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Double Production of Shallot (*Allium cepa L var. aggregatum*) based on Climate, Water, and Soil Management in Sandy Land

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***Abstract*—The objective of this study was to double production by True Shallot Seed (TSS) in sandy land agro-ecosystems, widely adapted especially in temperate climate regions. Even though vegetative planting has been carried out using tubers in rice fields and dry land in Indonesia, not much has been done on sandy land. Another research gap also presents from the considerably low actual productivity (10-15 t ha^{-1}) that still can be doubled (>20 - 30 t ha^{-1}) in sandy land. The study used three varieties (Lokananta, Bima, and Trisula) and carried out in three stages: characterization and identification of soil biophysical properties, an in-site study of the seed nursery system of TSS, and an assessment of cultivation development based on plant populations increasing production. This study resulted in TSS productivity 30.66-236.00% higher than average national productivity for all three varieties; this is a novel finding. TSS productivity on sandy land ranging from 14.831 to 28.178 t ha^{-1} was above the national average production at 10.48 t ha^{-1} of bulb-seed originated shallots. Thus, this result indicates that TSS seed planting system is more profitable, particularly for shallot seed producers (traders and farmers), aside from saving transportation costs. Another benefit is supporting planning and agronomy development, especially the progress of planting shallot from seeds in Indonesia.**

***Keywords*— Shallot; TSS; nursery; production; varieties; sandy land**

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I. INTRODUCTION

Genus Allium consists of more than 50 species [1], including Shallot (*Allium cepa L. var. aggregatum*), which is closely related to onion (*Allium cepa L. var. cepa*) [2], a biennial plant and a versatile vegetable that can be eaten fresh or processed. It is a commodity inseparable from people's daily lives worldwide, including in Indonesia [3]. Shallot's role in daily life includes uses as a cooking spice, consumer goods, or processed food [4]. Its pungent aroma and unique flavor are a noted quality for culinary [2]. Aside from that, the shallot is also known for having biomedical importance [5]. Shallot can be used to treat certain diseases as a traditional medicine because they contain antiseptic compounds with anti-microbial properties, including bacteria, so they function to cure diseases caused by bacteria [6].

Shallot's important value in Indonesia is proven yearly with consumption increases [7] and price fluctuations [8]. Shallot production reaches 7.21% of the total vegetable produced in Indonesia, ranking third after cabbage and potatoes. As a result, shallot per capita consumption also increases from 2.49 kg in 2014 to 2.71 kg [9]. However, if it is not handled properly, this consumption increase can be a problem considering it's a non-substituted commodity in Indonesia [10].

The average shallots harvest area from 2014-2018 in Indonesia reached 141.483 ha, increasing 10.11% each year [11]. The need for shallot bulb seed is 1.200 kg ha^{-1} [12] which can only be met 120,830,000 kg (16.0-17.8%) each year by local bulb seed production [13]. As a consequence, imported shallot bulb seeds reaches 6,330 tons [14]. A report

[15] stated that farmers in Indonesia are highly dependent on imported seeds such as the Super Philip and Thailand, India, and Vietnam variety that has inadequate purity, poor germination, and not very adaptable [16]. Therefore, shallot bulb seed shortage prompted true shallot seed (TSS) usage introduction to farmers.

Bulbs seed posed some problem as planting material [12]: it is expensive, voluminous and difficult to transport, and suffers postharvest losses in storage [17]. On the other hand, planting shallots from bulb seed resulted in low resistance to disease caused by an accumulation of tuber-borne pathogens and viruses, which decreased productivity [18], and caused low production [5]. TSS's use for cultivation has not been widely practiced in Indonesia[19], including in Yogyakarta Province, Indonesia. As an alternative planting material, TSS also comes with some shortcomings, such as a small number of tillers (1-2) per clump and large-sized tubers that are not favored by the market in Indonesia. From previous research, planting TSS with 10 x 10 cm^2 spacing in one hole was difficult for farmers to establish.

However, TSS possesses advantages compared to bulb seed, such as higher productivity, healthier plants, higher seed use efficiency, relatively long shelf life, easier handling in warehouses, and easier distribution [20]. Bulb seed provision costs about 40% of the total production costs, which is considerably high [21]. Previous research has stated that shallot cultivation from TSS has a higher production potential (>40 t ha^{-1}), is healthier, and has no accumulation of tuber-borne pathogens (bacteria, fungi, and viruses). Bulb seed also carries fungal diseases (e.g., *Fusarium spp.*) and latent viruses inherited by the next generations. [22].

TSS needs per hectare area are only about ±2.5-4 kg and cost about IDR ±9-12 million. TSS also resulted in an efficiency of 49.107 billion (43.8%) compared to using tuber seeds [23], [24]. Similar results were reported [25], with 63% savings from TSS use.

TSS's performance as propagation material for shallot production has been studied before. However, TSS-originated shallot production in sandy land has not been much explored. Table 1 details previous TSS studies and their difference from this study. As seen in the agro-ecosystem zone, this study is the first to research shallot production from TSS in the sandy land agro-ecosystem. The objective of this research was to double shallot production by planting the TSS-originated shallots in a sandy land agro-ecosystem in Yogyakarta, Indonesia. Aside from the new agro-ecosystem, this research also uses novel spacing of 20 x 20 cm with planting more seeds (4, 5, and 6 seeds) per hole (a seedling requirement for each spacing is 600,000, 700,000, and 800,000 seedling ha^{-1}) in a sandy land area.

