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Nitrogen effect on production, nutrients uptake and nitrogen-use efficiency of shallot (*Allium cepa* var aggregatum)

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Abstract. Certainly nitrogen it is one of the most essential mineral for the plant. Shallot (*Allium cepa* var aggregatum L.) was grown under fully irrigated conditions in a field experiment in the Central Java Indonesia to study and determine (i) optimum nitrogen dosage for bulb yield, (ii) nutrients uptake and (iii) nitrogen use efficiency. The field experiment was performed as a randomized complete block design with five nitrogen levels (100, 200, 300, 400, 500 kg/ha^{-1}) with six replicates. Our results showed that increased nitrogen rate enhanced shallot production. It was shown that the optimum dosage is 265 kg/ha^{-1}. The highest nutrients uptake was reached by 300 kg N/ha^{-1}. But, increasing the applied nitrogen rate decrease the NUE. The range of NUE values recorded was between 0.24 and 1.20 g bulb per g nitrogen.
Key Words: Bulb yield, irrigated conditions, N optimum dosage, shallot, nutrients uptake.

Introduction. The Allium genus is one of the most various and taxonomically difficult to set of the monocots (Fritsch 1996). The antifungal, antiviral, antibacterial, antiprotozoal and antihelmintic traits of the Allium genus are right established (Zammouri et al 2008). Shallot (*Allium cepa* var aggregatum) is one of the most important vegetables in Indonesia. It is a crop used as main ingredient in most traditional Indonesian cuisines. Shallot plants need balance of NPK nutrient supply in soil to get optimal growth and bulb yield (Sumarni et al 2012).

The key to sustainable agriculture production rest in increased output per unit input (Rezaei et al 2013). Efficiency in agriculture can be elucidated as the ratio between output and input (Van Duivenbooden et al 2000). Recently the nitrogen fertilizer application rates have increased in Indonesia. It shows that urea consumption is almost 70 % from Indonesian total fertilizer consumption (Amin 2013). Consequently, a preferable understanding of the plants requirements to nitrogen improve the nitrogen-use efficiency (NUE) and evade over fertilization (Zhu et al 2005). The NUE values for onion were between 0.59 to 0.78 under different rates of nitrogen usage. In addition, increasing the nitrogen fertilizer dosage from 56 to 168 kg N/ha^{-1} decrease the NUE by 18 % in onion plants (Drost et al 2002). Moreover, increasing nitrogen fertilizer application pointedly decreases the NUE and harvest index in garlic plants (Mollafilabi et al 2013).

Dry matter partitioning between vegetative and generative organs is obviously an important problem which immediately influences horticultural crop production (Marcelis 1996) which is really influenced by environmental conditions and different management praxis (Rizzalli et al 2002). Nitrogen application affects root/shoot partitioning (Hutchings & John 2004) by increasing dry matter partitioning to vegetative organs (Arduini et al 2006).

In outlook of the lack of studies on shallot growth and agronomic characteristics, the main aims of the current study where to determine optimum nitrogen dosage for bulb yield, nutrients uptake and nitrogen use efficiencies.

Material and Method. The experiment was conducted at Brebes, Central Java Indonesia in September – November 2013. Type of soil is alluvial with soil texture is 9 % sand, 32 % silt, 59 % clay, with neutral pH (6.1). Nutrients status before research are: organic C content is 0.97 %, N content is 0.15 %, C/N ratio is 6, P total is 149,57 mg/100 g and K_2O total is 52.02 mg/100 g. Randomized Complete Block Design with five treatments and six replications was arranged in the field. The treatments are different dosage level of nitrogen fertilizer i.e.: 100, 200, 300, 400 and 500. All treatments had 120 kg P_2O_5 /ha^{-1} and 150 kg K_2O/ha^{-1}. Source of nitrogen is urea and ZA with composition rate 1:1. Nitrogen and potassium fertilizer was applied two times at two and four weeks after planting, meanwhile phosphor fertilizer was applied one time as a basic fertilizer one day before planting. Plot sized was 1.2 x 6 m with 15 x 20 cm spacing. So, the population was constituted by 240 plants per plot.

Agronomic nitrogen use efficiency was calculated by (Raun & Johnson 1999):

$$NUE = BY/NP$$

Where NUE is nitrogen-use efficiency (g bulb g N^{-1}), BY is bulb yield (g/m^{-2}), and NP is nitrogen application rate (g N/m^{-2}).

