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Study of Fertilization Technology on Various Plant Population Densities of Shallots from True Shallot Seed Supports Proliga Technology

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Abstract
Shallot production can be affected by nutrient availability and plant population density in producing bulbs. The study aims to obtain the right dose of fertilizer and plant population for increased production through a double folding program (proliga) of shallot from true shallot seed (TSS). The study was conducted in Bonto Parang Village, Jeneponto Regency, South Sulawesi in January-December 2024. The study used a split-plot design with three replications. The population density as the main plot consisted of J1 = 100 plants/m^2 (1 seedlings per hole), J2 = 200 plants/m^2 (2 seedlings per hole) and J3 = 133 plants/m^2 (2 seedlings per hole). Fertilizer dosage as sub-plot consisted of P1 = 269,10 kg N, 311,40 kg P, 315,0 kg K (110% of recommendations); P2 = 246,68 kg N, 285,45 kg P, 288,75 kg K (recommendations); P3 = 224,25 kg N, 259,5 kg P, 262,5 kg K (90% of recommendations); P4 = 201,82 kg N, 233,55 kg P, 236,25 kg K (80% of recommendations); P5 = 179.4 kg N, 217,6 kg P, 210,0 kg K (70% of recommendations). The results of the study indicated that the interaction of NPK fertilizer dosage and population density had no different effect on the growth and yield components of shallot from TSS. The difference in population density showed a significant effect on the number of leaves aged 15, 30 and 45 DAP. While fertilizer dosage were not significant effect on plant height and leaf number at aged 30 and 45 DAP. The percentage of Fusarium wilt disease and the population of larvae Spodoptera were quite high in a population of 200 plants/m².The wet and dry weight of tubers (grams per clump and per plot) were higher at population of 133 plants/m^2 (J3), namely 1586.67 gram/plot than the other population treatments and significantly different with the population at J1 and J2. While wet weight of tubers per plot were higher at fertilizer dosage of 224,25 kg N, 259,5 kg P, 262,5 kg K (P3, namely 1588.89 gram/plot than the other fertilizer dosage and significantly different with fertilizer dosage at P1 and P5, but not significantly different with fertilizer at P4 and P5. The technology of shallot Proliga from seed is technically feasible to be developed because of its high productivity and benefit to farmers

Keywords: Shallots, True Shallot Seed, Population, Fertilizer

1. Introduction

Shallots are one of the horticultural commodities that receive priority in the program of increasing production and adding value in the horticultural sub-sector. In South Sulawesi, in 2020, the average shallot harvest area was recorded at 12,458 ha/year and productivity was 9.98 t ha^{-1} [1]. The productivity can still be increased to double and can even reach > 40 t/ha through a strategy of increasing shallot productivity through Proliga technology (the double production) can be done using true shallot seed (TSS) [2,3]. The use of TSS can increase plant populations up to 800,000/ha, optimal nutrient and water management, and integrated pest/disease management to reduce yield loss 10% [4].

To achieve optimal growth and yield, plants require a sufficient amount of ideal and balanced macro- and micronutrients in the soil [5]. Some research results show that the best fertilizer dose is different in each region as well as the best fertilizer dose is different in different varieties. A dose of organic fertilizer (Petroganik) of 3,000 kg/ha + 50 kg/ha of bio-fertilizer, 200 kg N/ha, 90 kg P2O5/ha, and 150 kg K2O/ha produced the highest dry weight of shallot tubers, amounting to 23.22 kg/15 m2 equivalent to 15.48 t/ha [6]. The excessive application of organic fertilizers has a serious impact on the soil. Inorganic fertilizers, if used in the long term, can harden the soil and degrade the stability of the soil aggregate [7].

