Phosphate solubilizing bacteria application to lowland shallot varieties cultivated in highland

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Abstract. Shallot (Allium ascalonicum L.) is a prioritized vegetable crop which cultivated intensively in Indonesia. During 2016, there was La Nina phenomena happened around Indonesia and gave little indirect influences in the growth of shallots. La Nina had increased the monthly and annual rainfalls, thus phosphate was not available in soil and Phosphate Solubilizing Bacteria (PSB) application was used to increase phosphate availability. The purpose of this research was to determine PSB application to lowland shallot varieties with which cultivated in highland. The research was in Pancot, Tawangmangu, 1100 m above sea level in June 2016-January 2017 using Completely Randomized Block Design (CRBD) with two factors: lowland shallot varieties (Bima, Manjung, Mentes, Ilokos, and Rubaru) and highland shallot variety Tawangmangu; and PSB (no PSB and with PSB 10x6 cell g⁻¹ soil). Observation variables included were plant height, number of leaves, the number of bulbs per plot, and dry weight of bulbs per plot. Data was analyzed by ANOVA continued by DMRT. Research showed that application of PSB had no effect on all observed variables and showed that Bima and Rubaru are the varieties which adaptive to the weather anomaly and could produced the optimal bulbs yield in highland.

1. Introduction

Shallots (Allium ascalonicum L.) is one of the horticultural commodities which are widely used as a spice, traditional medicine and priorities of vegetables [1], as well as the potential as a foreign exchange earner for Indonesia. The consumption of shallots in 2013 was 2.1 kg/capita/year, increasing to 2.5 kg/capita/year in 2014 [2]. The average productivity in Indonesia is 9.55 t/ha/year in the period 2006-2015. The productivity of shallots on Java Island is only 0.10 t/ha/year, less than the growth rate of Indonesia's productivity, which is 0.13 t/ha/year [3].

Shallot production can be increased by seeking superior lowland shallot varieties to be planted on highland land. The potential of the productivity of these varieties is acknowledge to increase Indonesia's productivity. The stability of shallot supply can be maintained and a production surplus can be exported to other countries.

The highland which has Andisols generally have problems with phosphorus low availability. Phosphorus that play a role in plant growth and development are not available in forms that can be absorbed by plants due to the acid characteristic of Andisols, even worse in 2016 there was the occurrence...
of La Nina activity in Indonesia as the continuation of ENSO in the last 2015. This weather anomaly had made the significant increases of rainfall in September - December 2016, including in Java [4]. This increases had also noted in annual rainfall data from Karanganyar Regency. The rainfall data recorded from Tawangmangu had increased from 18 mm/month in December 2014 to 20 mm/month in December 2016. The rainfall increases has decreased the soil pH due to the acidification, therefore the phosphorus has become unavailable due to the absorption by the Al and Fe which are dominating the acidic soils. One solution to release P from the impurities of Fe, Al, Ca, and Mg is to use Phosphate Solubilizing Bacteria [4].

Phosphate Solubilizing Bacteria (PSB) are also capable to remove organic acids such as citric acid, glutamate, succinate, and glyoxalate which can break down Fe, Al, Ca, and Mg metal bonds so that the phosphorus bound becomes soluble and available [5]. PSB increase the overall yield of plants by providing dissolved Phosphorus to plants in different production systems and also benefit plants with other mechanisms [6]. This study aims to determine PSB application to lowland shallot varieties and which one can be grown in highland.

2. Material and method

2.1 Experimental design
The experimental design used was a Complete Randomized Block Design (RCBD) with 2 treatment factors. The first factor was the vary of shallot varieties (6 varieties) and the second factor was without the application of Phosphate Solubilizing Bacteria (PSB) and by giving PSB $1 \times 10^6$ cell g$^{-1}$ soil $[7]$, 12 combinations of treatments were obtained which were repeated 3 times. The results of these observations are compared with the results of the description of the varieties of each variety. Data was analyzed using Analysis of Variance (ANOVA) based on F test level of 5% if the real difference is followed by Duncan's multiple range test (DMRT) level of 5%.