TABLE I
COMPARISON OF THE DIFFERENCES BETWEEN THE STATE OF THE ART PREVIOUS RESEARCH AND THE RESEARCH CONDUCTED

Author	Seed planting system	Zonal Agroecosystem	Addressing TSS-originated shallot production in sandy land
Sembiring et al. [26]	TSS	Altitude 1,000-1,500 m above sea level in Tobassa Regency, North Sumatera; Batu Regency, East Java; and Karanganyar Regency, Central Java	No
Istiqomah et al. [13]	TSS	In a plastic house (greenhouse) low land	No
Makhziah et al [25]	TSS mini bulb	Karang plosa, East Java Altitude 1017 meters above sea level.	No
Wijoyo et al Wibowo [27]	TSS twisted disease with salicylic acid application	Faculty of Agriculture's farm, laboratory of technology, and laboratory of plant production management in Gadjah Mada University, Yogyakarta.	No
Swastika et al. [20]	TSS	Riau Province, Kampar District in the lowland	No
Saidah et al. [19]	TSS	In Wuasa Village, North Lore Sub-district, Poso District, in 1083.7 meters above sea level.	No
Khoyriyah et al. [28]	TSS (F1) mini bulb	Shallots mini tubers True Shallot Seed in Grobogan Regency, in the lowland	No
Widiarti et al. [29]	TSS	At Experimental Farm, Faculty of Agriculture, Muhammadiyah Jember University, in the lowland	No
Sudaryono [21]	TSS of two shallot varieties (Trisula and Biru Lancor),	In the lowland located at Pelem Village, Pare District, Kediri Regency, East Java. Using 12.5 x 15 cm spacing, planting one seed per hole in beds.	No
This research (2018-2021)	TSS three variety (Bima, Trisula and Lokananta)	In soil sand or dry land agro-ecosystem, spacing 20 x 20 cm, with 4, 5 and 6 seeds per hole, and plant density of 600,000, 700,000 and 800,000 plants ha^{-1}	Yes

Thus, the present study aims to develop a feasible TSS-originated shallot farming system by analyzing the land suitability, nursery system (with and without rain cover or shelter), and shallot on farm production (with two factors: TSS varieties - *Bima, Trisula, Lokananta*, and plant density), that can be reproduced on soil family type of *Typic Psammaquents* in Yogyakarta, Indonesia.

II. Material and Methods

A. Location and Time

The research was carried out on the sandy land of the "Manunggal" Farmer Group in Srigading Village, Sanden District, Bantul Regency, Yogyakarta Province, Indonesia, with soil classified as *Typic Psammaquents* soil family. The study was implemented in three stages: The first one was the characterization and identification of the soil biophysics properties on 1-5 May 2018. The second stage was an in-site study of the TSS nursery system. Seeds were sown at the nursery on May 10, 2018, and planted on June 20, 2018. The third one was the assessment of shallot on farm production from May 21 - August 10, 2018, based on plant populations to increase production with a target of 40 t ha^{-1}.

B. Materials and Tools

This study used materials and tools that include a) TSS of the Lokananta, Bima, and Trisula varieties. b) Urea fertilizer, 15:15:15 (Phonska), KCl, NPK, organic fertilizer, rice husk ash, and foliar fertilizer. c) chemical pesticides, biophysical and chemical analysis of soil and chemical control of pests and diseases (insecticides and fungicides), botanical pesticides, exi pheromones, insect traps, and light traps, d) supporting materials in the form of rulers, plastic sacks, large envelopes for sample plants, black-silver plastic mulch, field wells, mist sprinklers, TSS nursery shade, for soil samples, and e) supporting facilities for soil and plant analysis: fertilizers (organic and inorganic), pesticides, fungicides, and herbicides. Other supporting materials were f) planting tools, sprayers, harvesting tools (paper bags, sacks, transparent plastic, label tapes.), and stationery.

C. Experiment 1. Preliminary Observation of Soil Biophysical and Chemistry Characterization for Land Suitability

Composite soil samples were taken using the diagonal sampling method as a representation for soil characterization and analysis. The samples were analyzed at the Yogyakarta Assessment Institute for Agricultural Technology Laboratory. Ten soil samples from different sampling points were composited. Composited soil samples were taken at the top layer depth (1-30 cm) using a special soil drill for sandland before and after the experiment. The laboratory analysis results were used to estimate the level of soil biophysics, soil fertility, soil nutrient status, and fertilizer requirements. The land suitability criteria refer to the origin of the shallot bulb [30].

D. Experiment 2 - The Study of Nursery System in-Situ

The TSS shallot nursery research was conducted at "Manunggal" Farmer Group, Srigading Village, Sanden District, Bantul Regency, Yogyakarta Special Region. TSS from three varieties of shallot (Bima, Lokananta, and Trisula) were used. There were two nursery systems: with and without rain shelter systems. The experiment used a complete randomized block design and was repeated eight times. The variety was used as a single factor. 200 g of TSS sown for each variety. Maintenance was done until 35 days after sowing or when seedlings were ready to be transplanted. The TSS seedling production process refers to the operational procedures for the Shallot 'Proliga' technology aimed to produce 40 t ha^{-1} shallot from TSS [31], with an in-situ specific location. Watering was done by mist irrigation, controlling *Spodoptera exigua* (Hbn.) with five Feromon E-xi [3], [32] patent No. P00201000047.

Systematic random sampling was used [33], with 10 plants selected. Plant density 1 x 1 m2 per treatment. Ten plants in each plot were collected randomly at maturity to determine the parameters. The seedling observation variables included: seed germination, vigor, seedling length, number of leaves, weight per plant, seedling density per square meter (m^2), and seedling adaptability after moving to cultivation fields 10 days after transplanting. The power of growth and adaptability are calculated using the following formulas.

$$\text{Seed Germination} = \frac{\sum \text{of seeds germinated normally on day 7}}{\sum \text{of seeds tested (100 grains)}} \times 100\% \quad (1)$$

$$\text{Adaptability} = \frac{\sum \text{TSS seeds planted}}{\sum \text{of seeds that lives on 14 DAP}} \times 100\% \quad (2)$$

Data were analyzed statistically with ANOVA with further tests using Fisher's LSD (BNT) 5% test with the PKBT-STAT 3: 1 program [34].

E. Experiment 3. Doubling Production of Three Shallot Varieties

The study applied cultivation technology packages to achieve production > 30 t ha-1 shallot from TSS, using two factors: technology packages and varieties. The practices done referred to technical guidelines [31]. The spacing was 20 x 20 cm, with 4 seedlings (P1: 600,000 plants ha-1), 5 seedlings (P2: 700,000 plants ha-1), 6 seedlings (P3. 800,000 plants ha-1) planted in a hole, and also traditional farmers technology (P4) as control (Fig 1).

