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GROWTH PERFORMANCE OF GREEN SHALLOTS FROM FIVE DIFFERENT VARIETIES IN INDONESIA

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Abstract

Shallot could be harvested and consumed as greens beside the bulb set. The objective of this current study was to evaluate the growth performance and yield of the green parts of shallot from five different varieties, *i.e.*, Bauji, Bantaeng, Rubaru, Tuk Tuk and Palasa. The experiment was carried out in a greenhouse using a randomized complete block design with three blocks as replications. The green shallots growth reached the maximum in 30 Days after Planting (DAP). Bantaeng achieved the fastest growth that was confirmed from the highest value of Net Assimilation Rate (NAR) of 1.97±0.31 mg cm^{-2} day^{-1} and Relative Growth Rate (RGR) of 0.251±0.01 mg g^{-1} day^{-1} in 10-20 DAP. Bantaeng also obtained the highest yield of green shallots based on Total Fresh Weight (TFW) of 38.49±2.76 g, Total Dry Weight (TDW) of 2.99±0.34 g and production (PRO) of 6.16 ± 0.69 tons ha^{-1} in 30 DAP. Based on the Heatmap hierarchical clustering, Bantaeng and Rubaru were classified in one cluster, which means it has a similar growth performance, while Buji, Tuk Tuk and Palasa were in the other cluster.

Key words: green shallots, growth, heatmap, varieties, production.

Introduction

Shallot is one of the two horticultural commodities that greatly influences the inflation rate in Indonesia (Bappenas, 2014). Shallot is one of the primary vegetable commodities that has been cultivated intensively for a long time. This vegetable commodity is included in an unsubstituted spice group that serves as a flavouring for food and traditional medicinal ingredients (Santas *et al.,* 2010, Mnayer *et al.,* 2014, Sachan *et al.,* 2018). Shallot is known as a rich source of phytochemicals. One of the active compounds contained in shallot as a reference for its quality are the flavonoids. Flavonoids are natural antioxidants that are widely found in plants and also in human daily food such as vegetables and fruit. It has an ability as antioxidants to prevent the harmful influence of free radicals (Tuladhar *et al.,* 2000).

In Indonesia, the shallot is commonly harvested as bulbs set. However, it also can be harvested and consumed as green vegetables although it is still unfamiliar for most people in Indonesia. The close relative of shallot, the onion, has been firstly used for its green leaves. The onion harvested in juvenile phase is called as green onions which are planted at higher densities and harvested when the plants are still green and the tubers have not been formed or have been formed but the tuber diameter is still small. The onion that is used as green vegetables can be harvested in 50-60 days after planting (Shrestha, 2016). Onion leaves contain dietary fiber and have higher iron content than its bulb. It is also rich in vitamin A and C (Yahaya *et al.,*2010, Santas *et al.,* 2010, Ogbonna *et al.,* 2016). Meanwhile, green shallots are still consumed in a limited quantity and are considered an exclusive vegetable which have a higher price compared to leeks and even the bulbs itself (Istiqomah *et al.,* 2019). However, in Indonesia, there are still no reports of shallot cultivation specifically being harvested as green shallots.

Growing leafy vegetables requires specific cultivation technique which is different from the plant

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that is harvested for its fruit or bulb. Leafy vegetables need a relatively short time to provide the harvest. The appropriate harvesting time is needed to be determined to obtain optimum yield. Early or late harvest could affect the quality and quantity of yield. The harvesting time of leafy vegetables would affect the biomass and compound contents in these vegetables. *Allium fistulosum* which was delayed in harvesting from age 60 to 120 days showed a significant increase in leaf biomass, but it was decreased in vitamin C, carotenoid, total chlorophyll, sugar, essential oil, nitrate, total N, K and Ca (Kolota *et al.,* 2012).