2.2 Phosphate solubilizing bacteria isolation
PSB preparations was done by taking 5 grams of soil samples from bamboo plants rizosphere and was diluted into $10^{-3}$ factor, then isolated on Picovskaya media with dilution factor $10^{-1}$, $10^{-2}$ and $10^{-3}$ and also incubated for 2x24 hours. The colonies formed the clear zone were then purified by streak for single colony on Picovskaya oblique media and propagated using Picovskaya oblique media $[8]$.

2.3 Growth condition and initial soil test
The study was conducted in Tawangmangu, Karanganyar, the altitude was 1100 m above sea level with Andisols soil types in June 2016-January 2017. The air temperature in the research area ranged from 14.9-26.4°C. Rainfall during the research ranged from 74-284 mm/month with a relative humidity of 80-95%.

The land used for research belongs to the category of low soil fertility. This is characterized by chemical properties which include low NPK soil content. The results of the initial soil analysis of organic matter was only 1.76% with a low rating, total N 0.41%, P available 4.7 ppm, K value available 0.06 me/ 100g, and pH 6.97. The diversity of vegetation around the research area includes garlic ($Allium sativum$), carrots ($Daucus carota$), oranges ($Citrus sp$) and various kinds of weeds.

2.4 Phosphate solubilizing bacteria application and shallot planting
Each experimental plot is 100 x 120 cm. The soil was given 10 t/ha of manure, SP36 fertilizer 250 kg/ha, Urea fertilizer 50 kg/ha, and KCl fertilizer 200 kg/ha $[9]$. N, P, and K basic fertilizers were given twice. PSB was inoculated by spraying evenly onto the surface of the soil with a concentration of $1 \times 10^6$ cells g$^{-1}$ soil as much as 2 ml per plot of land. The shallot bulbs used are lowland varieties such as Bima, Manjung, Mentes, Rubaru and Ilokos and local highland varieties namely Tawangmangu. Shallot bulbs were micro cut before planting.
2.5 Observation and harvesting
The rotten bulbs was replaced during the first week. Follow-up basic fertilizer was given at the age of 15 days after planting. Pest control was carried out mechanically to kill pests directly by collecting eggs and shallot caterpillars with hands then destroyed. Fungal control was carried out by spraying fungicides [10].

Observation variables included plant height and number of leaves observed at 14 to 70 days after planting. The number of bulbs per clump of plants and the results of dry bulbs t/ha was observed, calculated and weighed at harvest time and after being dried in the sun for 3 days. Harvesting was done when the bulbs were 106 days old. The harvested bulbs are weighed fresh and dried in the sun for 3 days and weigh the dry weight of the bulbs.

3. Results and discussion
3.1 Plant height
Highlands has altitude > 450 meters above sea level are thought to make shallot’s growth disrupted due to relatively low temperature and sunlight intensity. Results of the observation showed that among all the varieties originating from lowland; only Bima varieties had plant height in accordance with the description of variety. Bima variety treated without PSB application has a plant height of 27.37 cm, while the application of PSB 10^6 cells g⁻¹ soil has a plant height of 30.40 cm (Table 1). Putrasemedja [12] shows from the results of his research that different plant heights are caused by different genetic properties.