Fig. 1 Experiment 3: Doubling production of three shallot varieties (Bima, Trisula and Lokananta)

A complete randomized block design with five repetitions was used in this experiment. Ten plants in each plot were collected at maturity randomly to be observed for each parameter.

Complete tillage was done using the "Cultivator" machine. The size of the planting beds was 1.5 m in width, with length adjusted to the farmer's land area. After tillage, the soil was water saturated with 90% humidity. 100% organic and inorganic fertilizers were then applied at the beginning of planting. Organic fertilizer with 30 t ha-1 dosage and inorganic fertilizer NPKS (15:15:15:2) with a dose of 500 kg ha-1 fertilizer were mixed in the soil layer, then covered for 7 days using black silver plastic mulch [35], which has been perforated using hole machine at 20 x 20 cm. Then the TSS was planted according to the treatments.

Routine watering was done in the morning and evening using a 2.5 PK water pump-powered mist irrigation system with in-situ shallow groundwater wells (5 m). Pests and disease prevention and control were carried out by intensive monitoring. Shallot's main pest prevention was done by integrated pest management (IPM): 10 pieces of pheromone Exi [3] and five light traps ha-1 and 40 insect traps ha-1 were installed. Chemical insecticides and fungicides were used every 14 days (4 times of application) according to the recommended dosage.

Agronomic observation variables were carried out on bulb yield (weight of fresh bulb at harvest and weight of dry bulb after sun drying at seven days after harvest (DAH)). Agronomic data were analyzed descriptively and statistically using ANOVA with further testing using the 5% fisher's LSD (BNT) test with the PKBT-STAT 3: 1 program [34].

III. Result and Discussion

A. Climatic Conditions

According to Oldman's classification criteria, the Site experiment has a moderate climate (B.II.2). Annual rainfall between 1,500-2,000 mm, the number of dry months 3-7 and Wet months 5-9. The altitude of the place is 150 m above sea level with an air temperature of 18.1 - 22.4 ^{0}C. The climatic conditions are suitable for the cultivation of shallots.

B. Experiment 1: Land Suitability Analysis

Preliminary observation of soil biophysical characterization in *Typic Psammaquents* showed that the soil is sandy soil (Table 2).

TABLE II

Results of physical and chemical properties analysis of sandy soil, prior to and following research at Srigading Village, Sanden District, Bantul, Yogyakarta special region, Indonesia.

No.	Analysis and metode	Soil characteristics/ Comments			
		Before		After	
		Content	Classes	Content	Classes
1	Texture: Hydrometer Method				
	Sand (%)	97.99	Sand	96.88	Sand
	Dust (%)	1.76		2.77	
	Clay (%)	0.25		0.35	
2	pH (H_20) (%). pH meter	6.00	slightly acidic	6.00	slightly acidic
3	C-organic (%). Walkley-Black wet oxidation using chromic acid	0.42	Very Low	1.53	Very Low
4	N-total (%). Kjeldahl	0.02	Very Low	0.38	Very Low
5	P_2O_5 total (ppm 100 g^{-1}). Bray	139.03	High	414.30	Very High
6	K-dd (cmol (+) kg-^{1}). Flamephotometer	0.26	High	0.29	High
7	CEC (cmol (+) kg^{-1}). Saturation with Ammonium acetate pH 1 N.7.0	20.78	High	24.78	High
8	Base Saturation (%)	61.48	Moderate	80.41	High

Note: Soil analysis was carried out at the IAAT Yogyakarta Laboratory. Method of soil analysis by [36]. Classification based on the standard of soil fertility issued [37], [38].

The pH testing result showed the soil as a slightly acidic category. Macronutrients P and K were available in high amounts, while micronutrients were enough. Previous analysis has shown that sandy physical texture and chemical properties such as total N, CEC, and exchangeable Al influenced the number of clumps per shallot plant. Dhanalakshmi et al. [39] and Neina [40] reported similar results in India. A study by Sutardi [35] concluded that ameliorant application on planting media increased the percentage of silt fraction (0.55% to 2.37% change) and clay (0.45-0.51%), followed by P_2O_5 levels and reduced the sand content (1.05-2.07%). N content became the main limiting factor in soil with light P and K content, while P and K became limiting factors on sandy land for shallot. The site's study has similar characteristics to sandy land in Kediri, Indonesia, which showed slightly acidic pH, very low C organic content, and very low N, but with low P and K [39]. Another report analyzing coastal sandy land in the same regency as this study site (Bantul, Yogyakarta) showed similar low C organic and very low N content, varying P and K content.[40].

The agro-ecosystem zone (AEZ) map described that the study location has a dry climate (3-4 wet months, 5-7 dry months) with 1-2 valleys, an average rainfall of 397.3 mm per year, an average optimal temperature of at least 29 ^oC- 34 ^oC and classified as C and D climate. The soil series is classified as Waru and Samas Typic Hydraquents, very fine, mixed, non-acidic, and *isohyperthermic Typic Psammaquents* Complex. The primary material is sand sediment, with an area of 895-3.300 ha, about 0.34% of Yogyakarta, Indonesia [41]. A review of temperature and photoperiod effect on onion bulbing and flowering developmental process has been made [42]. Optimal onions at early growth temperatures ranged 15–20°C and 20–27°C throughout bulb development. Bolting could happen if the bulb suffered low temperatures at the development stage [42]. Otherwise, high-quality onions require cool temperatures during early development and warmer temperatures during maturity [43]. Onion cultivars of diverse origin under long photoperiod (17 h d^{-1}) bulbed at temperatures from 11 to 29°C [42].

The results of the land suitability analysis for shallot plants are presented in general in Table 2. Some specific factors that limit shallots' development are the soil's physical and chemical properties. The actual land suitability analysis showed that the soil was classified as N1 class (Table 3), which means it is not suitable for underground plant growth. However, the application of new amelioration technology to improve properties and chemistry for ±18-28 years will potentially upgrade the class into S2 or marginally suitable for shallot seeds from tubers and TSS [30]. The descriptive exploratory survey method was applied in this study with Land Mapping Unit (LMU) as an analysis unit.