Results and Discussion. Effect of nitrogen fertilizer on bulb yield is shown in figure 1. Optimum dosage for shallot bulb production was 265 kg N^{-1} with 11.65 kg per plot bulb yield. Meanwhile, Sumarni et al (2012) reported that optimum dosage for shallot on andisol soil was 146 kg N/ha^{-1}. Differences results because of different cultivars usage, sowing time and nitrogen application technique.

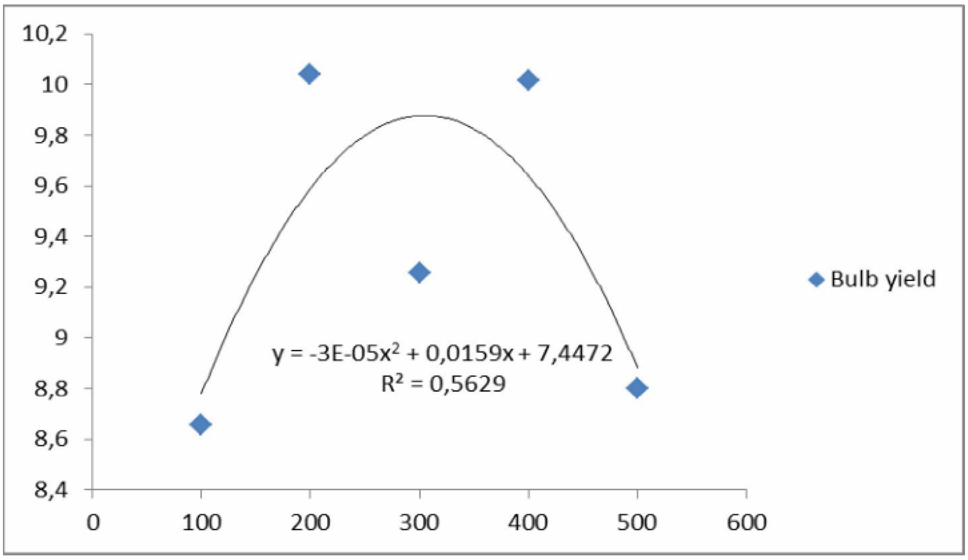

Figure 1. Effect of different nitrogen fertilization rates on bulb yield of shallot.

Application time and fertilization technique affect the yield (Moghaddam et al 2007). Persian bulb yield increased by 18 and 13 % under high rate of nitrogen (Rezaei et al 2013) and almost 42 % on fresh yield of shallot bulb (Woldetsadik & Workneh 2010). But, increasing nitrogen will decrease the uptake efficiency (Azam & Lodhi 2001).

Shallot production showed a positive response to increasing application of nitrogen in this study. Increasing the applied nitrogen significantly enhanced the leaf area expansion, crop growth rate and radiation-use efficiency (Rezaei et al 2013). Nitrogen was needed on formation of amino acids, protein, nucleic acid, enzymes, nukleoprotein and alkaloids which was required on plant growth especially on leaves development, green leaves and sets formation (Nasreen et al 2007; Abdissa et al 2011). Nitrogen deficiencies will limits division and cell enlargement (Sumiati & Gunawan 2007) and restricts chlorophyll formation, make the plant growth hampered and leads to yellowish leaves (Nurhayati et al 1986).

Organic C and macro nutrients uptake is showed in table 1. The highest organic C content and N, P, Ca, Mg uptake is reached by 300 kg N/ha^{-1} meanwhile the highest K and S uptake is reached by 400 kg N/ha^{-1}. Organic C content ranged between 6,209.84 and 7,742.79 mg per plant. Nutrients uptake ranged between 558.23 and 665.50 mg per plant for Nitrogen, 40.94 to 53.55 mg per plant for phosphor, 317.39 to 389.95 mg per plant for potassium, 153.09 to 277.29 mg per plant for calcium, 37.34 to 49.06 mg per plant for magnesium and 76.55 to 93.43 mg per plant for sulfur. The highest nitrogen (500 kg N/ha^{-1}) application not increase nutrient uptake but otherwise has low nutrients uptake compare the others.

