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Research Article

Differences in Cultivation Methods and Their Effects on Production and Physiological Characteristics of Shallots in the Highlands

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Abstract

Background and Objective: The productivity and quality of shallots from true shallot seeds are highly dependent on site-specific cultivation methods and the selection of appropriate varieties. The objective of the research was to evaluate the cultivation method and selection of the best varieties in the highlands to increase the productivity and physiological characteristics of shallots from TSS. **Materials and Methods:** The study took place on community land in Sempajaya, Berastagi, Tanah Karo Regency in June-September, 2022, using a factorial randomized block design. The first factor is the variety of shallots from tubers (Lokananta and Sanren F1) and the second factor is the difference in the method of cultivating shallots from TSS in the highlands. **Results:** Growth, production and chlorophyll content of the Lokananta variety were higher than Sanren F1. The shallot cultivation method recommended by seed suppliers is the best. The interaction between the Lokananta variety and the cultivation method of the seed supplier increased the growth and production of shallots from TSS. **Conclusion:** The dry weight of tubers increased by 9.84% on the use of the seed supply method when compared to the recommendation for double production. The use of the Lokananta variety increased tuber weight per plot (1 $\times$ 1 m) by 39.28% compared to Sanren F1.

Key words: True shallot seed, variety, highland, physiological character, production, chlorophyll content, stomatal density, cuticle thickness

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The use of TSS as a seed source has several advantages over tubers, including low seed requirements, low cost of supply (seed requirement ±7.5 kg ha^{-1} than tubers ±1.5 tons/ha), easier seed storage and long seed shelf life (1-2 years) so that it is flexible, can be planted when needed, is easy and cheap to distribute, variety of seed quality is low and productivity is high (up to 26 tons/ha)[1].

To increase the productivity and quality of location-specific shallots in the highlands, appropriate cultivation methods and the use of varieties are needed. The use of seeds from TSS is believed to increase crop yields because of the advantages of TSS, namely the volume of seeds is less, the yield of tubers is doubled (production of 26 tons/ha), the shelf life of seeds is longer (1-2 years), cheaper transportation, cost, easier storage, stronger and healthier because it is virus free, tubers are bigger[2].

Research on TSS shallot cultivation methods and varieties suitable for specific locations in the highlands is still very limited. Previous studies have studied the role of the cultivation method of TSS at lowlands[3,4], growth and yield of different varieties of TSS on highland in West Sumatra[5], the response of shallot from TSS on the application of sulfur and paclobutrazol[6], the effect of ecoenzyme[7], characteristics of shallot in highland and lowland[8], genetic diversity of shallot in North Sumatera[9] and evaluation of TSS for yield and yield components[10].

Based on the background, the objective of the study was to evaluate the best cultivation methods under highlands conditions on the production and physiological characteristics of shallot from TSS.

MATERIALS AND METHODS

Time and location: The research was conducted on the community land of Berastagi with an altitude of ±1276 m above sea level from June to September, 2022. The materials used were the seeds of two varieties of shallots (Lokananta and Sanren F1) as planting material, ZA fertilizer, NPK fertilizer, KCl fertilizer, SP-36 fertilizer, manure, Furadan 3G, *Trichoderma harzianum*.

This research uses tools in the form of silver plastic black mulch, hoe, meter, seedling media, analytical scale, treatment label, spectrophotometer and camera.

Research design: The design used in this study was a factorial randomized block design with 2 factors and 3 repetitions. The first factor is variety, namely V1 = Lokananta and V2 = Sanren F1. The second factor is the TSS cultivation method, namely C1: Treatment from supplier recommendations, C2: Modification of seed recommendations with the addition of paclobutrazol, C3: Modification of double production with the addition of paclobutrazol and C4: Recommendations for double seed recommendations (Table 1).

Procedures: The bed for the nursery measuring 1×1.5 m was made. The application of manure in the amount of 1 kg/bed was carried out when cultivating the soil. ZA fertilizer application of 100 kg/ha was carried out when the seeds will be sown. Seeding takes 35-40 days, plant care should be carried out intensively during seeding.

