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Effects of reducing rates of NPK, ZA, and KCl fertilizers on the growth and yield of shallot in multiple cropping system in Bantul

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ABSTRACT

The intensive application of synthetic/inorganic fertilizer on shallot cultivation tends to contaminate the environment and reduce soil quality. Meanwhile, the decrease of farmland area has been a limiting factor in increasing shallot production. Shallot farmers in Bantul District, D. I. Yogyakarta, commonly combine organic and inorganic fertilizers. Therefore, an alternative technology to sustain the production of shallot is through the application of fertilizer at the right rates and the practice of multiple cropping system. The objective of this research was to determine the growth and yield of shallot as affected by the reduced rates of inorganic fertilizer in multiple cropping systems. This research was conducted from August to November 2016 in Srigading Village, Sanden Sub-District, Bantul District, D. I. Yogyakarta. The research was arranged in a split plot design with three replications. The main plot was cropping system consisting of monoculture system (shallot) and multiple cropping system (shallot-chili). The subplot was fertilizer rates consisting of 100 % as control, 50 %, and 25 %. The results of this research showed that multiple cropping system did not decrease the growth and yield of shallot. Likewise, reducing inorganic fertilizer rates to 50 % of control did not decrease shallot yield. However, the inorganic fertilizer rate of 25 % significantly decreased shallot yield to 12.15 %.

INTRODUCTION

Shallot (*Allium cepa* L. Agregatum group) is one of horticulture crops that have high economic value in Indonesia (Firmansyah and Sumarni, 2013). The need for shallot in Indonesia tends to increase because of the increase in consumption, traditional medicine, and seed demand (Ghozali, 2010). The shallot consumption in Indonesia is about 2.76 kilograms per capita per year (Badan Pusat Statistik Kabupaten Kulonprogo, 2015) and the need for seed is around 1 ton.ha^{-1} to 1.5 ton.ha^{-1}, depending on the size of seeds and plant spacing that practiced (Sumarni et al., 2012a).

Bantul District, D. I. Yogyakarta is the central prodcution of lowland vegetables, such as shallot. Shallot production in Bantul District in 2010 was 19,950 ton, while in 2014, it decreased to 8,392 ton (Badan Pusat Statistik Kabupaten Kulonprogo, 2015). This production has decreased continuously over the past four years. To fulfill the domestic need of shallot, the production should be increased.

Shallot farmers in Bantul District commonly apply the inorganic and organic fertilizer simultaneously. According to the interview with some shallot farmers around the research location, the rates of inorganic fertilizer usually applied by farmers are 622 kg.ha^{-1} of NPK Mutiara, 228 kg.ha^{-1} of ZA, and

76 kg.ha^{-1} of KCl. Suwandi et al. (2015) stated that the recommendation of fertilizer for shallot is 500 kg.ha^{-1} of NPK, 200 kg.ha^{-1} of ZA, 50 kg.ha^{-1} of KCl, and 100 kg.ha^{-1} of SP-36. The previous study suggested that the application of 200 kg.ha^{-1} of NPK Phonska can increase dry mass per clump (Jazilah et al., 2007). This demonstrate that the use of inorganic fertilizer for shallot cultivation by farmers in Bantul District is above the threshold level of recommendation. Moreover, it would lead to land degradation. Land degradation decreases soil quality, thereby reducing shallot yield (Suwandi et al., 2015). It also has negative effect on the operational cost of shallot cultivation.

An effort to sustain the production of shallot bulb is by applying an appropriate rate of inorganic fertilizer. Sumarni et al. (2012b) reported the application of fertilizer at the right rate is expected to improve soil fertility, to enhance the growth of shallot, and to increase shallot bulb production. Furthermore, the reduction of inorganic fertilizer rate in Bantul District also can reduce the cost of production directly, thereby enhancing farmer's income.

