

Nitrogen Fertilizer Increased Bulb Diameter and Yields of True Seed and Bulb – propagated Shallot Varieties

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ABSTRACT: True seed shallots (TSS) have plenty of advantages in comparison to seed bulb (bulb-propagated) shallots. The experiment was conducted with an objective of the effects of N fertilizer rates on the growth and yields of TSS and bulb-propagated shallot varieties. The experiment was conducted at dryland farming area in Buahon village, Kintamani district, Bangli regency from 17 July until 15 October 2015. Four varieties (Tuktuk, BimaBrebres, BiruLancor and Lokal) and four rates of N fertilizer (0, 100, 200 dan 300 kg ha⁻¹) were the treatments with factorial arrangement in a completely randomized block design with three replicates. Tuktuk was a TSS variety while the other three were bulb-propagated shallot varieties. Results of the experiment showed that TSS Tuktuk was able to adapt in the village of Buahon, Kintamani and produced the highest bulb fresh weight (30.803 ton ha⁻¹), which was respectively 25.73%, 18.30% and 19.77% higher than that of BimaBrebres, BiruLancor and Lokal. Increased in N rates to 200 kg ha⁻¹ significantly increased bulb diameter and bulb fresh weights per ha by 31.03% dan 48.57% respectively. Optimum N rates for Tuktuk, BimaBrebres, BiruLancor and Lokal were respectively 285.122 kg ha⁻¹, 283.166 kg ha⁻¹, 208.508 kg ha⁻¹, 241.370 kg ha⁻¹.

KEYWORDS: Bulb-propagated, Nitrogen, True seed shallots

I. INTRODUCTION

Shallots has been one of important vegetable and used in Asian countries including Indonesia. It belongs to the family of Liliaceae and it has been a major source of income for farmers in tropical countries. Shallots are usually cultivated using bulbs, consequently results in high requirement for plant materials causing very high cost for supplying propagated-bulbs (40% of total production cost) (Permadi, 1992). The other problems are diseases caused by *Fusarium* sp., *Colletotrichum* sp., *Alternaria* sp. and viruses are often carried by infested plants resulted in lower shallot bulb production (Permadi, 1993). Therefore to increase shallot productivity the use of healthy plant materials such as true shallot seeds (TSS) is becoming important. In Indonesia the availability of TSS varieties is still limited (Tuktuk was the only variety available at the time of experiment), therefore Tuktuk variety was used in this experiment to represent TSS. The use of plant materials (3-4 kg seeds ha⁻¹ compared to 100-1500 kg cloves ha), free from pest and diseases in plant materials, and importantly is doubling the yields (Permadi, 1992; Van der Brink and Basuki, 2012) are the benefits of using TSS. Higher yields of Tuktuk (28.5 ton ha⁻¹) was reported by Basuki (2009) compared to that (average of 18.5 ton ha⁻¹) of bulb-propagated shallot varieties.

It has been well known that nitrogen has important roles in improving growth and increasing yields of onions and shallots (Hidayat and Rosliani, 1996; Yasoet *et al.*, 2007; Abdissa *et al.*, 2011; Van der Brink and Basuki, 2012). Shallots and other onions required higher amounts of nitrogen than other nutrients (Messele, 2016). The requirement for N fertilizer to give high shallot yields in Indonesia was in the range of 90-300 kg N ha⁻¹ (Suwandi and Hilman, 1992; Hidayat and Rosliani, 1996). Nitrogen is needed for protein and chlorophyll synthesis resulted in increasing

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photosynthates production, which are eventually translocated into the bulbs as storage organs (Marchner, 1995). Budi-Jaya (1994) stated that N fertilization increased growth, bulb fresh and dry weights of shallots in Indonesia. High yields of shallots (23.93 and 4.12 ton ha⁻¹ fresh and dry weights respectively), which was resulted from application of N fertilizer of 225 kg N ha⁻¹, was reported by Suwela (2005) in Songan village, Kintamani district, Bangli regency, Bali province. At the moment the use of TSS is still limited in Bali (Indonesia), however the needs to produce high yields, healthy crop and less cost production of shallots is the new direction and TSS could be a viable option for improving the competitiveness of Indonesia's shallot production (Van der Brink and Basuki, 2012). Therefore an experiment with N fertilizer application was carried out on TSS and bulb-propagated shallot varieties.