Land preparation for planting shallots is carried out before transplanting by cultivating the soil to a depth of 20 cm. Planting plots measuring 100×100 cm were made according to the number of treatments. The distance between blocks is 50 cm while the distance between the plots is 30 cm. Application of basic fertilizer in the form of SP-36 250 kg ha^{-1} was carried out at planting. *Trichoderma harzianum* (100 kg ha^{-1}) was applied a week before planting by dissolving in water and watering each treatment plot. Silver plastic black mulch is installed and then perforated according to the spacing.

Seedlings were transplanted in the field at 35 days after sowing, with 1 seedling/planting hole, spacing according to treatment (10×10×10×15 cm). The criteria for ready-to-plant seeds were studied, the colour of the seeds was fresh green and has 4-6 leaves. Fertilizer application is carried out according to the treatment dose.

Watering is done 2 times a day (morning and evening) in dry conditions (no rain). However, if there is rain, watering is only done once, namely in the morning or evening, according to needs. Weeding weeds once a week so that the plant roots are not disturbed. Pest control is done manually. Meanwhile, disease control was carried out by spraying fungicides with a concentration of 2 cc/L in the field.

If the plant has shown the harvest criteria, it can be harvested. Harvesting is done in the morning with sunny conditions, by planting carefully so that the stems are not broken and the tubers are not left in the soil. The harvest criteria have the characteristics of the upper leaves turning yellow, the tops of the plants starting to fall, the tubers already looking solid and appearing partially above the ground and the skin colour already shiny. After removal, the tubers were collected and cleaned from the soil.

Data analysis: The data were analyzed utilizing variance and continued with Duncan's Multiple Distance Test at $\alpha = 5\%$, if there is a significant effect.

RESULTS

Number of bulbs per plant: The treatment of varieties, cultivation methods and their interactions had no significant effect on the number of bulbs per plant (Table 2). The Sanren F1 variety tends to have more tubers per sample than Lokananta. The C4 treatment produced the higher number of bulbs per plant, while the M2 treatment produced the lowest number of bulbs per plant. The combination of the M4 treatment and Sanren F1 variety had more leaves than the other treatment combinations.

Wet weight and dry weight of bulbs per plant: Varieties, cultivation methods and their interactions have a significant effect on the wet weight and dry weight of bulbs per plant. The Lokananta variety had higher wet weight and dry weight of bulbs per plant than Sanren F1. The C11 cultivation method produced higher wet-weight and dry-weight bulbs per plant than other cultivation methods. The interaction between Lokananta and the M1 cultivation method resulted in the highest wet weight and dry weight of bulbs per plant (Table 2).

Dry weight of bulbs per plot: Varieties, cultivation methods and their interactions have a significant effect on the bulb's dry weight per plot. The Lokananta variety produced a higher tuber dry weight of bulbs per plot than Sanren F1. The M1 cultivation method resulted in a higher dry weight of bulbs per plot than other cultivation methods. The interaction between Lokananta and the M1 cultivation method resulted in the highest dry weight of bulbs per plot (Table 3).

Chlorophyll content: There are only varieties that significantly affect the content of chlorophyll a, chlorophyll b and total chlorophyll. While the cultivation method and the interaction between cultivation methods and varieties had no significant effect on the content of chlorophyll a, chlorophyll b and total chlorophyll. Lokananta variety has higher chlorophyll a, chlorophyll b and total chlorophyll content than Sanren F1. The interaction between the Lokananta variety and the M4 cultivation method tends to increase total chlorophyll when compared to other treatment combinations (Table 4).

Stomatal density and cuticle thickness: Based on Table 5, it can be seen that the interaction of treatment between varieties and shallot cultivation methods in the highlands had a significant effect on stomatal density. In the Lokananta variety, the M4 cultivation method produced the highest number of stomata (97.48 units/mm^2), while in the Sanren F1 variety, the M1 cultivation method produced the highest number of stomata (126.83 units/mm^2). F1 in the highlands tends to have a higher number of stomata when compared to Lokananta.