Besides the excess rates of inorganic fertilizer application, shallot farmers in Bantul District are also faced with the limited cultivating area (Janti et al., 2016). A way to enhance the farmer income despite the limited cultivating area is to practice multiple cropping system. In agriculture, multiple cropping is the practice of growing two or more crops in the same area of land in the same growing seasons. There are two forms of multiple cropping system, which are dual-cropping and mixed cropping. In dual-cropping, a second crop is planted after the first one has been harvested, while in mixed cropping, the second crop is planted during the growth period of the first one (Azam-Ali, 2003). Sharma and Banik (2013) reported that multiple cropping system potentially increase land productivity, which then enhance farmer's income. In multiple cropping system, one of some factors that are important to be considered is to choose the suitable commodity that has high agronomic and economic values.

Two commodities usually planted by farmers in Bantul District are shallot and chili. Most farmers in Bantul cultivate shallot and chili in multiple cropping system, in which chili is planted during the growth period of shallot. Chili is able to grow with shallot simultaneously because it has different habitus from shallot. Hence, it would minimize the competitions between them. Moreover, chili also has high economic value. The multiple cropping system applied in the field is expected to increase land use efficiency, to mitigate the failure of crop harvest, and to enhance the capital use efficiency. Therefore, this research aimed to determine the effects of reducing inorganic fertilizer rates in different cropping system on the growth and yield of shallot in Bantul District.

MATERIALS AND METHODS

The research was conducted in Srigading Village, Sanden Sub-District, Bantul District, D. I. Yogyakarta from August to November 2016. The materials used were shallot bulbs (cv. Biru), inorganic fertilizers (NPK Mutiara (16-16-16), ZA, and KCl). The research was arranged in split plot design with three blocks as replications. The main plots were cropping systems consisting of monoculture (shallot) and multiple cropping system (shallot-chili). For both cropping system, shallot bulbs were planted in five rows with a distance of 20 cm × 20 cm between each soil bed. The soil bed was 30 cm height. In multiple cropping, 20 day-old chili seedlings were planted between shallot plants in the first and fifth row with a spacing of 20 cm × 60 cm at 30 days after planting shallots. The sub plots were fertilizer rates consisting of 100% of the recommended rate as control (600 kg.ha^{-1} NPK Mutiara (16-16-16), 225 kg.ha^{-1} ZA, and 75 kg.ha^{-1} KCl), 50% of control (300 kg.ha^{-1} NPK Mutiara (16-16-16), 112.50 kg.ha^{-1} ZA, and 37.50 kg.ha^{-1} KCl), and 25% of control (150 kg.ha^{-1} NPK Mutiara (16-16-16), 56.25 kg.ha^{-1} ZA, and 18.75 kg.ha^{-1} KCl). The NPK Mutiara was applied two times, which were 82 % of fertilizer rate at 1 day after planting and 18 % of fertilizer rate at 3 weeks after planting (WAP). The ZA was applied two times, which were 67 % of fertilizer rate at 1 day after planting and 33 % of fertilizer rate at 3 WAP. Meanwhile, KCl was given once at 3 WAP.

Nitrate reductase activity was observed at 3 WAP using method reported by Hartiko et al. (1982). The variables were plant height (cm), number of leaves, leaf area index, total chlorophyll, net assimilation rate (g.dm^{-2}.week^{-1}), crop growth rate (g.cm^{-2}. week^{-1}), and total dry mass at 6 weeks after planting (WAP). Besides, leaf nitrogen content (%), leaf nitrogen uptake (mg.g^{-1}), number of bulbs per plant, weight per bulb (g), and productivity (ton per hectare) were observed at 9 WAP. Nitrogen (N) uptake was calculated using the formula of N uptake = leaf Nitrogen (N) content × leaf dry mass. Data were analyzed using variant analysis (ANOVA) with α = 5 % followed with Tukey test if there were significant difference between treatments.