The results of the study on shallot fertilization on alluvial soils using N 500 kg/ha fertilizer NPK Phonska + 2.5 t/ha organic fertilizer (Petroganic) + 10 kg/ha biofertilizer (Biotricho) to produce a high bulb weight [8]. To increase shallot bulb yield and quality, 100 kg/ha N and 1000 L/ha Biourine, 50-160 kg/ha P_2O_5, 50-200 kg K_2O and irrigation with 2,025 m3/ha or its half dosage combined with organic manures such as 20 t ha-1 chicken manure or 40 t ha-1 cow manure are used for bulb production [9]. The best shallot yields were obtained in the NPK 16-16-16 fertilizer treatment with a dose of 650 kg ha-1 (250 kg ha-1 at 10 HST, 200 kg ha-1 at 15 HST, and 200 kg ha-1 35 HST) and NPK 15-9-20 at a dose of 200 kg ha-1 (100 kg ha-1 25 HST and 100 kg ha-1 35 HST) with a yield of tuber weight per plant of 68.67 g [10]. Fertilizer dosage recommendations for shallot double folding production technology packages consist of organic fertilizer of 10 t/ha, Biotricho biofertilizer of 15 kg/ha, and inorganic fertilizers of 200-400 kg N, 120-150 kg P_2O_5, and 120-150 kg K_2O [11]. The appropriate fertilizer ratio can reduce competition between plants in meeting the needs of different plant nutrients based on the planting distance [12].

In addition to the nutrient availability factor, the population density of the plant affects the production of the resulting tubers. A high increase in plant population density can cause competition between plants for growing factors (water, nutrients, light, and growing space). It will affect the yield of shallot plants [13]. A population density of 100 plants/m² or with a planting distance of 10 x 10 cm shows better productivity in the Bima variety [14]. An increase in plant populations can be achieved by using 1 or 2 seedlings/holes. A plant density of 100 plants per m^2 in the Trisula variety gives good growth in shallot crops [15]. This activity aims to obtain the right dose of fertilizer and plant population to support the achievement of a double-fold increase in shallot production from TSS.

2. Materails and methods

The experiment was performed in the shalot development area of Jeneponto Regency from April to December 2024.

The experiment was arranged in a split-plot randomized complete block design with three replications consisting of three different rates of population densities as main plots and five different fertilizer dosages as subplots. Population densities consisted of J1 = 100 plants/m^2 (1 seedlings per hole), J2 = 200 plants/m (2 seedlings per hole) and J3 = 133 plants/m^2 (2 seedlings per hole). Fertilizer dosage (kg/ha) as sub-plot consisted of P1 = 269,10 kg N, 311,40 kg P, 315,0 kg K (110% of recommendations); P2 = 246,68 kg N, 285,45 kg P, 288,75 kg K (recommendations); P3 = 224,25 kg N, 259,5 kg P, 262,5 kg K (90% of recommendations); P4 = 201,82 kg N, 233,55 kg P, 236,25 kg K (80% of recommendations); P5 = 179.4 kg N, 217,6 kg P, 210,0 kg K (70% of recommendations). so that the study consisted of 45 experimental units.

The seedbeds are carried out on beds measuring 1 meter, the length of which varies according to the conditions of the land. A chicken manure dose of 2 kg m^{-2} is applied to the beds and sprinkled with burnt husks. Seedbed TSS is carried out by making lines at a distance of 5 cm and sowing TSS at 2 grams per line. The maintenance of the seedbed is carried out intensively, including watering, fertilizing, weeding, and pest and disease control. Transplanting is carried out after the seedlings are 6–8 weeks old.

Planting preparation was carried out by maximum tillage to a depth of 20 cm and turning over twice. Make beds 100 cm wide with drainage channels between the beds 40 cm deep and 30–40 cm wide. A planting rack adjusts to the treatment factor. The basic fertilizer consists of organic fertilizer at 20 t ha^{-1} and SP-36 doses according to the treatment, applied before planting. Fertilizers N and K, according to the treatment dose, are applied at the ages of 15 and 30 days after planting (DAP). At the NPK compound fertilizer treatment, 1/2 dose is applied as the basic fertilizer before planting, 1/4 dose at the age of 15 DAP, and 1/4 dose at the age of 30 DAP.

Integrated pest management is carried out by installing self-adhesive bottles, squeezing groups of eggs found, installing solar cell trap lamps for pests (*Spodoptera* sp.), and spraying with effective pesticides if the attack reaches the control threshold. Disease control is carried out by spraying effective fungicides (Azoxystrobin 200 g l^{-1} + Diphenoconazole 125 g l^{-1}; Mankozeb 80%; Chlorothalonil 75%; Propinep 70%) with a spraying strategy rotated every three sprayings with an interval of 5 days.