Shallot varieties, Rubaru and Bauji are quite popular in farmers, especially in the East Java region. Rubaru and Bauji varieties are superior varieties of shallots released by the Assessment Institute for Agricultural Technology, East Java, Indonesia. Bauji has an age between 58-60 days, while Rubaru has an age of 60-65 days after planting. Bauji's potential yield is 16 tons ha^{-1}, while Rubaru is 16 tons ha^{-1}. However, in terms of aroma, Rubaru has a stronger aroma than Bauji. Tuk Tuk variety is a variety originating from seeds that are widely cultivated from East West Seed Indonesia. This Tuk Tuk variety can be used either in direct planting or used in the production of mini bulbs. Meanwhile, in Sulawesi, Bantaeng variety is in great demand and competes to Bima variety. Bantaeng can be distinguished from Bima from its larger in size. In Central Palu, there is Palasa variety which is used as the main raw material for fried shallot industries in Palu of Central Sulawesi, which is famous for its good quality. Palasa is usually cultivated at an altitude of 500-900 m above sea level (Anshar *et al.,* 2016). The objective of this current study was to evaluate the growth performance and yield mainly of the green shallots from five different varieties in Indonesia, *i.e.,* Bauji, Bantaeng, Rubaru, Tuk Tuk and Palasa.

Materials and Methods

Site description and experimental design

The experiment was set up in polybags located in Cikabayan Greenhouse, IPB University (Latitude: -6°33′ 46″, Longitude: 106°43′ 14″, Altitude: 184 m above sea level) from November to December 2018 within an area 100 m^2 using a randomized complete block design with five varieties as treatments and three blocks as replications for each treatment. The total plant densities were 900 plants (300 plants per block). Planting media was prepared by mixing rice husk: compost: soil (1:1:1) and it contained 69% clay, 11% silt and 20% sand with pH (1:1 H_2O) 5.78, total nitrogen 0.31%, available phosphorous (P_2O_5) 158.84 ppm, potential phosphorous 141.57 mg 100 g^{-1}, potential potassium (K_2O) 366.79 mg 100 g^{-1} and 3.37% of C-organic. Planting media was added into polybags size 30×20 cm and each shallot bulb from every variety was planted (single tuber per polybag). Fertilizer was applied by hand for all varieties with dosage of 190 kg ha^{-1} of N, 92 kg ha^{-1} P_2O_5, dan 120 kg ha^{-1} K_2O.

Sampling Procedures, measurements and methods

Ten plants from each treatment in each block were signed randomly for plant height and leaf number measurement in 10, 20, 30, 40, 50 days after planting (DAP). Three plants from each treatment in each block were taken for measurements of leaf area, total fresh weight and total dry weight in 20, 30, 40 DAP. Leaf diameter was measured in 30 DAP. To calculate the leaf surface area, a digital image of pressed shallot leaf was taken using Flatbed Colour Image Scanner Epson L350 and processed by Image J (version 1.50i,). Total dry weight was determined after drying for 48 hours at 60°C. These measurements were used for growth analysis. The growth parameters or indices were calculated using the following formulas according to (Mohar and Schofer, 1985):

SLW (Specific Leaf Weight) = Lw/La (mg cm^{-2})

SLA (Specific Leaf Area) = La/Lw (cm^2 mg^{-1})

RGR (Relative Growth Rate) = (ln W2- ln W1)/(t2- t1) (mg $g^{-1}day^{-1}$)

NAR (Net Assimilation Rate) = (W2-W1)/(t2-t1) × (ln La2 - ln La1)/(La2 - La1) (mg cm^{-2} day^{-1}).

Results and Discussion

Growth indices for every individual plant

Net assimilation rate (NAR) is one of the parameters that show the growth performance of the individual plant. The net assimilation rate (NAR) from five varieties is presented in fig. 1. The highest value was achieved by Bantaeng (1.97±0.31 mg cm^{-2} day^{-1}) in early growth period (10-20 DAP), followed by Palasa (0.96±0.53 mg cm^{-2} day^{-1}), while the lowest in early growth was Bauji (1.97±0.31 mg cm^{-2} day^{-1}). NAR value for all varieties then was decreased rapidly during 20-30 DAP and 30-40 DAP. Bantaeng which first had the highest value was declined even lower than Bauji, Tuk tuk and Rubaru during 20-30 DAP. In the last period, NAR was observed in all varieties to have insignificant low NAR value.