II. MATERIALS AND METHOD

The field experiment was conducted in Buahon village, district of Kintamani, Bangli regency from 17 July until 15 October 2015. The average annual rainfalls during 10 years periode of 2016-2015 was 3076.64 mm with 93.64 rainy days (Department of Agriculture, Plantation and Forestry Bali Province, 2015). The experimental land was loamy sand texture and contained neutral pH of 6.87, high organic carbon of 3.22%, low total N of 0.18, very high available P of 81.19 ppm, very high exchangeable K of 631.41 ppm but very low electric conductivity (Soil Laboratory of Agriculture Faculty, Udayana University, 2015). The experiment was arranged factorially in a randomized complete block design with three replicates. The treatments were four varieties (Tuktuk, Bima Brebes, Biru Lancor and Lokal) and four rates of N fertilizer (0, 100, 200 dan 300 kg ha⁻¹). Tuktuk was a True Seed shallot (TSS) (produced by PT East West, Indonesia) while the other three were bulb-propagated shallot varieties. The objective of experiment was to investigate the effects of N fertilizer (urea fertilizer) rates on the growth and yields of shallots. Plastic mulch with 15 cm holes for each plant was laid on the soil surface to minimize the evaporation and to suppress weed growths. Prior to transplanting into the field, seeds of Tuktuk was germinated in the nursery for 21 days, while bulbs of the other three varieties were directly planted at the same time with Tuktuk. N fertilizer was applied three times with 1/3 of each rates at 15, 30 and 45 dap. Due to high content of phosphorus and potassium in the soil there was no application of those nutrient. Water in bulb: leaf g was done to keep plants healthy and to avoid plants drying out in the field. Variable measured harvesting age, leaf number plant⁻¹ at 21 dap, leaf FW and DW ha⁻¹, bulb diameter, bulb FW and DW ha⁻¹, ratio of FW bulb: leaf. Data were collected and subjected to analysis of variance technique (Steel and Torrie, 1980) using COSTAT and MSTATC computer software package. Duncan's Multiple Range Test and LSD at 5% level were adopted for comparing means among treatments. The graph was created using Excell.

III. RESULTS AND DISCUSSION

Interaction effects of N rates and variety of shallots were significant (p<0.05) on most variable observed except on harvesting age, number of bulbs per plant, and ratio of bulb: leaf fresh weight. Variety of Tuktuk had significantly lower number of leaves plant⁻¹ at all N rates compared to other varieties, while Local variety had the highest number of leaves (Table 1).

TABLE-1. EFFECTS OF INTERACTION BETWEEN VARIETY AND N RATES ON LEAF NUMBER (LEAF PLANT⁻¹) AT 21 DAP

	N rates (kg/ha)			
	0	100	200	300
Varieties				
Tuktuk*	4.00 g	3.33 g	4.00 g	4.00 g
Bima Brebes**	19.00 def	25.67 bc	19.67 def	21.00 cde
Biru Lancor**	16.33 ef	18.33 ef	15.67 f	20.00 def
Lokal**	25.67 bc	26.33 b	31.33 a	23.33 bcd

Notes: Means followed by the same letters are not significantly different at 5% Duncan's Multiple Range Test.

*True seed shallots; ** Bulb-propagated shallots.

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At the rate of 0 kg N ha⁻¹ there was no significant different in leaf FW of all varieties. However, when N rates increased up to 300 kg ha⁻¹, only leaf FW of BimaBrebes and BiruLancor were increased significantly (Table 2). An increase in photosynthetic areas (leaves) in response to N fertilization had substantially contributed to enhance onion productivity that could be through the production of more assimilates (Nasreen *et al.*, 2007).

TABLE-2. EFFECTS OF INTERACTION BETWEEN VARIETY AND N RATES ON LEAF FRESH WEIGHTS (KG HA⁻¹)

	N rates (kg/ha)			
	0	100	200	300
Varieties				
Tuktuk*	8.41 cd	6.95 d	8.43 cd	8.99 cd
BimaBrebes**	9.25 cd	13.30 ab	15.28 a	14.94 ab
BiruLancor**	9.42 cd	11.78 bc	9.64 cd	13.85 ab
Lokal**	6.98 d	7.7 d	6.44 d	8.43 cd

Notes: Means followed by the same letters are not significantly different at 5% Duncan's Multiple Range Test.
*True seed shallots; ** Bulb-propagated shallots.