Shallots are harvested at the age of 70-75 days after transplanting or when the plant has fallen and there is a change in leaf color to yellow 60–75%. Harvesting is carried out by pulling out the plants. The bulbs are left for several hours on the beds, then tied up. Shallots bulbs infected with pathogens are separated by healthy bulbs. Shallots that have been tied up and dried in the sun with the position of the leaves on top for 5-7.

Data collected were plant height and number of leaves (at 15, 30 and 45 DAP), the percentage of disease attacks, and tuber yield per clump and per plot. ANOVA was used to analyze all data, and DMRT (= 5%) was used to test mean comparisons.

3. Results and discussion

Vegetative Growth

The results of the analysis of the vegetative growth of shallot plants of TSS are presented in Tables 1 and 2. The analysis showed that there was no interaction between NPK fertilization and plant density to plant height, and the number of shallot leaves. Plant density and Fertilizer dose had not effect on changes in plant height, except fertilizer doses had effect significantly at 15 DAP. However those had effect on changes on the number of leaves aged 15 DAP, 30 DAP and 45 DAP significantly, except fertilizer dose at 30 DAP and 45 DAP.

A plant density of 133 plants per m2 (two seeds per hole) indicates a higher tendency of plant height at observations of 45 DAP and at the number of leaves aged 30 DAP and 45 DAP. Plant height growth and the number of leaves tends to be higher at a planting density of 133 plants per m2 at the age of 45 DAP. Furthermore, the fertilizer dose of 179,4 N+217,6 P+210 K and 224,25 N+259,5 P+262,5 K showed higher plant height than the other dose at the age of 45 DAP, while the fertilizer dose of 246,68 N+285,45 P+288,75 K showed higher the number of leaves than the other dose at the age of 45 DAP. This shows that in this study, the planting density and the fertilizer dosage used tend to be able to support the growth of shallots from TSS.

Table 1. The effect of plant density and NPK fertilizer dose on the height of shallot

Treatment	Plant height (cm)		
	15 DAP	30 DAP	45 DAP
Plant density			
J1= 100 plant/m^2	33,73 a	39,42 a	37,96 a
J2= 200 plant/m^2	34,88 a	39,53 a	37,51 a
J3= 133 plant/m^2	34,75 a	38,16 a	38,58 a
Fertilizer dosage			
P1= 269,10 N+311,40 P+315,0 K	34,20 ab	39,16 a	37,92 a
P2= 246,68 N+285,45 P+288,75 K	34,25 ab	38,33 a	38,03 a
P3= 224,25 N+259,5 P+262,5 K	33,38 b	39,53 a	38,29 a
P4= 201,82 N+233,55 P+236,25 K	34,39 ab	37,69 a	37,21 a
P5= 179,4 N+217,6 P+210 K	36,06 a	40,47 a	38,62 a

Note: The number followed by the same letter in the same column does not differ markedly at the level of 5% based on the DMRT

Genetics are factors that cause the occurrence of a gap in the appearance of the plant. Plant height is related to the genetic factors of each variety [16] and is influenced by the ability of plants to adapt to the environment, including in the absorption of nutrients, water, climate, and sunlight [17]. Research results from Sumarni et al. [18] show a plant density of 100 plants per m^2 and 150 plants per m^2 does not cause competition, which means between plants. Similarly, at a density of 400 plants per m2, it is still possible for growth and yield of shallot bulbs of seed origin well. Differences in seed spacing from TSS showed a noticeable effect on the number of leaves aged 45 DAP as well as on the number of saplings aged 30 and 60 DAP [19].

Table 2. The effect of plant density and NPK fertilizer dose on the number of shallot leaves

Treatment	Number of leaves		
	15 DAP	30 DAP	45 DAP
Plant density			
J1= 100 plant/m^2	4,47 b	7,61 b	9,91 b
J2= 200 plant/m^2	7,42 a	11,84 a	15,48 a
J3= 133 plant/m^2	7,41 a	12,50 a	16,22 a
Fertilizer dosage			
P1= 269,10 N+311,40 P+315,0 K	6,27 b	10,11 a	13,77 a
P2= 246,68 N+285,45 P+288,75 K	6,60 a	10,32 a	14,10 a
P3= 224,25 N+259,5 P+262,5 K	6,34 ab	10,74 a	13,71 a
P4= 201,82 N+233,55 P+236,25 K	6,44 ab	10,45 a	13,80 a
P5= 179,4 N+217,6 P+210 K	6,52 ab	10,88 a	13,97 a