Relative growth rate (RGR) is one of the primary components for plant growth analysis. RGR express the increase in size per unit size of the plant, a component that counts the original plant different size in plant growth. RGR value of five shallot varieties showed a similar pattern with their NAR value during the observation. The highest value of RGR was Bantaeng (0.251±0.01 mg g^{-1} day^{-1}) which was reached in early growth (10-20 DAP), followed by Palasa, Rubaru and Tuk Tuk, while the lowest

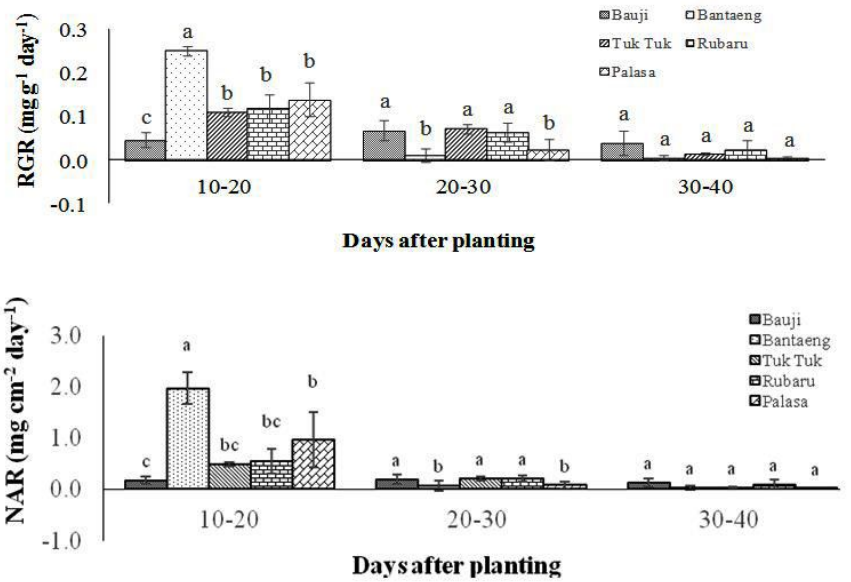


Fig. 1: Net Assimilation Rate (NAR) (a) and Relative Growth Rate (RGR) (b) of five shallot varieties during 10-20 DAP, 20-30 DAP and 30-40 DAP.

RGR during the early growth was Bauji (0.046 ± 0.016 mg g^{-1} day^{-1}).

The contrary was found in the second observation during the period of 20-30 DAP. Three varieties which were Bauji, Tuk Tuk and Rubaru showed a significantly higher value than Palasa and Bantaeng. RGR and NAR value tended to decrease during this study in line with the increase of plant age. The higher NAR and RGR expressed the faster growth of a plant and it occurred in the early phase of plant growth.