The highest leaf DW (1.96 ton ha⁻¹), which was 36.69% higher than control, was performed by BimaBrebes (bulb-propagated) variety at the rate of 200 kg N ha⁻¹, which was not significantly different from that at rate of 300 kg N ha⁻¹. Increased N rates did not significantly increase leaf DW of Tuktuk and Local varieties (Table 3).

TABLE-3. EFFECTS OF INTERACTION BETWEEN VARIETY AND N RATES ON LEAF DRY WEIGHTS (TON HA⁻¹)

	N rates (kg/ha)			
	0	100	200	300
Varieties				
Tuktuk*	3.25 e	3.58 de	4.28 de	3.90 de
BimaBrebes**	4.29 de	6.33 bc	7.27 ab	8.00 a
BiruLancor**	4.24 de	4.47 de	3.31 de	5.07 cd
Lokal**	4.13 de	4.34 de	3.73 de	4.26 de

Notes: Means followed by the same letters are not significantly different at 5% Duncan's Multiple Range Test.
*True seed shallots; ** Bulb-propagated shallots.

Increasing nitrogen rates up to 200 kg ha⁻¹ significantly increased bulb diameter of Tuktuk by 31.03%, which was not significantly different from that at rate of 300 kg ha⁻¹. Among varieties, Tuktuk had the biggest bulb diameter at all N rates (Table 4). Compared to Local variety, Tuktuk had 24.23% and 46.42% bigger diameter respectively at N rates of 0 and 200 kg ha⁻¹. Abdissa *et al.* (2011) reported that regardless of the rate of application, N fertilization increased bulb diameter by about 12% over the control. Bulb diameter was reported to increase the yield of onion (Nasreen *et al.*, 2007). Yadav *et al.* (2003) found that N at 150 kg ha⁻¹ enhanced the formation of bulbs with larger diameters.

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TABLE-4. EFFECTS OF INTERACTION BETWEEN VARIETY AND N RATES ON DIAMETER OF SHALLOT BULBS (CM)

	N rates (kg/ha)			
	0	100	200	300
Varieties				
Tuktuk*	2.60 c	2.90 b	3.77 a	3.61 a
BimaBrebes**	1.95 ef	1.92 f	2.09 def	2.20 def
BiruLancor**	2.03 def	2.22 de	2.26 d	2.10 def
Lokal**	1.97 def	1.99 def	2.02 def	2.11 def

Notes: Means followed by the same letters are not significantly different at 5% Duncan's Multiple Range Test.

*True seed shallots; ** Bulb-propagated shallots.

Increasing N rate to 100 kg ha⁻¹ did not increase bulb FW ha⁻¹ of all varieties (Table 5). Increasing N rates up to 200 kg ha⁻¹ increased the bulb FW ha⁻¹ of Tuktuk (by 48.57%) and other varieties except BimaBrebes. Increased N rate from 200 to 300 kg ha⁻¹ did not significantly increase the bulb FW of all varieties (Table 5). This finding was in line with that reported by Abdissaet *et al.* (2011) that N fertilization increased average bulb weight by 21.5%. The application of N fertilizer to the soil could increase the capacity of plant to absorb more nutrients, which might be attributed to increase root surface per unit of soil volume and rate of nutrients uptake as assumed by Badr and El-Shebiny (1999) and the explanation of Khalil *et al.* (1988) that nitrogen application enhanced metabolic activities within plant, which improved vegetative growth and thereby may encourage much more metabolites to be stored in bulbs as storage organs. At N rate of 200 kg ha⁻¹ Tuktuk variety had 24.19% higher bulb FW compared to average bulb FW ha⁻¹ of other varieties. The high bulb FW ha⁻¹ of Tuktuk was associated with its bigger bulb diameter (Table 4). Nasreen *et al.* (2007) reported that bulb diameter has strong and positive correlation ($r = 0.33^{**}$) with the total bulb yield of onion suggesting that the increased individual bulb size is fundamental to maximize onion productivity per unit area.