TABLE III
LAND CHARACTERISTICS AND ACTUAL SHALLOT GROWING REQUIREMENTS

Land characteristic	Land characteristic Class				Actual Land characteristic Class (bulb seed planting)	Actual Land characteristic Class (TSS Planting)
	S1	S2	S3	N1		
Temperature (tc)						
Maen temperature (°C)	20-25	26-30 18-20	30-35 16-19	<15 >35	S3	S3
Water availability (wa) Mean annual rainfall (mm/year)	1,000-1,400	900-<900 >1,400-1,700	800-900 >1,700-2,500	<800 >2,500	S3	S3
Total rainfall in one season (3 months)*) (mm)	4-6 350-600	>6 600-800 300-350	- 800-1,600 230-500	- >1,600 <250	S1	S1
Long of the dry month (< 100 mm /months	-	-	2-4	<2	S3	S1
Oxygen availability (oa)	Well drained. Somewhat poorly drained	Somewhat excessively drained. moderately well drained	Poorly drained	Very poorly drained. excessively drained	N1	S2
Drainage Rooting condition (rc)						
- Texture	Moderately fine	Fine	Moderately coarse – very fine	Coarse	N1	S2
- Coarse material (%)	< 15	15– 35	35 – 55	>55		
- Soil depth (cm)	>50	30 –35	20 – 30	>20		
Nutrient retention (nr)						
- CEC (cmol/kg)	>16	5-16	<5	-	S2	S2
- Base saturation (%)	> 35	20-35	< 20	-		
- pH (H_2O)	6.0 – 7.5	7.5 – 8.0	>0.8	- -		
- C-organic (%)	<2. 0	0.8-2.0		-		
Nutrient available (na)						
Total Nitrogen (%)	Moderate	Low Moderate,Low	Very Low,Low-Very Low, Very low	-	S3	S3
P_2O_5 (mg/100g)	High	Moderate	Low-Very, Low	-	S1	S1
K_2O (cmol/kg)	Moderate	Low	Very Low	-	S1	S1
Toxicity (xc) Salinity (dS/m)	< 2	2– 3	3 – 5	>5	S2	S1
Sodicity (xn) Alkalinity/ESP (%)	<20	20-35	35-50	<50	S1	S1
Erosion Hazard (eh) - Slope (%)	< 3	3-8	8-15	>15	S1	S2
- Erosion	-	Very light	Light-moderate	Heavy – very heavy		
Land preparation (lp) - Surface stoniness (%)	< 5	5 – 15	25– 40	> 40	S1	S1
- Surface outcrops (%)	< 5	5 - 15	15 – 25	> 25		

Source: [44]; [30];[45]
Note : Matching results show the characteristics of the suitable land, the growth of shallots which were classified into four suitability classes : highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and not suitable (N1).

Previous studies have recommended that Nitrogen is an essential nutrient to achieve high yields and increase bulb size. Nitrogen fertilization can improve bulb development [42]. Shallot bulb diameter and dry weight increased 31.03% and 35.95%, respectively, from the application of 200 kg N ha^{-1} [46]. Onion bulbs dry matter percentage increased with the application of 350 mg kg^{-1} potassium sulfate and 100 mg kg^{-1} ammonium nitrate [47]. A fertilizer minus one test on sandy land for shallot showed that N becomes the main limiting factor with light P and K content, whereas P and K nutrients were the limiting factor on sandy land for shallot [35], [41]. The Nitrogen content of the site soil before and after research continued to be low (Table 2). Therefore, for the Nutrient available (na) parameter, the site soils' total Nitrogen (%) is classified into S3, while high P_2O_5 and K_2O content of the site soil made it as S1 class (Table 3).

The actual land suitability analysis result showed that innovative sand land amelioration could increase the class into S3 or S2, but it is not suitable for tuber planting with physical properties and soil safety limiting factors (N1). It is different for the actual development of TSS with S2 land suitability class (moderately suitable), which is potential with the introduction of technological innovation in S1 class (highly suitable) that can be seen in Table 2. This is a new finding. The C-organic content is still in the very low category (<1%), but the CEC is high, and the base saturation is moderate (Table 3). Soil amendments by adding organic fertilizer as well as irrigation and crop rotation increased soil C-organic content and water-holding capacity [48]. Combining organic matter and clay minerals as sandy soil amelioration also increases the soil N content, improves soil fertility by forming microaggregates, influences soil acidity, and controls microbial activities [49], [50].

Modification to Oxygen Availability (oa), texture (rc), and Nutrient available (na) parameters is one of the efforts to improve soil class from not suitable (N1) into marginally (S3) or moderately (S2) suitable. Applying what was suitable for the season, making raised beds, mulching, using shade, adding supplements such as organic matter, fertilizer, and liming the soil can overcome the limiting factors and increase the potential land suitability class. The growing environment or land characteristics significantly affect the growth performance of shallot plants. A case study in Iran [51] reported that proper environment management could help improve agricultural practice sustainability for onion production. On the other hand, besides soil biophysics analysis results, farmers greatly appreciate the increased communication with the researchers.

The analysis of the suitability of shallot land on psamment soil for the island of Java shows that the suitable soil potential for shallot plants is 495,478 ha spread over West Java, Central Java, DI Yogyakarta. East Java and Banten Provinces. 91,685, 141,027, 57,586, 16,.978, 44,202 ha (Table 4 and Fig 2).