Table 1

Effect of nitrogen on organic C and macro nutrients uptake

Treatments	*Organic C*	*N*	*P*	*K*	*Ca*	*Mg*	*S*
	(mg/plant)						
100 kg N/ha^{-1}	6,695.74	582.08	50.93	352.89	229.19	38.20	81.86
200 kg N/ha^{-1}	6,209.84	562.98	40.94	330.96	185.95	37.53	76.77
300 kg N/ha^{-1}	7,742.79	665.50	53.33	366.88	277.29	49.06	89.59
400 kg N/ha^{-1}	7,348.16	664.14	46.71	389,95	251.84	40.62	93.43
500 kg N/ha^{-1}	6,667.06	558.23	41.07	317.39	153.09	37.34	76.55

Micro nutrients uptake is showed in table 2. Micro nutrients uptake ranged between 127 to 173 mg per plant for clorin, 116 to 141 mg per plant for natrium, 15.5 to 27.6 mg per plant for Fe, 16.8 to 32 mg per plant for Aluminum, 3.14 to 4.37 mg per plant to mangan, 0.12 to 0.19 mg per plant for cuprum, 0.71 to 1 mg per plant for zinc, 0.51 to 0.68 mg per plant for boron, 0.11 to 0.50 mg per plant for Pb, 0,001 to 0,004 for Ag. The highest Na, Fe, Al, Mn, Cu, Zn, and B uptakes were reached by 300 kg N/ha^{-1}. Meanwhile, the highest Cl uptake was achieved at 400 kg N/ha^{-1}and the highest Pb uptakes was reached at 500 kg N ha^{-1}. Overall the highest nutrients uptake was reached by 300 kg N/ha^{-1}.

Table 2

Effect of nitrogen on micro nutrients uptake

Treatments	*Cl*	*Na*	*Fe*	*Al*	*Mn*	*Cu*	*Zn*	*B*	*Pb*	*Ag*
	(mg/plant)									
100 kg N/ha^{-1}	162	126	15.5	14.7	3.69	0.15	0.82	0.51	0.42	0,001
200 kg N/ha^{-1}	145	118	15.8	16.8	3.48	0.12	0.73	0.56	0.11	0,002
300 kg N/ha^{-1}	169	141	27.6	32.0	4.37	0.19	1.00	0.68	0.15	0,004
400 kg N/ha^{-1}	173	116	26.4	21.2	3.72	0.16	0.73	0.65	0.29	0,004
500 kg N/ha^{-1}	127	116	20.6	22.1	3.14	0.15	0.71	0.65	0.50	0,002

Not all of fertilizers were assimilated by the plant. Some of them remained in the soil, leaching, or up in the air. Effect of fertilizer on soil chemistry status is shown in table 3.

Table 3

Effect of nitrogen on soil chemistry status

Treatments	*pH*	*C*	*N*	*C/N*	*P_2O_5*	*K_2O*	*Ca*	*Mg*	*K*	*Na*	*CEC*	*KB*
		(%)			*(mg/100 g)*			*cmol(+)/kg*				*%*
100 kg N/ha^{-1}	5.6	1.10	0.14	8	169,1	57.9	32.2	5.3	0.7	1.1	44.5	87
200 kg N/ha^{-1}	5.6	1.02	0.15	7	178,2	57.6	32.6	4.8	0.7	1.0	45.7	86
300 kg N/ha^{-1}	5.5	0.97	0.15	7	164,0	54.0	33.6	4.9	0.6	1.0	45.1	89
400 kg N/ha^{-1}	5.7	0.94	0.14	7	177,6	45.5	33.6	5.0	0.5	1.2	46.2	88
500 kg N/ha^{-1}	5.6	0.94	0.16	6	188,2	46.0	34.8	5.2	0.4	1.2	46.1	90

Fertilizer decreased pH value from 6.1 (pro research) to 5.5 – 5.7 (post research). Decrease in soil pH was caused by cations absorbed by the roots which absorb H^+ ions from the roots and lead to an acid soil (Firmansyah & Sumarni 2013).

When plants have 7 weeks age after planting, were revoked and get analyzed. Partitioning between bulb and leaves for organic C and all nutrients (macro and micro) were not different. The partitioning between bulb and leave is shown on figure 2. The partitioning was almost balanced for the bulb and leaves on this age. But with age, bulb partitioning will increase more than the leaves partitioning. Dry matter content will increase during the period of bulb development (Henrisken & Hansen 2001).