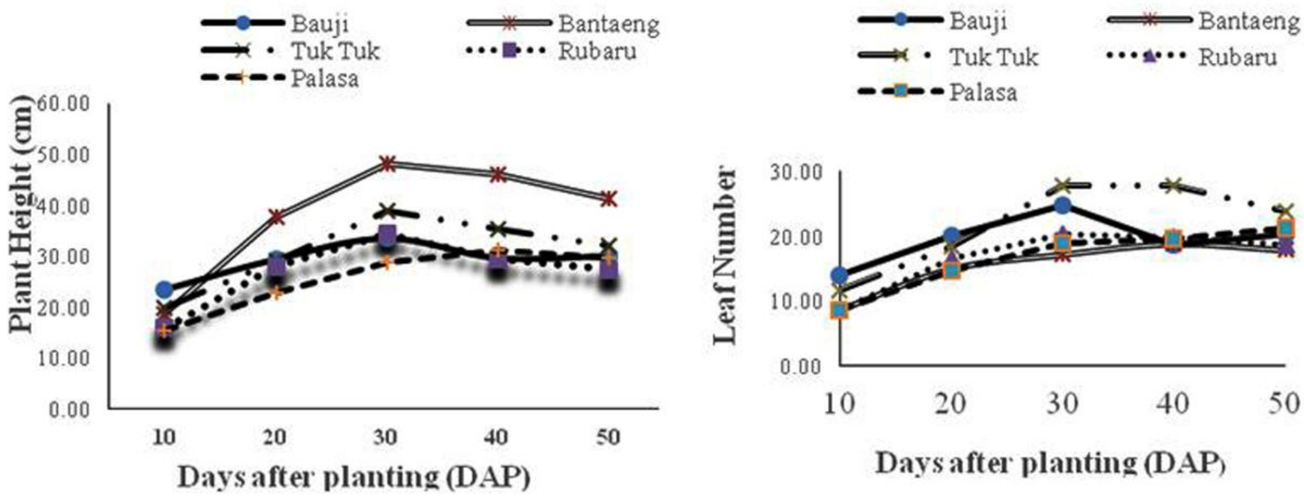
Plant growth performance is also affected by the leaf condition as showed in Specific Leaf Area (SLA) and Specific Leaf Weight (SLW) values (Table 1). SLA and SLW values are also related to the leaf thickness of shallot leaf. The value was changed during the increasing of plant ages. In the three initial observations that were taken during this experiment in 20, 30 and 40 DAP, Bantaeng obtained a significant low SLA value compared to Bauji, Tuk Tuk, Rubaru and Palasa. In contrast, SLW (leaf dry weight per unit leaf area) value showed that Bantaeng achieved the highest value in all three observation compared to other varieties. The SLW value of Bantaeng was maximum in 20 DAP. The SLW values of shallot varieties were varied during this experiment. Higher SLW and lower SLA values showed thicker leaf.

Individual leaf area is the most important parameter in plant growth analysis. It is used in many growth analysis formulas to illustrate individual plant growth performance. Leaf area value was changed during the increasing of plant age. The highest leaf area was Bantaeng in 30 DAP (544.08±1.28 cm^2), while the lowest was Palasa in 20 DAP (104.74±3.18 cm^2). Bantaeng showed the least

Table 1: Analysis of Variance for Specific Leaf Area (SLA), Specific Leaf Weight (SLW), Leaf Area, Total Fresh weight (TFW), Total Dry Weight (TDW), Production (PRO) of green shallots in 20, 30 and 40 days after planting (DAP)

Variety	SLAcm mg^{1}	SLWmg cm^{-1}	LAcm^{2}	TFWg	TDWg	PROTons ha^{-1}
20 DAP						
Bauji	0.41±0.05^{a}	2.50 ±0.33^{b}	168.75±2.69^{b}	7.19±0.69^{b}	0.49 ±0.08^{b}	1.15 ± 0.11^{b}
Bantaeng	0.14±0.02^{b}	7.45±1.22^{a}	327.21±2.38^{a}	32.18±2.36^{a}	2.71± 0.44^{a}	5.15 ± 0.96^{a}
Tuk Tuk	0.34±0.02^{a}	2.98±0.22^{b}	171.32±1.36^{b}	9.34±0.44^{b}	0.56± 0.04^{b}	1.49 ± 0.07^{b}
Rubaru	0.31±0.08^{a}	3.36±1.04^{b}	169.10±3.29^{b}	8.14±2.44^{b}	0.61 ±0.16^{b}	1.30 ± 0.39^{b}
Palasa	0.19±0.08^{ab}	6.02±0.27^{ab}	104.74±3.18^{c}	5.82±1.95^{bc}	0.62±0.19^{b}	0.93 ± 0.31^{c}
30 DAP						
Bauji	0.42±0.12^{a}	2.52±0.61^{b}	348.92±2.37^{c}	13.86±0.64^{b}	0.98±0.22^{b}	1.15 ± 0.11^{b}
Bantaeng	0.21±0.02^{b}	4.85±0.53^{a}	544.08±1.28^{a}	38.49±2.76^{a}	2.99±0.34^{a}	5.15 ± 0.96^{a}
Tuk Tuk	0.43±0.05^{a}	2.36±0.29^{b}	447.50±4.71^{b}	17.07±2.50^{b}	1.17±0.14^{b}	1.49 ± 0.07^{b}
Rubaru	0.36±0.04^{a}	2.83±0.33^{b}	353.99±1.65^{c}	15.01±1.48^{b}	1.13±0.13^{b}	1.30 ± 0.39^{b}
Palasa	0.42±0.07^{a}	2.40±0.37^{b}	286.20±3.72^{d}	8.34±1.02^{c}	0.76±0.10^{b}	0.93 ± 0.31^{c}
40 DAP						
Bauji	0.24±0.02^{b}	4.13±0.33^{c}	321.79±1.54^{c}	18.33±1.66^{b}	0.93±0.12^{b}	2.22 ± 0.10^{b}
Bantaeng	0.18±0.01^{c}	5.43±0.32^{a}	472.71±2.23^{a}	37.07±4.04^{a}	2.83±0.27^{a}	6.16 ± 0.69^{a}
Tuk Tuk	0.40±0.04^{a}	2.52±0.22^{d}	452.46±1.61^{ab}	19.80±1.04^{b}	1.23±0.08^{b}	2.73 ± 0.40^{b}
Rubaru	0.22±0.03^{bc}	4.57±0.55^{b}	284.32±1.64^{d}	18.14±1.04^{b}	1.42 ±0.17^{b}	2.40 ± 0.24^{b}
Palasa	0.43±0.08^{a}	2.38±0.45^{d}	283.83±2.32^{d}	8.38±0.91^{c}	0.74 ±0.13^{b}	1.33 ± 0.16^{c}