The application of PSB did not significantly affect the height of shallot; it was suspected that role of PSB was not optimal for the growth of shallots. Pinem et al. [13] stated in her research that there was no significant effect on the application of PSM (Phosphate Solubilizing Microbial) to plant height and number of leaves. PSB can have a more optimal effect on plant growth if aided by Nitrogen-Fixing Bacteria (NFB). In line with the opinion of Permatasari and Nurhidayati [14] that the combination of NFB and PSB produces the highest plant height.

| Shallot Varieties | Plant height (cm) | Plant height according Description of variety (cm) |
|-------------------|-------------------|-----------------------------------------------|
|                   | Without PSB       | PSB 10^6                                      |                                  |
| Bima              | 27.37±6.03a       | 30.40±1.61a                                   | 24-44                             |
| Manjung           | 19.29±4.90a       | 19.88±5.13a                                   | 41.8-46.5                         |
| Mentes            | 16.97±3.33a       | 14.20±4.28a                                   | 41.13                             |
| Ilokos            | 19.98±5.59a       | 16.78±5.69a                                   | 30.5-36.3                         |
| Rubaru            | 26.17±4.39a       | 22.35±2.34a                                   | 35-44                             |
| Tawangmangu       | 28.20±4.44a       | 26.63±3.16a                                   | (unidentified)                    |

3.2 Number of leaves
Manjung, Mentes, Ilokos and Rubaru varieties originating from lowland have a number of leaves that tend to be lower than the varieties’ description, only Bima varieties are treated without PSB or PSB which has a number of leaves according to the description of varieties, 17.67 and 18.07 leaves (Table 2).

The number of leaves lower than the description of variety can be influenced by environmental conditions. Jumini et al. [15] states that, every plant variety always has a difference in genotypic response to various environmental conditions in which it grows. In the opinion of Putrasemedja [12] there is no real difference caused by a less supportive environment, namely the existence of continuous rainfall so that growth is not optimal. Purba [16] suggested variations in the number of leaves on several shallot varieties indicate that number of leaves is very sensitive to the influence of environmental conditions during cultivating. High rainfall could also be the reason why shallots only produced leaves lower than description of variety. According to Rahayu et al [17] high rainfall could add environmental
moisture thus increasing the risk of pests and diseases attacks to the leaves, therefore the leaves counted were lower than the description should be.

Table 2. Effect of PSB application on number of leaves on several varieties of shallots in highland.

| Shallot varieties | Number of leaves (leaves) | Number of leaves according to Description of varieties (leaves) |
|-------------------|---------------------------|---------------------------------------------------------------|
|                   | Without PSB | PSB 10⁶ |                                            |
| Bima              | 17.67±3.23  | 18.07±3.42  | 15-50                                      |
| Manjung           | 14.60±6.88  | 15.47±4.36  | 23-39                                      |
| Mentes            | 16.40±2.43  | 11.00±6.16  | 36-39                                      |
| Ilokos            | 15.47±6.73  | 13.40±6.54  | 28-39                                      |
| Rubaru            | 31.87±9.71  | 25.93±3.19  | 40-48                                      |
| Tawangmangu       | 14.73±5.49  | 13.80±4.39  | (unidentified)                             |

3.3 Number of bulbs per plant clump

Different shallot varieties have different number of bulbs. Rubaru variety has the highest number of bulbs, which is 7.20 bulbs per plant clump (Table 3). All varieties have a lower number of bulbs compared to the description of variety, only Rubaru was almost in accordance with the description of variety.

Giving PSB did not show significantly different results on number of bulbs, suspected PSB did not work optimally or the amount was not sufficient, or PSB applied was only add Phosphorus availability without getting absorbed by shallots due to leach by the heavy rainfall, and formation of bulbs in addition influenced by genetic factors such varieties also influenced by environmental factors when planting. Azmi et al. [18] states shallot is a long day plant; bulbs formation process requires more length of sunlight than short-day plants. Shallot bulbs can continue to grow and then form tillers when the minimum day length limit is reached, something that was hard to achieve when heavy rainfall was occured.