RESULTS AND DISCUSSIONS

Soil in the research location (Srigading Village Bantul District) was classified into Regosol soil type (Masnanto, 2006). This soil was characterized with sandy loam texture, which lacks of soil organic matter. The lack of soil organic matter was due to high soil porosities. The soil also had low Nitrogen and Phosphorus, but contained high Potassium (Table 1). The growth and yield of shallot were affected by soil fertility in the research location since soil fertility is represented by nutrient availability in soil affecting plant growth in that soil.

There was no interaction effect of cropping system and reducing rates of inorganic fertilizers on the number of leaves and leaf area index (Table 2). Cropping system did not significantly affect the number of leaves and leaf area index of shallot. However, reducing rates of inorganic fertilizers had significantl effect on leaf area index of shallot, but not on the on number of leaves. Inorganic fertilizers reduced up to 50% gave the highest leaf area index that was not significantly different from that resulted

Table 1. Soil characteristic in research location in Srigading Village, Bantul District

Parameter	Value	Note (*)
Texture		
Sand (%)	32.12	
Silt (%)	43.65	Sandy loam
Clay (%)	24.23	
Soil organic material (%)	1.74	Low
pH H2O	7.01	Neutral
N Total (%)	0.07	Very low
P Availability (ppm)	0.01	Very low
Potassium Availability (%)	1.05	High

Remark: *Classified according to Balai Penelitian Tanah (2009). Soil analysis was conducted in Integrated Laboratory of INSTIPER, Yogyakarta (2016).

Table 2. The number of leaves and leaf area index of shallot at 6 WAP in different cropping systems and reducing rates of inorganic fertilizers

Treatment	Number of leaves	Leaf area index
Cropping system		
Monoculture	34.07 a	0.81 a
Multiple cropping system	39.15 a	0.76 a
Fertilizer rates (% of recomendation rates)		
100	32.06 p	0.79 pq
50	39.44 p	0.82 p
25	38.34 p	0.74 q
Interaction	(-)	(-)

Remark: Means followed by the same letters in the same column were not significantly different according to Tukey α=5%; (-): no interaction effect of both factors.

Table 3. Total Chlorophyll content (6 WAP), N Content (9 WAP), and N Uptake (9 WAP) of shallot in different cropping systems and reducing rates of inorganic fertilizers

Treatment	Total chlorophyll ($mg.g^{-1}$)	Leaf N uptake ($mg.g^{-1}$)	Leaf N content (%)
Cropping system			
Monoculture	0.04 a	8.54 a	1.54 a
Multiple cropping system	0.06 a	7.79 a	1.58 a
Fertilizer rates (% of recomendation rates)			
100	0.05 p	8.91 pq	1.53 p
50	0.03 p	8.97 p	1.58 p
25	0.06 p	6.62 q	1.52 p
Interaction	(-)	(-)	(-)

Remark: Means followed by the same letters in the same column were not significantly different according to Tukey α=5%; (-): no interaction effect of both factors.

Table 4. Nitrate reductase activity (3 WAP), net assimilation rate (3–6 WAP), and crop growth rate (3–6 WAP) in different cropping systems and reducing rates of inorganic fertilizers

Treatment	Nitrate reductase activity ($\mu mol.g^{-1}.h^{-1}$)	Net assimilation rate ($g.dm^{-2}.week^{-1}$)	Crop growth rate ($g.cm^{-2}.week^{-1}$)
Cropping system			
Monoculture	3.11 a	0.50 a	0.03 a
Multiple cropping system	2.84 a	0.47 a	0.03 a
Fertilizer rates (% of recomendation rates)			
100	2.10 q	0.52 p	0.03 p
50	2.70 pq	0.48 p	0.03 p
25	4.13 p	0.45 p	0.03 p
Interaction	(-)	(-)	(-)

Remark: Means followed by the same letters in the same column were not significantly different according to Tukey α=5%; (-): no interaction effect of both factors.

by the application of inorganic fertilizers at a rate of 100% of recommendation. It represented that plant had stability in the metabolic activity in leaf in spite of the difference rates of inorganic fertilizers applied.