*Means within a column followed by the same letter are not significantly different at $p \leq 0.05$, and the different letters are significantly different at $p \leq 0.05$.



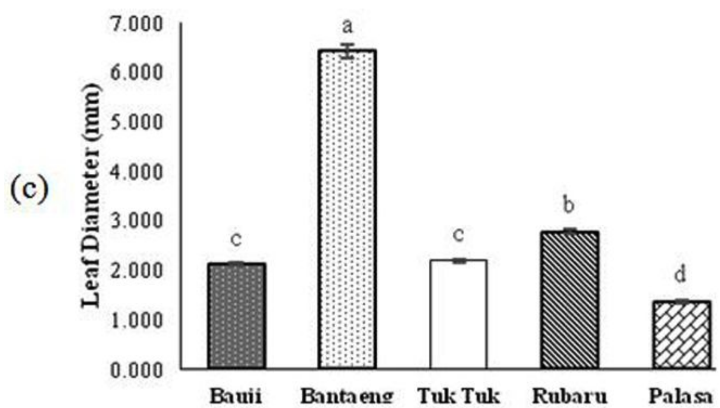


Fig. 2: Plant height (a), leaf number (b) and leaf diameter in 30 DAP (c) of five shallot varieties

increasing in leaf area from 20 to 30 DAP, it was only increased about 66.28%. Leaf area of Bauji, Tuk Tuk, Rubaru and Palasa were increased more than 100% within 10 days from 20 DAP to 30 DAP. Nevertheless, the leaf area values of most varieties were decreased from 30 to 40 DAP, except for Tuk Tuk variety.

The growth of five shallot varieties showed differences in plant heights at each observation time. Plant height of the five varieties tested in this experiment was average a peak in 30 DAP and then began to decrease due to plants started to switch from the vegetative phase to the generative phase, except for the Palasa variety which tended to be stable until the end of the observation. (Fig. 2a) shows that in 30 DAP, Bantaeng achieved the highest plant height (48.09±5.12 cm), while Palasa showed the lowest plant height (26.68±1.48 cm) of all varieties. Plant height is one of the plant growth variables that can be observed as a differentiator of each variety. Plant height, in general, is also strongly and genetically influenced and inherited (Dangi *et al.,* 2018).