Note: The number followed by the same letter in the same column does not differ markedly at the level of 5% based on the DMRT

In addition to requiring optimal planting density to be able to grow and produce optimally, shallot plants also require the availability of nutrients in sufficient and balanced amounts, especially nitrogen (N), phosphorus (P), and potassium (K) nutrients. The difference in NPK fertilizer doses does not have a noticeable different effect on the height of the plant and the number of leaves of shallot origin TSS. This shows that the NPK dose given shows the same effect on the growth of shallots of TSS origin. Thus, based on the results of this study, the reduction of NPK doses from NPK doses by 90-70% can still support the growth of shallots from TSS. This can support efforts to reduce the use of chemical fertilizers and reduce production costs due to fertilizer purchases. The planting distance of 15 cm x 20 cm with a dose of N 190 kg/ha, P 92 kg/ha, and K_2O 120 kg/ha is the planting distance and the dose of NPK fertilizer is optimal for the production of shallot bulbs from mini bulb seeds, which results in a dry bulb weight of 35.48 g/plant [18].

Percentage of Pests and Diseases

The results of the analysis of the percentage of disease showed that there was no interaction between NPK fertilizer doses and planting distances on the intensity of shallot disease attacks and the population of Spodoptera from TSS.

There is a tendency that the higher plant density (J2) and the dose of fertilizer (P1, P2, P3) the higher the percentage of plants that attacked by fusarium wilt and larvae Spodoptera (Table 3). the tighter the plant, the higher the percentage of wilt disease. Similarity, increased doses of fertilizers, especially those with nitrogenous element content, cause growth-spurred vegetative plants. Fertilizing N causes the plant to become long, and the width and area of the leaves increase, but the thickness of the leaves decreases. This causes the plant to become less resistant to pests and diseases [20]. The density of the plant affects the microclimate around the plant, especially moisture. In denser plant populations, this means increased humidity. This condition causes the pathogen to develop faster.

The factor affecting the level of shallot production is the presence of pathogen attacks and larvae Spodoptera, especially pathogens that cause systemic diseases such as fusarium wilt. The percentage of plants affected by fusarium wilt and larvae Spodoptera at each treatment is presented in Table 3.

Table 3. The percentage of fusarium wilt and the population of *Spodoptera* sp.

Treatments	Fusarium wilt (%)	Larvae population of Spodoptera (ekor/plot)	
	50 DAP	23 DAP	37 DAP
Plant density			
J1= 100 plant/m^2	0,33 b	8,33 b	8,0 b
J2= 200 plant/m^2	8,67 a	17,67 a	20,0 a
J3= 133 plant/m^2	5,67 a	19,67 a	9,33 b
Fertilizer dosage			
P1= 269,10 N+311,40 P+315,0 K	3,33 a	8,33 a	14,0 a
P2= 246,68 N+285,45 P+288,75 K	2,67 a	10,33 a	11,0 a
P3= 224,25 N+259,5 P+262,5 K	4,67 a	10,33 a	6,67 a
P4= 201,82 N+233,55 P+236,25 K	3,0 a	6,00 a	4,00 a
P5= 179,4 N+2017,6 P+210 K	1,0 a	10,67 a	1,67 b

Note: The number followed by the same letter in the same column does not differ markedly at the level of 5% based on the DMRT

Yield Component

The results of the analysis of the yield components showed that there was no interaction between the NPK fertilizer dose and the population density to the yield componrnts of the shallot plant from TSS. While the results of the analysis of population density and fertilizer dose showed significantly different influences at the yield components This shows that the response of shallots was relatively different at different doses of fertilizer and population densities

The weight of wet tuber per plot obtained was between 1319.99 and 1588.89 gr. The wet weight of tubers (grams per clump and per plot) was higher at population of 133 plants/m^2 (J3), namely 1586.67 gram/plot than the other population treatments and significantly different with the population at J1 and J2. But dry weight of tubers was not significantly different at the population treatments (Table 3). The total result analysis reveals that best growth performance of onion was found from 20 cm × 10 cm spacing (50 seedlings per m2) combined with 160 kg N/ha, 70 kg P/ha and 100 kg K/ha fertilizer [21]. While a plant distance of 10 cm x 10 cm results in a larger weight of the tuber/seed and a diameter of the tuber/seed [22]. This may be caused by low population density (wider planting distance) gave the plants the opportunity to absorb more water, thus increasing the wet weight both per tuber and per plant.