TABLE-5. EFFECTS OF INTERACTION BETWEEN VARIETY AND N RATES ON BULB FRESH WEIGHTS (TON HA⁻¹)

	N rates (kg/ha)			
	0	100	200	300
Varieties				
Tuktuk*	20.73 bcde	26.44 b	30.80 a	31.26 a
BimaBrebes**	16.67 e	20.31 cde	21.68 bcd	22.49 bcd
BiruLancor**	19.36 de	22.38 bcd	24.08 b	23.56 b
Lokal**	19.68 de	21.48 bcd	23.64 b	22.87 bc

Notes: Means followed by the same letters are not significantly different at 5% Duncan's Multiple Range Test.

*True seed shallots; ** Bulb-propagated shallots.

The bulb DW ha⁻¹ of Tuktuk variety increased by 35.95% when N rate increased up to 200 kg ha⁻¹ but not that of other varieties (Table 6). Increased N rate to 300 kg ha⁻¹ only increased bulb DW of BimaBrebes. Increased N rates from 0 to 200 kg ha⁻¹ only increased bulb DW of Tuktuk, which was higher than that of the other three varieties (Table 6).

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TABLE-6. EFFECTS OF INTERACTION BETWEEN VARIETY AND N RATES ON BULB DRY WEIGHTS(TON HA⁻¹)

	N rates (kg/ha)			
	0	100	200	300
Varieties				
Tuktuk*	3.51 cdef	4.45 b	5.48 a	5.44 a
BimaBrebres**	2.81 f	3.30 def	3.56 cdef	4.12 bc
BiruLancor**	3.17 def	3.55 cdef	3.90 bcd	3.82 bcde
Lokal**	3.07 ef	3.51 cdef	3.77 bcde	3.52 cdef

Notes: Means followed by the same letters are not significantly different at 5% Duncan's Multiple Range Test.

*True seed shallots; ** Bulb-propagated shallots

Tuktuk variety was harvested at 74 dap (after transplanting), which was 6 days later than the other varieties, had less bulbs plant⁻¹ (Table 7). That was in agreement with the finding by Pleasant (2010) on seed-propagated shallots can only have 3-4 bulbs than bulb-propagated ones. Despite that, Tuktuk had higher ratio of bulb: leaf fresh weights than the other varieties except Local. This finding indicated that Tuktuk variety probably was more effective in translocating assimilates from leaves to the bulbs. In the present experiment, N rates did not significantly affect harvesting age and number of bulb plant⁻¹, but increased ratio bulb: leaf FW at N rate of 200 kg ha⁻¹ (Table 7). The finding of high ratio bulb: leaf FW at N rate of 200 kg ha⁻¹ was in line to that reported by Hutchings and John (2004) mentioning nitrogen application influences root/shoot partitioning by increasing dry matter partitioning to vegetative organs (Arduinet *al.*, 2006).

TABLE-7. EFFECTS OF VARIETY AND N RATES ON HARVESTING AGE, NUMBER OF BULB PLANT⁻¹ AND RATIO OF BULB: LEAF FRESH WEIGHTS

	Harvesting Age (dap)	Number of Bulb (bulb plant ⁻¹)	Bulb: Leaf ratio
Varieties			
Tuktuk*	74.00***a	4.08 b	3.39 a
BimaBrebres**	68.75 b	5.92 a	1.10 c
BiruLancor**	67.75 b	5.25 a	2.08 b
Lokal**	67.58 b	5.50 a	3.13 a
5% LSD	1.561	0.697	0.604
N Rates			
0	74.17 a	4.67 a	2.09 b
100	75.00 a	5.17 a	2.43 ab
200	75.17 a	5.17 a	2.98 a
300	74.75 a	5.50 a	2.19 b
5% LSD	-	-	0.604

Notes: Means followed by the same letters within the same column are not significantly different at 5% LSD.

*True seed shallots; ** Bulb-propagated shallots. ***after transplanting

Relationship between N rates and bulb FW ha⁻¹ of each shallot variety (true seed and bulb-propagated shallots) were in quadratic forms with respective regression equations (Fig.1). The optimum N rate was determined as 285.122 kg ha⁻¹, 283.166 kg ha⁻¹, 208.508 kg ha⁻¹, and 241.370 kg ha⁻¹ respectively of Tuktuk, BimaBrebres, BiruLancor and Local varieties. Tuktuk(TSS) had the highest optimum N rate among varieties (Fig. 1), which probably contributed to the biggest bulb diameter and the highest bulb fresh weight of it. The optimum N rate of Tuktuk found in the present experiment was higher than 180 kg N ha⁻¹ reported by L. van der Brink and Basuki (2012). This was probably due to

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different soil texture and nutrient content. The soil texture in the present experiment was loamy sand that may cause nitrogen easily leach into deeper soil layer, which consequently needs more nitrogen to apply.