There was no interaction effect of the cropping system treatment and reducing rates of inorganic fertilizers on the N content, N uptake and total chlorophyll content (Table 3). Cropping system did not significantly affect the N content, leaf N uptake, and total chlorophyll content in the shallot leaves. However, reducing rates of inorganic fertilizers showed a significant effect on the N uptake. Reducing inorganic fertilizers rate to 50 % of control resulted in the highest value of N uptake that was not significantly different from that resulted by control treatment (100 % fertilizer rate). Meanwhile, reducing inorganic fertilizer rate to 25 % of control decreased the N uptake. Interestingly, there was no significant difference in the total chlorophyll content resulted by inorganic fertilizer at a rate of 25 % of control and control (100 % fertilizer rate). Firmansyah and Sumarni (2013) reported that high fertilizer rate (> 90 $kg.ha^{-1}$ N) made NO^{3-} and NH^{4-} unavailable for cultivated crop because nitrogen is easily leached and volatilized.

This condition was affected by high activity of nitrate reductase enzyme in shallot plants (Table 4). This result indicated that shallot had sensitivity in nitrate reductase activity with low content of available nitrogen in soil. Chen et al. (2004) reported that sensitivity of vegetable plant in nitrate reductase activity to nitrate supply depends on the plant species. Among three leafy vegetables (rape, spinach, cabbage), rape performs the most sensitive in nitrate reductase activity, while spinach is the least sensitive. The result of Daras et al. (2011) showed that reducing fertilizer rates to 25 % of control did not affect the total chlorophyll in cashew plant, and chlorophyll played an important role in photosynthesis process.

Photosynthesis process is reflected in net assimilation rate, and this variable will influence crop growth rate. Based on. Table 4, there was no interaction effect of both factors on the net assimilation rate and crop growth rate. Cropping system did not significantly affect the net assimilation rate and crop growth rate. Likewise, reducing rates of inorganic fertilizers did not give a any significant effect on the net assimilation rate and crop growth rate. These results showed that reducing rate of inorganic fertilizers to 25 % of recommendation did not disturb the assimilation activity and crop growth rate of shallot plants at 6 weeks after planting. It proved that shallot effectively used the available nutrient in soil for its growth. As comparison, Pandey and Singh (2015) reported that, in multiple cropping system of wheat and spinach, reducing rate of inorganic fertilizers to 50 % of control (212.5 $kg.ha^{-1}$ N, 92.5 $kg.ha^{-1}$ P_2O_5 and 30 $kg.ha^{-1}$ K_2O) showed the optimum net assimilation rate value.

Crop growth rate would affect plant morphology such as plant height and dry weight. Cropping system and reducing rates of inorganic treatments did not significantly affect plant height and dry mass of shallot plants (Table 5). Shallot could grow normally in condition of low inorganic fertilizer application (25 % of control). This result indicated that despite the low rate of inorganic fertilizer application, the N, P, and K nutrients were absorbed efficiently by shallot plants. The research by Kumar et al. (2017) showed that appropriate crops planting in multiple cropping system could reduce the competition of space between crops and enhance light interception. The competition space could increase effectiveness of solar radiation, water, and nutrient absorption, thereby optimizing plant growth. In addition, chili had different habitus from that of shallot so that it minimized the competition of sun light resource.

According to Table 6, there was no interaction effect of both factors on the number of bulbs, weight per bulb, and productivity of shallot. These variables were not significantly affected by cropping system. However, reducing rates of inorganic fertilizers showed a significant effect on the bulb weight and productivity of shallot. Reducing inorganic fertilizer

Table 5. Plant height and dry mass of shallot (6 WAP) in different cropping systems and reducing rates of inorganic fertilizers

Treatment	Plant height (cm)	Total dry weight (g)
Cropping system		
Monoculture	32.81 a	5.68 a
Multiple cropping system	37.58 a	5.20 a
Fertilizer rates (% of recomendation rates)		
100	33.30 p	5.73 p
50	34.73 p	5.75 p
25	37.56 p	4.84 p
Interaction	(-)	(-)

Remark: Means followed by the same letters in the same column were not significantly different according to Tukey α=5%; (-): no interaction effect of both factors.