TABLE IV
INDICATIVE DISTRIBUTION OF SHALLOT LAND AREA IN PSAMMENT SOIL OF JAVA ISLAND

No.	Province	Landform	Soil	Area (ha)
1	West Java	Volcanic plains, coasts, sand shores, sub-coastal ridges & basins, coastal ridges & basins	Inceptisol, Entisol	91,685
2	Central Java	Volcanic plains, coasts, sand shores, ridges & subrescent coastal basins	Inceptisol, Entisol	141,027
3	Yogyakarta	Volcanic plains, sand beaches	Incceptisol	57,586
4	East Java	Volcanic plains, coasts, sand shores, coastal ridges & basins, coastal ridges & basins, tidal flats	Inceptisol, Entisol	160,978
5	Banten	Volcanic plains, sand shores, ridges & sub-coastal basins	Inceptisol	44,202
		Total		**495,478**

Note: Source BBSDLP, 2015 [52]

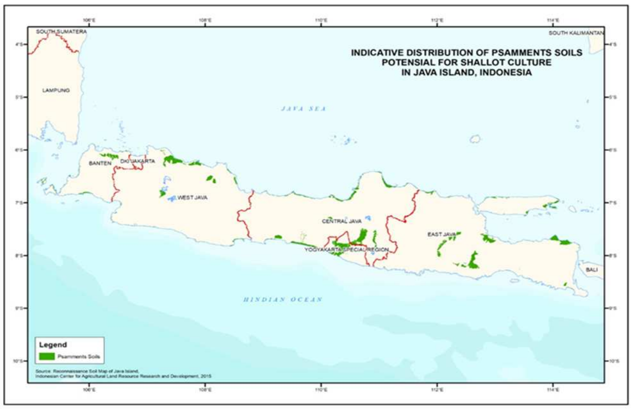

Fig. 2 An indicative map of shallot land area in Java [52]

Furthermore, for the province of the Special Region of Yogyakarta, the potential area of shallot land in psamment land is 57,586 ha. The widest is in Bantul Regency with an area of 31,207 ha. In the research location, the Village of Sanden Subdistrict, Bantul Regency is one of the locations suitable for developing shallots (Table 5 and Fig 3).

TABLE V
THE POTENTIAL AREA OF ONION IN THE PSAMMAQUENTS LAND OF YOGYAKARTA PROVINCE

No	Regency / City	Landform	Soil	Area (ha)
1	Yogyakarta	Volcanic plain	Inceptisol	3,288
2	Bantul	Volcanic plain, Coast	Inceptisol	31,207
3	Gunung Kidul	Volcanic plain	Inceptisol	320
4	Kulon Progo	Volcanic plain, Coast	Inceptisol	8,599
5	Sleman	Volcanic plain	Inceptisol	14,172
		Total		**57,586**

Note: Source BBSDLP, 2015 [52]

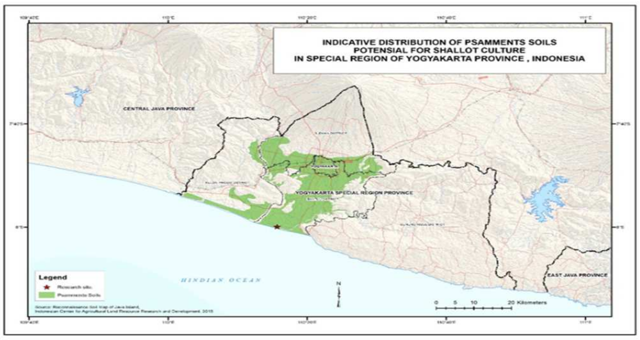

Fig. 3 An indicative map of shallot land area in Yogyakarta [52]

C. Experiment 2. Study of the in-Situ Nursery System

The TSS nursery experiment was carried out in two ways. The first one was a nursery with rain shelter, and the second one was without any cover or shelter. Before sowing, TSS seeds were soaked in warm water (50 ºC) with Previcur N fungicide solution (2 cc l^{-1}) for 3 hours, then drained for 24 hours or overnight (Fig 4). TSS were sown in the in-situ seedlings' beds covered with UV plastic (0.08 mm) for the nursery with rain shelters and uncovered for the one without. All the TSS seedlings media were in-situ on sandy soil. The media was sterilized by burning straw mixed with rice husk from broiler cage waste with a thickness of 5 cm or 2 kg per m^2 atop the media for 24 hours or overnight. Afterward, the sandy soil and the burning residue were processed lightly. Research by Jaiswal[53] has reported that biochar can reduce pre-grown disease caused by *P. aphanidermatum* by up to 71%. Pre-conditioning period of only 14 days is effective in suppressing diseases, substantially increasing its practical use for nurseries. Nursery soilborne diseases are a production factor that can significantly limit planting materials' quality [54]. The seed and soil sterilization processes are shown in Fig 4 and 5.

Fig. 4 TSS seeds after soaking in warm water 50 ºC + Previcur N fungicide (2 cc per liter)

Fig. 5 Sterilization of land by burning straw under rice husk waste of broiler chicken coop in Typic Psammaquents.

The TSS seeds were sown in a 5 cm deep groove with a hoe, 25 cm between rows. Then, the TSS seeds are evenly distributed in the rows with a population of 40-50 g m^{-2}. After that, the finished seeding is covered with straw and roasted husks and then watered until wet (90%). To maintain moisture and stimulate growth, the TSS seedlings were tightly closed with black silver plastic mulch for 7 days (Figure 4). The plastic mulch cover was opened after seed germination. The seedlings with rain shelter nursery system were then kept under a plastic shade, while the others were left uncovered.

The observation of the seedling performance at 30 DAS showed that the three TSS originated shallot varieties (Bima, Trisula, and Lokananta) were quite healthy and good. Table 3 shows the recapitulation result. The growth power was not significantly different. Meanwhile, the plant height, the number of leaves, and the seed weight of the two models of planting (sheltered and without shelter) was significantly different. Root length and seedling population were not significantly different, but adaptability was very significant (Table 3). The nursery system in both locations used direct seed sowing system with good yields. It is evident that at the age of 30 DAS (days after sowing) the seedlings are ready for transplanting. Seed germination significantly affected seedling weight between Bima, Trisula, and Lokananta varieties. Root length and population were not significantly different, indicating that the number of seeds of 40-50 g m^{-2} was good enough. It did not affect the competition for nutrient absorption and sufficient sunlight, positively impacting seed quality and health as well as simultaneous and homogeneous growth (Fig 6 and 7).