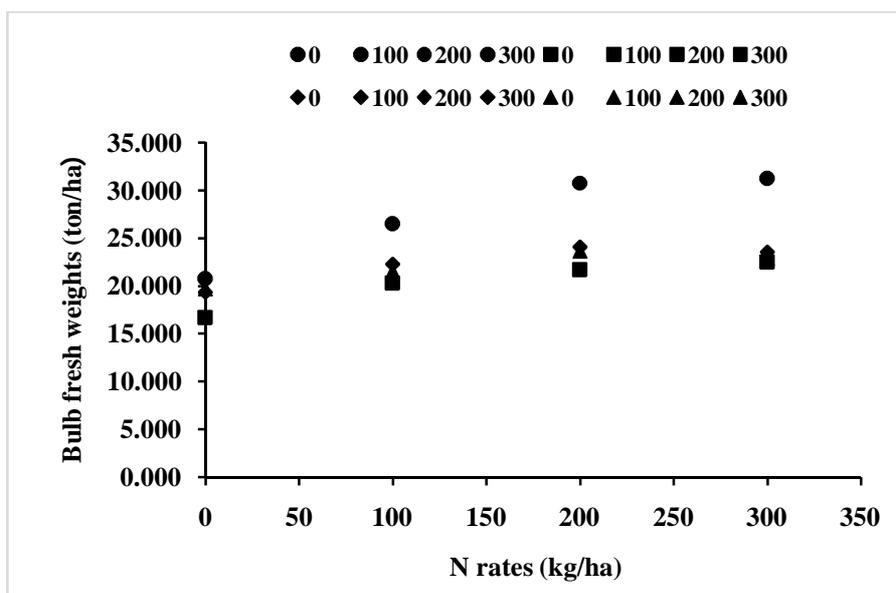


Fig. 1 Relationship between N rates and bulb fresh weights (ton ha⁻¹) of true seed and bulb-propagated shallots.

- Tuktuk: $Y = 20.613 + 0.0757 X - 1.327e^{-4}X^2$; $R^2 = 0.996^{ns}$; $X_{opt} = 285.122 \text{ kg ha}^{-1}$
- BimaBrebis: $Y = 16.762 + 0.0400X - 7.067e^{-5}X^2$; $R^2 = 0.993^{ns}$; $X_{opt} = 283.166 \text{ kg ha}^{-1}$;
- ◆ BiruLancor: $Y = 19.467 + 0.0473X - 1.134e^{-4}X^2$; $R^2 = 0.985^{ns}$; $X_{opt} = 208.508 \text{ kg ha}^{-1}$;
- ▲ Lokal: $Y = 19.514 + 0.0310X - 6.42e^{-5}X^2$; $R^2 = 0.942^{ns}$; $X_{opt} = 241.370 \text{ kg ha}^{-1}$

IV. CONCLUSION

Increased rates of N fertilizer up to 200 kg N ha⁻¹ significantly increased bulb diameter (by 31.03%), bulb FW (by 48.57%) and DW (by 35.95%) of true seed shallot variety (Tuktuk) respectively. At N rate of 200 kg ha⁻¹ Tuktuk had 24.19% higher bulb FW compared to average bulb FW ha⁻¹ of other varieties. The yields, except bulb diameter, of the other varieties (bulb-propagated shallots), were also increased with the increased rates of N fertilizer. The optimum rates of N for Tuktuk, BimaBrebis, BiruLancor and Local varieties were 285.12, 283.17, 208.51, and 241.37 kg N ha⁻¹ respectively. The true seed shallot of Tuktuk resulted in the highest bulb fresh weights (30.803 ton ha⁻¹), which was respectively 25.73%, 18.30%, and 19.77% higher than that of BimaBrebis, BiruLancor and Local varieties.

