b	18.26b
SS Sakato	5.62c	8.43c	9.87c	10.63c	12.20c
Ameliorant + Actinobacteria					
Control	5.29d	7.77d	10.13b	10.97c	11.54c
Actinobacteria	5.63c	8.64c	10.26b	12.27c	15.85c
Actinobacteria+ameliorant (AA)	6.82b	10.89b	13.53a	18.48b	23.39b
Actinobacteria+ameliorant+dolomite (AAD)	7.79a	13.51a	16.92a	21.99a	26.87a

Note: Values followed by the same letter in the same column indicate nonsignificant differences according to DMRT at the level of 5%.

The application of AAD in combination with shallot varieties is prospective in tidal land, even though the research field conditions had a very acidic pH, and Al-dd and Fe stress were very high. Maintaining water-saturated cultivation with a water level of 20 cm is suitable for shallot production. In such a situation, roots of shallot plants might produce ethylene which stimulates the formation of aerenchyma tissue as a general adaptation mechanism of plants to anaerobic conditions. However, in the present experiment, the ethylene level and aerenchime tissue formation were not observed. The role of actinobacteria can produce siderophores and IAA and chelate Fe and Al (Retnowati et al., 2019; Alfiyah et al., 2021).

Tuber weight and number of tubers

Differences in tuber weight and number of tubers were significant between Bima Brebes and SS Sakato (Table 7). The application of AAD fertilizer increased the number of tubers. It seems that the application of AAD fertilizer has a more significant effect on the growth and development of shallot bulbs. In the control treatment without AAD, tubers had poor growth. It is probable that in control plants, excess Al and Fe stress might limit the plant growth. Pyrite formation could be available in control plants, although no symptom of pyrite poisoning was visible in the present experiment. Chaerunisa et al. (2021) noted that pyrite can cause a decrease in soil pH, and the application of ameliorant can increase plant tolerance to Fe and Al.

Table 7. Tuber weight and number of tubers of shallot varieties.

Treatment	Tuber weight (g)	Number of tubers
Varieties		
Bima Brebes	5.14ab	8.23a
Batu Ijo	7.21a	4.15b
SS Sakato	3.50c	5.32b
Ameliorant + Actinobacteria		
Control	2.25c	5.19c
Actinobacteria	3.17b	7.23b
Actinobacteria+Ameliorant	4.68b	8.03ab
Actinobacteria+Ameliorant+Dolomite	5.23a	8.28a

Note: Values followed by the same letter in the same column indicate nonsignificant differences according to DMRT at the level of 5%.

Interaction effect on shallot productivity

The application of AAD has a significant effect on shallot productivity (Figure 1). It is probably that ameliorant enriched with actinobacteria and dolomite increase humic acid, resulting in an increase in soil pH, activity of phosphate solubilizing bacteria, soil P availability, and a decreased solubility of Al and Fe (Ifansyah et al., 2013). The increase in shallot productivity also occurred due to manure application as organic material. However, in the present research, N status was low. According to Messele (2016), the growth of shallot is determined by the amount of N applied. In the present research, applying manure at 20 tons ha^{-1} and dolomite at a dose of 2 tons ha^{-1} seems suitable to ameliorate tidal land with a pH of 3.81-4.35. Provision of ameliorant is essential for crop productivity in tidal areas according to Kim et al. (2016).

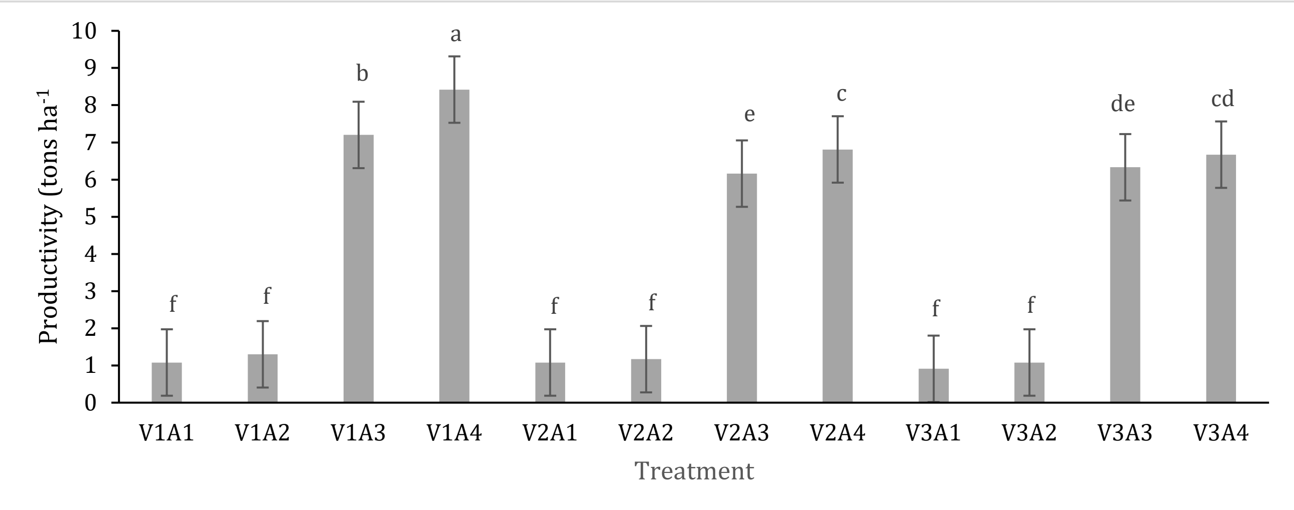

Figure 1. Interaction effect on shallot productivity. V1A1: Bima Brebes + No Ameliorant, V1A2: Bima Brebes + Actinobacteria, V1A3: Bima Brebes + AA, V1A4: Bima Brebes + AAD, V2A1 : Batu Ijo + No Ameliorant, V2A2: Batu Ijo + Actinobacteria, V2A3: Batu Ijo + AA, V2A4: Batu Ijo + AAD, V3A1: SS Sakato + No Ameliorant, V3A2: SS Sakato + Actinobacteria, V3A3: SS Sakato + AA, V3A4: SS Sakato + AAD.

CONCLUSIONS

Except for productivity parameters, the interaction between shallot varieties (Bima Brebes, Batu Ijo, and SS Sakato) and the provision of actinobacteria+ameliorant+dolomite (AAD) was not significant for all growth variables. The AAD treatment had the most significant effect, and the Bima Brebes variety was the most suitable and sound to be developed on tidal land with water-saturated cultivation.

ACKNOWLEDGEMENTS

Thanks to the Agricultural Development Research Agency of the Ministry of Agriculture, and the Directorate General of Higher Education, Research, and Technology of the Ministry of Education Culture Research and Technology Republic of Indonesia. Also, thanks to the Department of Agronomy and Horticulture, IPB University. This research is part of the Doctoral Dissertation (PDD) research supported by No.082/E5/PG.02.00.PT/2022 dated May 10, 2022.

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