Table 1: Treatment of cultivation methods of shallot varieties in lowlands

Treatment	Paclobutrazol (ppm)	An organic fertilizer (WAT) -7	7	14	21	28	42	Spacing (cm)
C1	0		ZA 150 kg ha^{-1}	NPK (16-16-16) 200 kg ha^{-1}		NPK (16-16-16) 250 kg ha^{-1}	NPK (16-16-16) 250 kg ha^{-1} KCl 187.5 kg ha^{-1}	10×10
C2	15	NPK (16-16-16) 500 kg ha^{-1}			NPK (15-15-15) 150 kg ha^{-1} ZA 150 kg ha^{-1}		NPK (15-9-20) 150 kg ha^{-1}	10×15
C3	15		ZA 150 kg ha^{-1}	NPK (16-16-16) 150 kg ha^{-1}		NPK (16-16-16) 200 kg ha^{-1}	NPK (16-16-16) 200 kg ha^{-1} KCl 150 kg ha^{-1}	10×15
C4	0	NPK (16-16-16) 500 kg ha^{-1}			NPK (15-15-15) 200 kg ha^{-1} ZA 150 kg ha^{-1}		NPK (15-9-20) 200 kg ha^{-1}	10×10

Table 2: Number of bulbs per plant of two shallot varieties with different cultivation methods in highlands

Variety	Cultivation method C1	C2	C3	C4	Mean
	.... bulb				
Lokananta (V1)	3.47	3.63	3.87	3.00	3.49
Sanren F1 (V2)	3.53	3.20	3.27	2.63	3.16
Mean	3.50	3.42	3.57	2.82	

Numbers followed by the same letters show no significant difference according to Duncan's Multiple Range Test at the level of α = 5%

Table 3: Bulbs production and harvest index of two shallot varieties from TSS with different cultivation methods

		Cultivation method				
Variable observed	Variety	C1	C2	C3	C4	Mean
Wet weight of bulb/plant (g)	Lokananta (V1)	41.1	53.4	54.4	39.0	47.0[a]
	Sanren F1 (V2)	31.8	33.7	32.2	28.9	31.6[b]
	Mean	36.4[bc]	43.6[a]	43.3[ab]	34.0[c]	
Dry weight of bulb/plant (g)	Lokananta (V1)	30.49	41.69	40.11	30.63	35.73[a]
	Sanren F1 (V2)	21.70	24.22	21.07	19.94	21.73[b]
	Mean	26.09	32.96	30.59	25.28	
Dry weight of bulb/plot (g)	Lokananta (V1)	3360	2313	2419	2922	2754[a]
	Sanren F1 (V2)	2022	1482	1254	1930	1672[b]
	Mean	2691[a]	1898[bc]	1836[c]	2426[ab]	

Numbers followed by the same letters and variable observed show no significant difference according to Duncan's Multiple Range Test at the level of α = 5%

Table 4: Chlorophyll content of two shallot varieties from TSS with different cultivation methods

		Cultivation method				
		C1	C2	C3	C4	
Variable observed	Variety	mg/g of fresh weight				Mean
Chlorophyll-a	Lokananta (V1)	22.70	19.86	18.67	32.79	23.50[a]
	Sanren F1 (V2)	21.79	10.06	8.61	13.68	13.53[b]
	Mean	22.24	14.96	13.64	23.24	
Chlorophyll-b	Lokananta (V1)	25.26	7.57	5.38	28.88	16.77[a]
	Sanren F1 (V2)	14.87	7.72	5.33	13.97	10.47[b]
	Mean	20.06	7.65	5.35	21.42	
Total of chlorophyll	Lokananta (V1)	47.95	27.43	24.05	61.67	40.28[a]
	Sanren F1 (V2)	36.65	17.78	13.94	20.78	22.29[b]
	Mean	42.30	22.61	18.99	41.22	

Numbers followed by the same letters and variable observed show no significant difference according to Duncan's Multiple Range Test at the level of α = 5%

Table 5: Stomatal density and cuticle thickness of two shallot varieties from TSS with different cultivation methods

		Cultivation method				
Variable observed	Variety	C1	C2	C3	C4	Mean
		unit/mm^2				
Stomatal density	Lokananta (V1)	53.46[c]	92.24[ab]	75.47[bc]	97.48[a]	79.66
	Sanren F1 (V2)	126.83[a]	81.76[bc]	83.86[bc]	84.91[bc]	94.34
	Mean	90.15	87.00	79.66	91.19	
		µm				
Cuticle thickness	Lokananta (V1)	12.33	9.80	11.38	11.89	11.35
	Sanren F1 (V2)	10.46	12.31	12.66	11.79	11.80
	Mean	11.39	11.05	12.02	11.84	

Numbers followed by the same letters show no significant difference according to Duncan's Multiple Range Test at the level of α = 5%

Varieties, cultivation methods and interactions between the two had no significant effect on cuticle thickness. There is a tendency that the cuticle thickness of the Sanren F1 variety in the highlands to be thicker than that of Lokananta. In the Lokananta variety, the M1 cultivation method tends to produce thicker cuticles, while in the Sanren variety, the thicker cuticle was found in the M2 cultivation method.