Fig. 6 Performance of TSS growth in rain shelter treatment conditions at 15 DAS in *Typic Psammaquents*

Fig. 7 Performance of TSS growth without rain shelter at 15 DAS in Typic Psammaquents

The seed germination of Bima, Trisula, and Lokananta varieties in both nursery systems were more than 80%, meeting the seed quality requirement. Seed germination result in the laboratory test were similar to the percentage of seedling growth in the field (77.87-78.13%) [22], [55]. Lokananta variety's seedling height was significantly higher by 4-5 cm compared to Bima and Trisula varieties, followed by the number of leaves and seed weight per plant (0.9-0.29 grams per plant). The adaptability of Lokananta varieties was significantly better (6%) than the Bima and Trisula varieties. However, the seed population per square meters was not significantly different. The adaptability of Lokananta variety with several different superiorities was significantly higher (6.43%) than Bima and Trisula (Table 6). The three TSS shallot varieties yielded quite well in sandy land.

A research recommended Trisula variety to produce TSS in the dry highlands of South Sulawesi [56]. TSS shallot in Brebes with single seed treatment and soil, sand, and horse manure as covering material gave the best yield result [57].

TABLE VI
YIELD OF 3 VARIETIES OF TSS NURSERY 30 DAS IN TYPIC PSAMMAQUENTS IN 2018

Variety	Percentage of seed germination (%)		Plant height (cm)		Number of leaves plant^{-1}		Seedling weight (g) plant		Root length (cm)		Seed population m^{-2}		Adaptability (%)	
	Rain Shelter	Without rain shelter	Rain Shelter	Without rain shelter	Rain Shelter	Without rain shelter	Rain Shelter	Without rain shelter	Rain Shelter	Without rain shelter	Rain Shelter	Without rain shelter	Rain Shelter	Without rain shelter
Bima	84	85	17.69^{b}	18.69^{b}	3.04^{b}	3.04^{b}	1.41^{ab}	1.41^{ab}	9.29	9.29	1,312	1,324	93.00^{b}	93.00^{b}
Trisula	83.73	85.73	16.71^{b}	17.71^{b}	2.96^{b}	2.96^{b}	1.21^{b}	1.21^{b}	10.51	10.51	1,348	1,351	93.00^{b}	93.00^{b}
Lokananta	87.43	88.43	21.14^{a}	23.14^{a}	3.36^{a}	3.36^{a}	1.50^{a}	1.50^{a}	10.31	10.31	1,484	1,489	99.43^{a}	99.43^{a}

Note: Numbers followed by different superscript letters in the same column are significantly different at 0.05 level Tukey's HSD Test (BNJ)

D. Experiment 3. Study of the Double Production of the Three Shallot Varieties

1) Plant Growth: The plant growth parameters were observed at 30 DAP and at harvest or 84 days after planting (DAP). At harvest, the leaves of most plants have fallen, and the pseudo stems were deflated. Other research reported that spacing differences significantly affected shallots' number of leaves at 45 DAS and the number of tillers at 30 and 60 DAS [58]. The number of leaves is the main source of assimilation for the increase in dry weight because it is a place for photosynthetic activity to produce energy that will be needed for the growth process and yield of shallot plants. The majority of shallots bulb per clump at 30 DAP and at harvest in this study were not significantly different at each plant population treatment. However, a denser population (700,000 and 800,000 ha^{-1}) tends to result in a higher bulb per clump than the lesser one (600,000 ha^{-1}), followed by farmer patterns (P4).

The results of a 5% variance showed that the number of bulb per clump was not affected by the plant population per hectare and the TSS-derived shallot variety. An exception was noted from Bima variety, which produced a significantly different number of bulb per clump at harvest, affected by population (Table 7). On the other hand, the TSS shallot varieties Trisula and Lokananta were not significantly different. The highest number of bulbs per clump was produced by Lokananta, even though Bima and Trisula variety had almost the same number of bulbs (Table 4, Fig.5). Number of bulb per clump will highly affect shallot productivity when it is combined with its' individual bulb weight. The results and comparison of the average number of bulb per clump were shown in Table 7 and Figure 8.

Planting 4, 5 and 6 seedlings per hole resulted in Bima's total number of tillers at 13.68-17.17 bulbs, Trisula at 13.68-16.97 bulbs and Lokananta at 16.22-16.50 bulbs in each hole at harvest (Tabel 5).

TABLE VII
THE NUMBER OF BULB PER CLUMP AGED 30 DAP AND AT HARVEST (84 DAP) VARIETIES OF TSS IN TYPIC PSAMMAQUENTS SOIL IN 2018

Treatment Plant ha^{-1}	30 DAP	At harvest (84 DAP)	30 DAP	At harvest (84 DAP)	30 DAP	At harvest (84 DAP)
	(Leaf blade: Variety)					
	Bima		Trisula		Lokananta	
P1 (600,000)	10.51	13.68^{a}	9.45	13.68	11.43	16.22
P2 (700,000)	12.88	16.97^{b}	11.29	16.97	12.88	16.97
P3 (800,000)	14.40	17.17^{b}	12.03	14.83	14.40	16.50
P4 (Farmer Pattern)	10.40	13.67^{a}	10.54	13.67	12.99	15.33
CV	23.26	16.63	18.94	21.12	17.86	20.51

Note: Numbers followed by different superscript letters in the same column are significantly different at 0.05. level Tukey's HSD Test (BNJ)

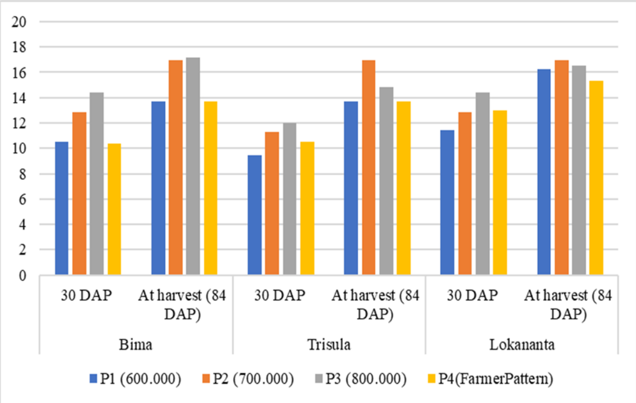

Fig. 8 Number of bulb per clump of the three TSS originated shallot varieties in *Typic Psammaquents* soil

Plant densities of 100 plants m^{-2} and 150 plants m^{-2} (150.000 ha^{-1}) did not show substantial competition amongst plants, according to a study [22]. The three shallot varieties produced an average of 1-3.8 tillers per clump. Research by Sumarni et al. [23] reported that Maja, Bima, and Tuk-Tuk shallot varieties produced an average of two tillers per clump. The number of bulbs per plant hole will have a significant effect on increasing the production with the target of 40 t ha^{-1} with the "PROLIGA" program or *Produksi Lipat Ganda* (the production is doubled) [31]. The results of this study indicated that there were more than 4, 5, and 6 tillers from TSS-originated plants per hole, so it could support increasing or doubling the production.