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REFERENCES

- [1] Y. Abdissa, T. Tekalign, and L. M. Pant, "Growth, bulb yield and quality of onion (*Allium cepa*L.) as influenced by nitrogen and phosphorus fertilization on vertisol I. growth attributes, biomass production and bulb yield", African Journal of Agricultural Research 6 (14), pp. 3252-3258, 2011.
- [2] L. van der Brink and Basuki, "Production of true seed shallots in Indonesia", I International Symposium on Sustainable Vegetable Production in Southeast Asia. Acta Hort. 958.12, 2012.
- [3] S. Nasreen, M.M. Haque, M.A. Hossain, A.T.M. Farid, "Nutrient uptake and yield of onion as influenced by nitrogen and sulphur fertilization", Bangladesh J. Agric. Res., 32(3): 413-420, 2007.
- [4] H. Marschner, "Mineral Nutrition of Higher Plants", 2nd ed. Academic press. London, p. 196, 1995.
- [5] R.L. Yadav, N.L. Sen, B.L. Yadav, "Response of onion to nitrogen and potassium fertilization under semi-arid condition". Indian J. Hort., 60(2): 176-178, 2003.
- [6] Basuki, "Penelitian Daya Hasil dan Preferensi Petani terhadap varietas Bawang Merah Lokal dari Berbagai Daerah. Laporan Hasil Penelitian: APBN 2005-ROPP DI (in Bahasa Indonesia), 2009.
- [7] A. Hidayat dan Rosliani. "Pengaruh pemupukan N, P, dan K pada pertumbuhan dan produksi bawang merah kultivar Sumenep", J. Hort 5 (5): 39-43 (in Bahasa Indonesia), 1996.
- [8] R. G. Steel and J. H. Torrie, "Principles and procedures of statistics". 2nd Ed., New York, Mc. Graw-Hill Book Co. 196p, 1980.
- [9] F.I.M. Badr and G. M. El-Shebinly, "Effect of urea formulations and nitrogen rates on onion yield and quality under calcareous soil conditions". Egypt. J. Appl. Sci. 14(7): 524-534, 1999.
- [10] I. A. Yaso and H. S. Abdel-razzak, "Effect of NPK fertilization on bulb yield and quality of onion under reclaimed calcareous soil conditions", J. Agric. & Env. Sci. Alex. Univ., Egypt Vol. 6 (1), 2007.
- [11] R. M. Khalil, A. A. Midan and O. S. Abu-Grab, "Adaptation of some onion cultivars under middle Delta conditions in relation to nitrogen fertilization. I- Growth, bulbing behaviour and nutritional status", Minufiya J. Agric. Res. 13(1): 157-178, 1988.
- [12] Suwandi and Y. Hilman, "Penggunaan Pupuk Nitrogen dan Triple Super Phosphate pada Bawang Merah". Bul. Penel. Hort. XXII(4) (in Bahasa Indonesia), 1992.
- [13] N. Suwela, "Pengaruh Dosis Nitrogen dan Pupuk Kandang Sapiterhadap Pertumbuhan dan Hasil Bawang Merah (*Allium Ascalonicum* L.) di Lahan Kering, di Desa Songan, Kabupaten Bangli" (tesis). Denpasar: Universitas Udayana, 2005.
- [14] B. Messele, "Effects of nitrogen and phosphorus rates on growth, yield, and quality of onion (*Allium cepa* L.) at Menschen Fur Menschen Demonstration site, Harar, Ethiopia". Agricultural Research & Technology: Open Access Journal, 1 (3): 1-8, 2016.
- [15] N. Sumarni, R. Rosliani, R.S. Basuki, dan Y. Hilman, "Respon tanaman bawang merah terhadap pemupukan fosfat pada beberapa tingkat kesuburan lahan (Status P - Tanah)". J. Hort., 22(2), 2012.
- [16] A.H. Permadi, "Pemuliaan tanaman bawang merah. dalam Teknologi Produksi Bawang merah" Pusat Penelitian dan Pengembangan Hortikultura. Jakarta (in Bahasa Indonesia), 1992.
- [17] B. Pleasant, "Getting started with shallots", Growveg, 2010.
- [18] M.J. Hutchings and E.A. John, "The effects of environmental heterogeneity on root growth and root/shoot partitioning", *Ann Bot.* 94(1): 1-8, Epub 2004.
- [19] I. Arduini, A. Masoni, L. Ercoli, M. Mariotti, "Grain yield, and dry matter and nitrogen accumulation and remobilization in durum wheat as affected by variety and seeding rate", Europ. J. Agronomy 25, 309-318, 2006.