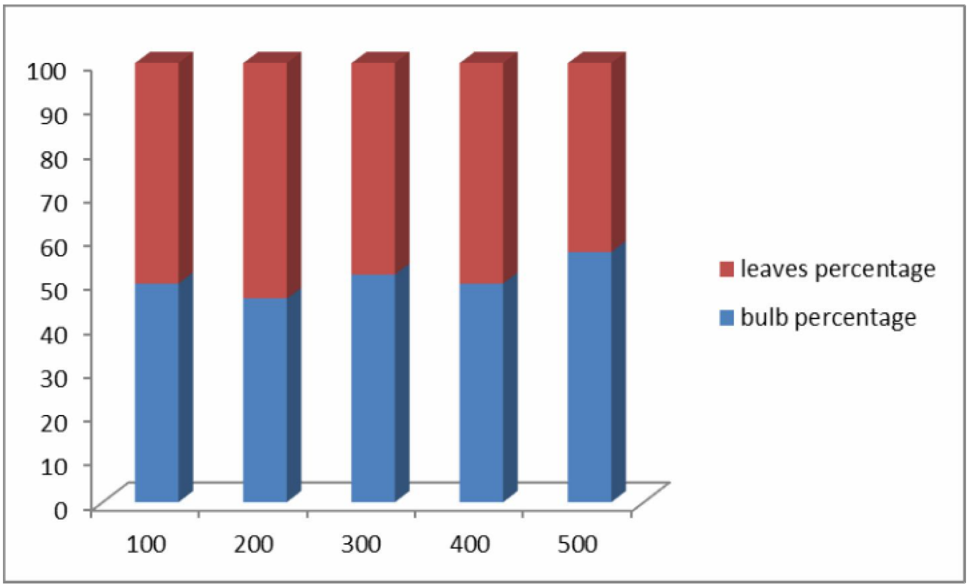

Figure 2. Percentage of organic C and nutrients uptake (macro and micro) between leaves and bulb.

In general, increasing the applied nitrogen rate decrease the NUE (Figure 3). The range of NUE values was between 0.24 and 1.20 g bulb per g nitrogen. Highest and lowest values of NUE were achieved by 100 kg N/ha^{-1} and 500 kg N/ha^{-1} respectively. Increasing nitrogen application from 100 to 500 kg/ha^{-1} caused 80 % decrease in nitrogen-use efficiency.

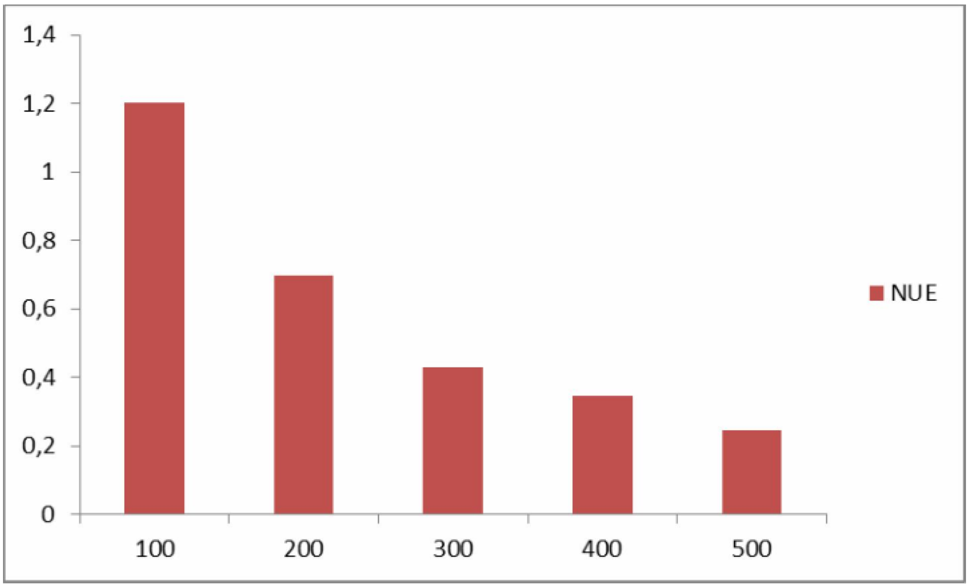

Figure 3. Shallot nitrogen use efficiency as affected by different nitrogen application rate.

A negative relationship between nitrogen application rate and nitrogen use efficiency is highly documented under different conditions due to volatilization, denitrification and leaching of nitrogen (Cassman et al 2002). Rezaei et al (2013) showed that increasing nitrogen application from 100 to 300 kg/ha^{-1} caused a 67 % decrease in nitrogen-use efficiency of Persian shallot.

Conclusions. Optimum dosage for shallot bulb production was reached at 265 kg N^{-1}/ha, and the highest nutrients uptake reached at 300 kg N/ha^{-1}. But, increasing the applied nitrogen rate decrease the NUE. The range of NUE values was between 0.24 and 1.20 g bulb per g nitrogen.

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