2) Production of stover, bulbs and harvest index: Analysis of variance test showed a significant difference in stover weight per clump in different treatments, mainly between 700,000 (P2) and 800,000 (P3) plants per hectare compared to the 600,000 (P1) plant per hectare population. However, there were no significant differences in bulb weight per clump and harvest index. Stover weight and bulb weight of Bima variety were significantly higher in P2 population than in other treatments, but the harvest index was not significantly different. Meanwhile, stover weight, bulb weight, and harvest index of Trisula variety was not influenced by plant population per hectare (Table 8).

TABLE VIII
AVERAGE PRODUCTION OF STOVER WEIGHT, BULB, AND HARVEST INDEX ON TSS VARIETIES IN TYPIC PSAMMAQUENTS SOIL IN 2018

Treatment Plant population ha^{-1}	Varieties								
	Lokananta			Bima			Trisula		
	Stover weight clump^{-1} (g)	Bulb weight clump^{-1} (g)	Harvest Index (%)	Stover weight clump^{-1} (g)	Bulb weight clump^{-1} (g)	Harvest Index (%)	Stover weight clump^{-1} (g)	Bulb weight clump^{-1} (g)	Harvest Index (%)
P1 (600,000)	86.87^{b}	59.33	67.33^{a}	88.47^{b}	70.66^{b}	83.78	96.87	69.99	74.07
P2 (700,000)	133.33^{a}	64.04	52.92^{ab}	123.27^{a}	95.84^{a}	75.87	115.13	76.04	67.98
P3 (800,000)	136.80^{a}	64.66	44.73^{b}	109.80^{ab}	81.33^{ab}	72.78	113.00	72.66	63.15
P4 (Farmer Pattern)	101.03^{ab}	64.43	48.17^{b}	90.00^{b}	65.15^{b}	74.22	94.93	69.81	62.90
CV	22.06	17.85	17,82	12.61	15.28	15.05	16.59	25.51	15.99

Note: Numbers followed by different superscript letters in the same column are significantly different at 0.05 level Tukey's HSD Test (BNJ)

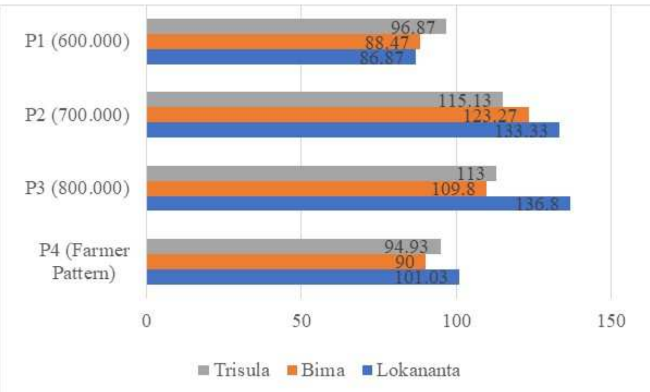

Fig. 9 Stover weight per clump of the three TSS originated shallot varieties

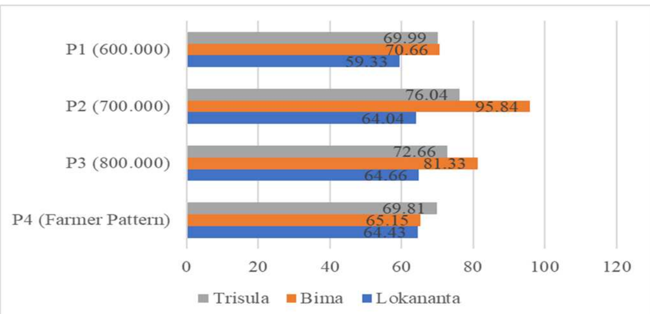

Fig. 10. Bulb weight per clump of the three TSS originated shallot varieties

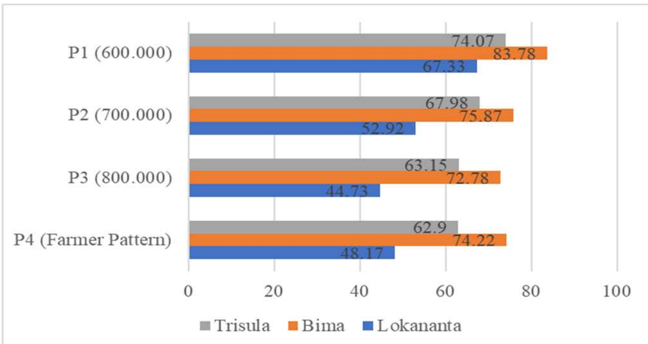

Fig. 11 Harvest index of the three TSS originated shallot varieties

3) Production (t ha^{-1}): Total production was calculated based on the production in an area (2.5 x 2.5 m2) converted into production per hectare for each treatment. The population of P2 (700,000 ha^{-1}) and P3 (800,000 ha^{-1}) at the three varieties were higher compared to P1 (600,000 ha^{-1}). Table 9 and Figure 12-13 show the details of the production between the three shallot varieties at different population treatments compared to shallot planted from bulb seed and cultivated in farmers' original cultivation pattern. The bulb yield difference between TSS-origin cultivation and double-fold bulb-origin (P4) ranged 0.05-7.7 t ha^{-1} or 0.26 to 47.12% (Table 9). Ministry of Agriculture stated that the average shallot productivity in 2014-2018 was 9.77 t ha^{-1} [11]. This study produced 14.831-28.178 t ha^{-1} bulb from TSS-originated shallot or an increase of 4.35-28.98 t ha^{-1} (30.66-280.00%) from the average shallot productivity in Indonesia. This result is better than another research [58] which stated that a population of 400 plants per m^2 (400,000 ha^{-1}) still allows for good growth and yield of shallot bulbs from seeds. The Lokananta variety population also had a very significant effect on its production. Table 9 detail the production between the three shallot varieties at different population treatments in comparison to shallot planted from bulb seed and cultivated in farmers' original cultivation pattern.