DISCUSSION

The high wet weight of tubers per plant, dry weight of tubers per plant and dry weight of tubers per plot have proven that the Lokananta variety can adapt well in the highlands. This was also in line with previous research that Lokananta also produces higher production in the lowlands[8]. This means that Lokananta can adapt better in the highlands and lowlands when compared to the Sanren F1. The interaction between Lokananta and the M1 cultivation method, at the highest dry weight of tubers per plot (Table 4), proved that in selecting the shallot cultivation method from TSS in the lowlands, the M1 method can be used with the selected variety Lokananta.

In plants, photosynthesis is the most important source of energy for plant growth. In photosynthesis, chlorophyll is an important pigment. There are 3 main stages of photosynthetic reactions, namely (1) primary reactions, (2) photosynthetic electron transport and photophosphorylation and (3) carbon assimilation. In the primary reaction, chlorophyll a) and chlorophyll b is needed. The wavelengths absorbed by chlorophyll a and chlorophyll b are different, i.e. chlorophyll a mainly absorbs red-orange light and chlorophyll b mainly absorbs blue-violet light, which leads to the assumption that the total amount of leaf chlorophyll content (Chl a+b) and allocated ratio (Chl a/b) directly affects the photosynthetic capacity of plants[11].

Chlorophyll a, chlorophyll b and total chlorophyll in Lokananta were higher than Sanren F1. The highest content of chlorophyll a, chlorophyll b and total chlorophyll was found in the M1 method. This is related to the administration of 700 kg ha^{-1} of NPK in the M1 method. N contained in NPK plays an important role because nitrogen is an element essential in various plant-making compounds including the constituent elements of chlorophyll. There are two kinds of chlorophyll a with the molecular formula $C_{55}H_{72}O_5N_4Mg$ and chlorophyll b with the molecular formula $C_{55}H_{70}O_6N_4Mg$. Chlorophyll is a pigment that works as an antenna, collecting light as well as the transfer of energy to the reaction centre in the process of photosynthesis. Chlorophyll a plays a direct role in a reaction that converts radiant energy into chemical energy and absorbs and transports energy to the reaction centre molecular. Meanwhile, chlorophyll b works as an absorber of radiant energy which then opens chlorophyll a. Many studies have reported the relationship between nutrient N supply and the rate of photosynthesis. Photosynthesis rate will decrease under N nutrient stress conditions[12,13].

Stomata in plants act as a means of CO_2 exchange in physiological metabolic processes, evaporation tools and related production processes. The stomata mechanism that opens and closes automatically has the opportunity to enter organisms that play a role in the process of plant pathogenic fungal infections. The greater the density of the stomata, the greater the chance of infection[14,15].

The research implications are very useful for determining the best varieties and cultivation methods and their effects on the physiological characteristics of shallots.

CONCLUSION

The Lokananta variety has higher growth, production and chlorophyll content than Sanren F1. There was an increase in tuber dry weight of 9.84% in the use of the seed supply method when compared to the recommendation for double production. There was an increase in tuber weight per plot (1×1 m) by 39.28% in the use of the Lokananta variety when compared to Sanren F1.

SIGNIFICANCE STATEMENT

The results of this study have found findings regarding the interaction between cultivation methods and shallot varieties and their impact on the production and physiological characteristics of shallot varieties from TSS in the highlands. The urgency of this research is very useful for shallot farmers in the highlands in using good agricultural practices for shallot cultivation in the highlands. A new theory was found in this study, namely, the recommended cultivation method of seed providers increased the dry weight of bulbs by 9.84%. There was an increase in tuber weight per plot (1×1 m) by 39.28% in the use of the Lokananta variety when compared to Sanren F1.

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