Table 3. Effect of PSB application on number of bulbs per plant on several varieties of shallots in highland.

| Shallot varieties | Number of bulbs per plant (bulbs) | Number of bulbs per plant according to Description of variety |
|-------------------|----------------------------------|--------------------------------------------------------------|
|                   | Without PSB | PSB 10⁶ |                                            |
| Bima              | 3.33±0.83  | 3.47±1.27  | 7                                           |
| Manjung           | 1.93±0.61  | 4.87±0.70  | 6                                           |
| Mentes            | 6.13±1.68  | 5.13±1.14  | 3-7                                         |
| Ilokos            | 4.27±2.55  | 4.40±3.49  | 7.56                                        |
| Rubaru            | 6.87±0.64  | 7.53±1.17  | 8                                           |
| Tawangmangu       | 3.47±0.95  | 3.27±0.95  | (unidentified)                             |

Sutarja and Grubben [11] suggested that the optimal height for the growth and development of shallots is 0-450 m asl. According to Relf and McDaniel [19] shallots are suitable for cultivation in full lighting environments such as in the lowland. Even so, the process to make lowland shallots suitable for highland was highly depends on macro nutrient availability which could also loss due to the heavy rainfall.

3.4 Dry bulbs of shallot per Ha

Shallot bulbs are harvested longer in highland than in lowland. Harvesting was done when the plants were 106 days old which normally should be harvested at the age of 60-70 days after planting (if planted in lowland). Sumarni and Hidayat [8] suggested that shallots can still grow on highland, but are 0.5-1 months longer and have lower yields.
Table 4. Effect of PSB application on dry bulbs of shallot (t/ha) on several varieties of shallots in highland.

| Shallot varieties | Dry bulbs of shallot (t/ha) | Dry bulbs of shallot according to Description of varieties (t/ha) |
|-------------------|-----------------------------|---------------------------------------------------------------|
|                   | Without PSB | PSB $10^6$ |                                                                 |
| Bima              | 8.59±1.53$^a$ | 6.03±1.32$^a$ | 9.9                                                               |
| Manjung           | 6.05±3.69$^a$ | 8.99±2.96$^a$ | 10.41-13.25                                                        |
| Mentes            | 10.24±5.87$^a$ | 3.59±1.32$^a$ | 6.90-23.70                                                        |
| Ilokos            | 3.98±4.30$^a$ | 3.03±2.26$^a$ | 13.33-19.44                                                        |
| Rubaru            | 10.25±3.25$^a$ | 14.73±10.36$^a$ | 14-17                                                            |
| Tawangmangu       | 10.45±4.83$^a$ | 12.58±7.94$^a$ | (unidentified)                                                    |

The yield of shallots dry bulbs only in Rubaru varieties by the application of PSB was suitable according to the description of varieties, which was 14.73 t/ha and Mentes variety was treated without PSB which is 10.24 t/ha (Table 4). According to Ambarwati and Yudono [20] yield fluctuations that occurred were caused by environmental factors because they are related to the mechanism of plant appearance stability. Thus, the availability of varieties that are in accordance with the local environment and potentially has high yields is a factor that directly affects yield and adaptation of varieties. Bima varieties in highland have fewer results than if planted in lowland the same opinion according to Idhan et al. [21] in his research Bima variety produces larger bulbs in lowland than in highland.

The application of PSB has no effect on dry weight of bulbs. In line with the opinion of Abdissa et al. [22] that P does not significantly affect dry weight of shallot bulbs. It is suspected by Permatasari and Nurhidayati [13] in their study that plant dry weight showed significant differences in combination treatment of Phosphate Solubilizing Bacteria (PSB) and Nitrogen-Fixing Bacteria (NFB), whereas there was no significant effect on PSB treatment alone. Environmental conditions that are not in accordance with its growth, there will be no development of the character of plant. According to Giamerti and Mulyaqin [23] in highland, shallots are difficult to form bulbs, if they can form bulbs but the yield is fewer compared to lowland.

4. Conclusion

Based on the results and discussion above, it can be concluded that the application of PSB didn’t effect the growth of lowland shallot varieties. Bima and Rubaru lowland varieties can grow and produce bulbs in highland which are able to match the bulbs yield of the description of variety so that Bima and Rubaru are the varieties which adaptive to the weather anomaly and could produced optimal bulbs yield in highland.

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