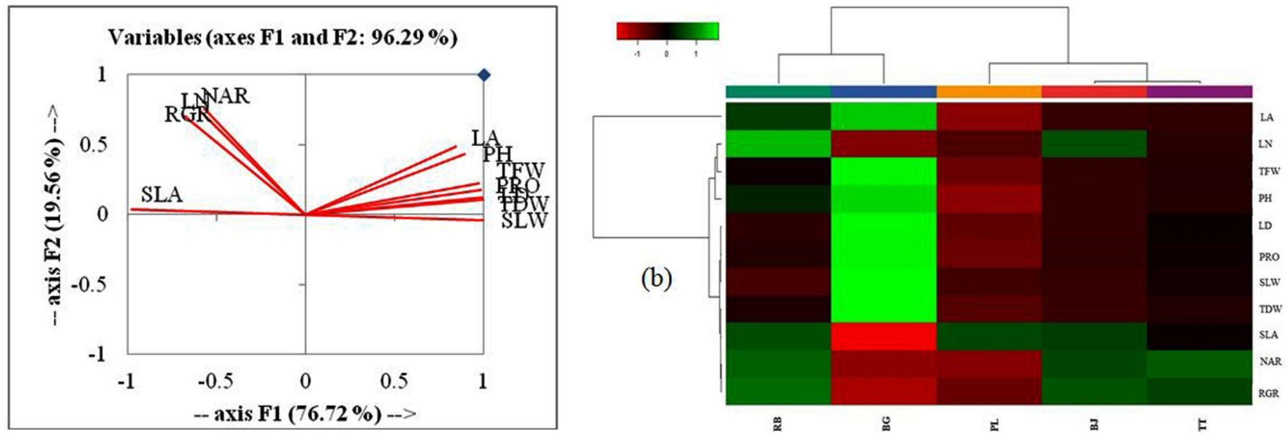
The leaf number was observed by counting the number of leaves that have appeared perfectly in one clump of shallot. Most of leaf number was known to increase from the beginning of planting to 30 DAP which it tended to be constant and then was decreased except for the Palasa which still showed a slight increase until the end of the observation. The leaf number reached the maximum in 30 days after planting (Fig. 2b). In 30 DAP, Tuk Tuk achieved the highest leaf number (27.77±0.71), while the lowest was Bantaeng (17.23±1.25). The number of leaves was increased rapidly at the beginning of plant growth and then became stable after reaching a particular time in growth as a sign that the plant has experienced a slowdown in growth (Deshi *et al*., 2018). The leaf number is an essential factor in achieving optimal production from plants (El-Magd *et al.,* 2013).

Leaf diameter also showed differences among the varieties. Bantaeng leaf diameter (6.43±0.14 mm) was significantly bigger than of Rubaru, Bauji, Tuk Tuk and the smallest was Palasa (1.36±0.03 mm). Leaf size, including leaf diameter, is thought to affect the photosynthesis process that occurs in plants. The bigger diameter of the leaf will provide the bigger surface area of the leaf to absorb CO_2. Large leaf diameters also indicates a higher photosynthesis activity and accumulation of dry weight than leaves which have smaller leaf diameter sizes (Ávila-Lovera *et al.,* 2019). Onion plants with 24 different varieties planted in Bengal India have diverse plant height and leaf diameter. Plants with a more extended leaf size may not necessarily have a larger leaf diameter. The length and diameter of the leaves change with increasing age (Behera *et al.,* 2017).

Production of green shallots

Green shallots are bought mainly for its weight, thus the yield of leafy vegetables is assumed from its fresh weight. Green shallots are sold as the whole plant, including root. Therefore, total fresh weight and total dry weight are essential to be determined. As shown in table 1. Total fresh weight of five shallot varieties was varied

(a)



(b)

Fig. 3: PCA of growth parameters (a) and Heatmap hierarchical clustering (b) presenting Pearson's correlations between shallot varieties and growth parameters. LA, leaf area; LN, leaf number; TFW, total fresh weight; PH, plant height; LD, leaf diameter; PRO, production; SLW, specific leaf weight; TDW, total dry weight; SLA, specific leaf area; NAR, net assimilation rate; RGR, relative growth rate. The name of varieties: RB, Rubaru; BG, Bantaeng; PL, Palasa; BJ, Bauji; TT, Tuk tuk.