Table 6. Number of bulbs, weight per bulb (g), and productivity of shallot at 9 weeks after planting in different cropping systems and reducing rates of inorganic fertilizers

Treatment	Number of bulb	Weight per bulb (g)	Productivity (ton.ha^{-1})
Cropping system			
Monoculture	6.78 a	3.45 a	5.89 a
Multiple cropping system	6.41 a	3.42 a	5.64 a
Fertilizer rates (% of recomendation rates)			
100	6.17 p	3.90 p	6.03 p
50	6.39 p	3.75 p	5.91 p
25	7.22 p	2.65 q	5.34 q
Interaction	(-)	(-)	(-)

Remark: Means followed by the same letters in the same column were not significantly different according to Tukey α=5%; (-): no interaction effect of both factors.

Table 7. Climate in Province of Yogyakarta in 2016

Variable of climate	Month in 2016				
	August	September	October	November	December
Rainfall (mm) #	94.50	237.20	324.20	508.20	267.80
Rainfall days (day) #	12	18	21	25	27
Air temperature average (°C) *	29.0	29.6	30.6	27.6	26.40
Humidity (%) *	72	72	80	77	77

Remark: (#) Source: Badan Pusat Statistik Provinsi D.I.Yogyakarta (2016); (*) Source: Data primer thermohygrometer

rate from 100 % to 50 % did not significantly decrease bulb weight but reducing inorganic fertilizer rate to 25 % significantly decreased bulb weight compared to that in 100 % rate of inorganic fertilizer. This result concluded that inorganic fertilizer rate that was reduced to 50 % of control was still sufficient for plant, but reducing inorganic fertilizer rate to 25 % led to nutrient deficiency in shallot plants.

Jazilah et al. (2007) reported that the most optimal bulb weight was obtained with the application of NPK fertilizer at a rate of 200 kg.ha^{-1}, and NPK application less than that rate would decrease dry mass. The selection of appropriate crops in multiple cropping highly influence the yield. Farhad et al. (2014) showed that chili and garlic cultivated in multiple cropping could increase their production and farmer's income. Sakya et al. (2015) explained that assimilate distribution was affected by plant nutrient absorption.

Shallot yield in this research was categorized low because of high rainfall intensity and flooding disaster in September 2016 (Table 7). Cultivating shallot under high rainfall intensity will increase air humidity, thereby decreasing transpiration rate of shallot and inhibiting photosynthesis process (Jasmi et al., 2013). Photosynthesis product will be translocated to yield component of shallot. Reducing rate of inorganic fertilizers to 50 % of control resulted in bulb weight and productivity of shallot that were not significantly different from those of control (Table 6). It was caused by ineffective nutrient absorption in plants with 100 % fertilizer rate. Meanwhile, reducing rate of inorganic fertilizers to 25 % of control caused nutrient deficiency and decreased shallot yield. Soil nutrients should be in well-balance. The excess nutrients will inhibit the availability of each other, while the deficiency in nutrient will decrease yield of plant (Novizan, 2005;

Jazilah et al., 2007). By providing actual yield of plant without increased inputs, or greater stability of yield with decreased inputs, multiple cropping becomes one unique route to achieve sustainable intensification (Hossain et al., 2017).

CONCLUSIONS

Multiple cropping system did not decrease the growth and yield of shallot. Inorganic fertilizers rate could be reduced to 50% of recommendation rate in shallot plants, resulting similar productivity to the application of 100% inorganic fertilizers rate.

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