The high density of a plant can give a higher total tuber yield per unit area, but most of the tubers produced are small in size. Conversely, with a low plant density, it can produce a greater percentage of large-sized tubers, but the total tuber yield per unit area is lower. The decrease in the weight of each tuber is due to the occurrence of competition between plants in the use of light, water, nutrients, and space [23].

Table 3. The yield of wet and dry tubers

Treatments	The yield of wet and dry tubers			
	The wet tuber weight (g per clump)	The dry tuber weight (g per clump)	The wet tuber weight (gr per plot)	The dry tuber weight (gr per plot)
Plant density				
J1= 100 plant/m^2	17,874 c	14,106 b	1337,33 c	920,00 a
J2= 200 plant/m^2	21,434 b	16,880 b	1503,33 b	1019,99a
J3= 133 plant/m^2	29,422 a	24,300 a	1586,67 a	1120,00 a
Fertilizer dosage				
P1= 269,10 N+311,40 P+315,0 K	24,31 a	18,80 a	1319,99 b	911,11 a
P2= 246,68 N+285,45 P+288,75 K	24,66 a	19,97 a	1442,22 a	972,22 a
P3= 224,25 N+259,5 P+262,5 K	22,37 a	17,96 a	1588,89 c	1061,11 a
P4= 201,82 N+233,55 P+236,25 K	22,17 a	17,81 a	1555,56 c	1116,67 a
P5= 179,4 N+217,6 P+210 K	21,05 a	17,61 a	1472,22 c	1038,89 a

Note: The number followed by the same letter in the same column does not differ markedly at the level of 5% based on the DMRT

The application of NPK fertilizer with different doses shows significant influence on the wet tuber weight per plot, but not significant on the dry tuber weight per plot and the dry tuber weight per clump. This shows that the range of doses of NPK fertilizers provided the different influence to the production of shallots of TSS origin. The dose of 224,25 N+259,5 P+262,5 K (kg/ha) gave the higher tuber weight (1588,89 g/plot) than the other doses. Treatment of 75% NPK compound (675 kg per ha) obtained the highest results of fresh bulbs weight at 41.64 g per clump and dry bulbs weight at 25.27 g per clump [24]. Based on this study, the NPK dose range is based on proliga recommendations, and doses up to 90% of the proliga recommendations can be used to support the formation of shallot yield components from TSS.

The growth and development of shallot bulbs requires a fairly high and balanced NPK fertilization. Shallot plants required a continuous supply of N, P, K, S and Mg for vegetative growth, bulb growth and bulb quality [25]. Soluble N nutrients produce nucleic acids, which play a role in the cell nucleus in the process of cell division, so that the layers of leaves can be formed properly, which subsequently develop into shallot bulbs [18]. The availability of sufficient nitrogen (N) during the vegetative growth of plants can enable the formation of amino acids into proteins [26]. Nutrient P deficiency can reduce the growth and development of roots and leaves, reduce tuber size and tuber yield, and slow maturity [9,27]. The high K content causes the large number of K+ ions that bind water in plants to speed up and optimize the process of photosynthesis.

4. Conclusions

The interaction of plant density and NPK fertilizer doses has no different influence on the growth and yield of shallot components.

The difference in plant density of seedlings from TSS shows a noticeable influence on the number of leaves aged 15 DAP, 30 DAP and 45 DAP. A planting density of 133 plant per m^2 with two seedlings per hole shows the wet weight of the tubers per clump and per plot is higher at 29.422 g/clump and 1586,67 g/plot

Differences in NPK fertilizer doses show an significantly influence on the growth and yield of shallots of TSS origin. 90% of the proliga fertilizer recommendations (224,25 N+259,5 P+262,5 K) tend to show higher yield of 1588,89 g wet tuber per plot.

The technology of shallot Proliga from seed is technically feasible to be developed because of its high productivity and benefit to farmers

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