explain: 88.70 % of the total data variance (Fig. 3). As observed, PC1 explained 70.98 % of the total variance whilst PC2, explained only 17.71 % of explain 88.70 % of the total data variance (Fig. 3). As observed, PC1 explained 70.98 % of the total variance whilst PC2 explained only 17.71 % of

during the observation. Bantaeng achieved the highest total fresh weight in 30 DAP (38.49±2.76 g), followed by Tuk Tuk, Rubaru and Bauji. Although Bantaeng had the highest total fresh weight value in 30 DAP, it was only increased about 18.58% from 20 DAP, while the other varieties were increased about more than 80% from 20 DAP such as Bauji (92.9%), Tuk Tuk (82.73%), Rubaru (84.47%) and Palasa (43.19%). Bantaeng total fresh weight was declined in 40 DAP, while other varieties were still increased. This could happen because Bantaeng started to form bulbs set. The production of green shallots is shown in table 1. Bantaeng obtained the highest production started from 20 DAP of 5.15 ± 0.96 tons ha^{-1}, which is five-time higher than the other varieties which only reached 0.93 to 1.49 tons ha^{-1}. Varieties play key roles in plant production. Shallot has a lot of varieties that have been produced based on the environmental characteristics, in which some varieties are suitable for the low land such as Tuk Tuk and Bauji and some others are suitable for high land such as Palasa. Season and altitude also give an impact to the shallot growth and production, especially for the bulbs. Some varieties have good production at high land area, while others achieved their best production at low land area (Idhan *et al.,* 2015).

Identification of key parameters and correlation between the growth parameters of five shallot varieties

Principal component analysis (PCA) was performed to evaluate the contributions of each parameter to differences within the shallot varieties. According to the data analysis of the five varieties, two principal components of F1 and F2 explained 96.29%. As observed, F1 explained 76.72% of the total variance, while F2 explained only 19.56% of the total variance which showed that the disparity among the variety was described by the F1. The PCA result showed that the production of green shallots has close relations with leaf area, plant height, total fresh weight, leaf diameters, total dry weight and specific leaf weight which means those parameters positively supported the production of green shallots, since those parameters were at the same quadrant. Furthermore, the production of green shallots has not related to net assimilation rate, leaf number, relative growth rate and specific leaf area.

Significant differences in plant growth parameters (identified through ANOVA) were analyzed by Heatmap hierarchical clustering in order to visualize the different growth performance in five different varieties. Two clusters were identified in varieties, in which Bantaeng and Rubaru were in the same cluster, while Tuk Tuk, Bauji and Palasa were in the other one. High growth performance of Bantaeng was characterized by the high value of leaf area, total fresh weight, plant height, specific leaf weight, leaf diameter and total dry weight. It was followed by Rubaru, although it was not as high as Bantaeng. The other three varieties, which are Tuk Tuk, Bauji and Palasa showed a lower value for most plant growth parameters that classified them into one cluster. Leaf area was the growth parameters that provide the highest contribution in the differences among the varieties.

The process of plant growth is very important to be studied in order to optimize crop production. The process of plant growth can be examined through plant growth analysis. Plant growth analysis is a quantitative approach used to understand the growth of individuals and plant populations both in natural and controlled environments. At the same time, growth analysis helps researchers to obtain important information in order to manipulate growth that leads to optimum crop production. Growth analysis is widely used to study the factors that influence the development and yield of plants by observing the accumulation of dry weights over a certain period (Jerez *et al.,* 2016).

Conclusions

Plant growth performance provides initial information to optimize the cultivation technique in term to achieve the maximum yield of green shallots. The green shallots reached the maximum growth in 30 DAP based on the plant height. Bantaeng achieved the fastest growth compared to Bauji, Tuk Tuk, Rubaru and Palasa. Bantaeng also obtained the highest yield of green shallots based on total fresh weight, total dry weight and production. PCA shows that several growth parameters such as leaf area, plant height, total fresh weight, total dry weight, leaf diameter and specific leaf weight had close relations in term to support the growth and yield of green shallots, while those parameters had least relations with net assimilation rate, leaf number, relative growth rate and specific leaf area. The variance analysis of plant growth parameters using Heatmap hierarchical clustering classified two clusters among tested varieties. Bantaeng and Rubaru were in one cluster, while Bauji, Tuk Tuk and Palasa were in the other cluster and leaf area had the highest contribution in this clustering. The varieties in the same cluster have a similar growth performance.

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