TABLE IX
PRODUCTION OF THE THREE TSS SHALLOT VARIETIES AT HARVEST (84 DAP) IN TYPIC PSAMMAQUENTS IN 2018

Treatments	**Yield (Stover + bulb)**	**Bulb Yield**	**Yield (Stover + bulb)**	**Bulb Yield**	**Yield (Stover + bulb)**	**Bulb Yield**
	t ha^{-1}; variety					
	Bima		**Trisula**		**Lokananta**	
P1 (600,000)	22.261^b	17.665^b	23.837^a	17.498^a	22.237^a	14.831^a
P2 (700,000)	29.149^a	23.960^a	28.178^a	19.010^a	32.466^a	16.010^a
P3 (800,000)	27.517^a	20.331^{ab}	24.574^a	18.165^a	27.379^a	16.165^a
P4 (Farmer pattern)	22.509^b	16.286^b	25.954^a	17.453^a	27.893^a	15.462^a
CV	12.50	17.82	18.50	24.48	27.05	21.31

Note: Numbers followed by different superscript letters in the same column are significantly different at 0.05 level Tukey's HSD Test (BNJ)

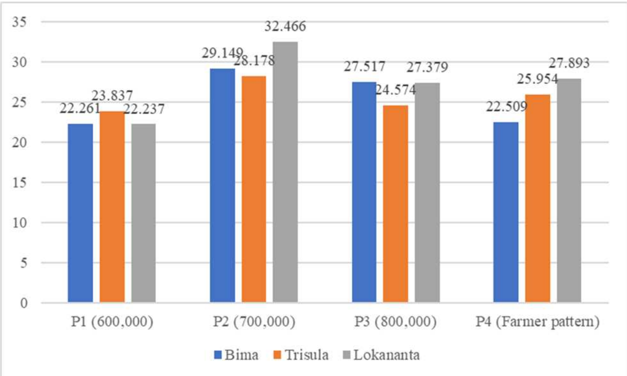

Fig. 12 Yield (stove+bulb) of the three TSS-originated shallot varieties in Typic Psammaquents (t ha^{-1}

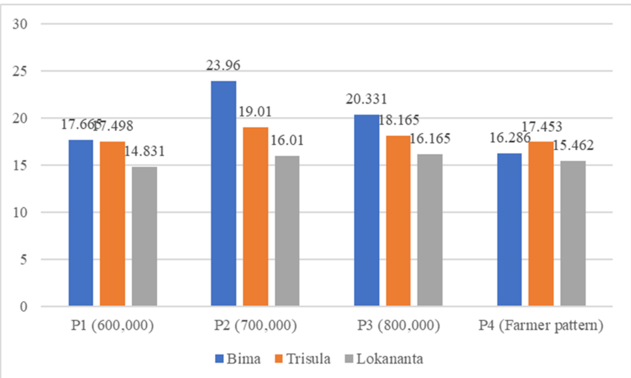

Fig. 13 Bulb yield of the three TSS-originated shallot varieties in Typic Psammaquents (t ha^{-1})

The Lokananta shallot in P2 and P3 treatments produced a significantly higher yield than P1. The yield difference between P2 and P3 treatment of Lokananta variety compared to that of P1 ranged from 5-10 t ha^{-1} of stover+bulb production and 2 t ha^{-1} of bulb production. Its implementation is based on the study result, which showed that a population of 700,000 - 800,000 plants per hectare could be used as a reference for TSS cultivation technology for specific sand land areas. Sumarni et al. [23] research recommends that the optimal spacing for TSS production (4-5 g per bulb) is 10 x 20 cm^2 or 15 x 20 cm^2 with a population ranging from 50.000 – 33.000 clumps ha^{-1}.

These results are better than previous studies [58], with Tuk-Tuk and Trisula varieties' highest yield at 7.45 t ha^{-1}, followed by Tuk-Tuk varieties 7.10 t ha^{-1}. Furthermore, [2] reported that shallot planted on Vertisol produced a higher bulb yield (38.2 t ha^{-1}) than on Alfisol (30.2 t ha^{-1}). It could be associated with Vertisol's better fertility and water holding capacity. The yield was obtained with 30 plant m^{-2} or 300.000 plant ha^{-1} density.

The success in TSS propagated shallot varieties development is highly anticipated by the Indonesian Vegetable Research Institute (part of Indonesian Agency for Agricultural Research and Development / IAARD) and will result in a breakthrough in domestic TSS-originated shallot production of Bima and Trisula varieties and also Lokananta (import). The TSS of Bima, Trisula, and Lokananta varieties in this study yielded on par results or even higher than others. Bima and Trisula's skin color is deep red with light red flesh color. Those traits and a higher harvest index (HI) make them much more preferred than the Lokananta variety, with lighter red skin color and white flesh.

IV. CONCLUSION

Innovation to increase shallot (TSS) production is great hope for the future. This research has proven that planting TSS from Bima, Trisula, and Lokananta varieties with multiple seedlings per hole obtained a total population of plants ha^{-1}, doubling their production. This gives possibilities in utilizing sandy dry land for shallot production, which may extent shallot TSS production area and consequently shallot production in Indonesia. The shallot production from TSS of Bima, Trisula, and Lokananta varieties will also benefit dealers in agricultural input, farmers, sellers, and others in the value chain. The benefit includes cheaper seed cost and two times higher efficiency compared to planting shallot bulb seed.

A concern might rise about the possibility of farmers abandoning vegetatively propagated varieties and changing to seed propagated ones, which may erode local genetic resources. Therefore, developing more shallot varieties for TSS production and consumption bulb production needs to be further pursued. Best agronomic and dissemination practices must be further researched and strengthened to increase these TSS-originated shallot varieties' bulb and seed productivity.

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