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Accelerating Growth and Yield Components of Bangkok Red Onion Variety Through Plant Spacing and NPK Phonska Fertilizer Dosage

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A B S T R A C T

Shallots (Allium ascalonicum L.) of the Bangkok variety have high productivity potential, but their genetic expression heavily depends on optimizing vegetative density and the proper supply of macro nutrients. This study aimed to analyze the effect of the interaction between NPK Phonska fertilizer doses and planting spacing on the acceleration of growth and yield components of Bangkok shallots. The field experiment was conducted in Kediri Regency, East Java, using a Randomized Block Design (RBD) with a factorial pattern and three replications. The first factor was the NPK Phonska dose (0, 400, 600, and 800 kg ha-1) and the second factor was planting spacing (20 cm×10 cm, 20 cm×20 cm, and 20 cm×30 cm). The analysis of variance showed that the interaction of the two factors had a very significant effect ($p<0.01$) on plant height, number of bulbs, dry bulb weight per clump, and dry bulb weight per plot. Applying NPK Phonska at 800 kg ha-1 combined with a wide planting distance of 20 cm × 20 cm produced the best individual performance, with an average of 21.30 tubers and a dry weight of 70.30 grams per clump. On the other hand, the highest absolute yield per area was achieved by the combination of NPK Phonska 800 kg ha-1 with a close planting distance of 20 cm × 10 cm, producing 7.85 kg per plot (equivalent to 19.63 tons ha-1). This study concludes that close spacing combined with high-dose macro nutrient sufficiency can compensate for reduced individual performance through higher population multiplication to achieve maximum land productivity

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INTRODUCTION

Shallots (Allium ascalonicum L.) are one of Indonesia's high-value horticultural commodities whose price fluctuations often trigger national inflation (BPS, 2025). Amid efforts to meet the growing domestic market demand driven by population growth and the culinary industry, introducing superior varieties like the Bangkok variety is a promising alternative. Bangkok shallots have potential genetic advantages, such as generally larger bulb size, an adaptive root system, and relatively better resistance to certain tropical environmental stresses compared to several local varieties (Anis & Santosa, 2020). However, the full potential of these superior agronomic traits in the Bangkok variety heavily depends on optimizing external factors in the field, especially managing plant density and ensuring a balanced supply of macro nutrients.

The main challenge in cultivating this variety of red onions is the low efficiency of space use and the inaccurate fertilizer application doses, which end up reducing the plants' physiological performance. So far, farmers often apply conventional planting patterns that are not proportional, along with speculative fertilization doses (Permadi & Sumarni, 2019). Manipulating the planting space through precise spacing arrangements is a crucial strategy to control interspecific competition for sunlight intensity, micro-air humidity, and soil nutrients (Setyowati & Utami, 2023). Planting too close can increase the population per unit area but risks causing etiolation and reducing bulb weight due to limited assimilates. On the other hand, planting too far apart can optimize individual plant growth but lowers land conversion efficiency per hectare.

In addition to spatial engineering, speeding up plant metabolism to form superior yield components requires a balanced supply of essential macronutrients through compound NPK Phonska fertilizer (15:15:15). Nitrogen (N) plays a vital role in stimulating the early vegetative phase such as plant height and leaf number; Phosphorus (P) initiates the development of a strong root system and intrasellular energy transfer; while Potassium (K) acts as an enzymatic activator that regulates the translocation of carbohydrates from leaves to storage organs, namely red onion bulbs (Hardjowigeno, 2021). Considering that the Bangkok variety has more robust morphological characteristics, its nutrient absorption kinetics differ significantly from smaller local varieties. Therefore, synchronizing land spatial modification and the precise NPK Phonska dosage becomes key in manipulating plant architecture to achieve an optimal harvest index (Mulyati et al., 2022).

Previous studies have examined the effects of NPK fertilization and planting distance manipulation on red onions separately in different varieties. However, comprehensive studies that integrate the dynamic interaction between population density and specific NPK Phonska dosage in the Bangkok variety are still very limited (Wibowo et al., 2024). Understanding how spatial compensation affects the efficiency of multiple nutrient absorption is highly needed to develop precise and sustainable cultivation technology packages.

Based on this research gap, this study was initiated with the goal of analyzing and understanding the effect of the interaction between NPK Phonska fertilizer doses and planting distance arrangements on accelerating vegetative growth as well as the yield components of Bangkok shallot (Allium ascalonicum L.) variety. The hypothesis proposed in this study is that there is suspected to be a significant interaction effect between the combination of NPK Phonska fertilizer doses and variations in planting distance in driving growth parameters and maximizing the production components of Bangkok shallot plants.

LITERATURE REVIEW

Botanical Characteristics and Genetic Capacity of the Bangkok Shallot Variety

Shallots (Allium ascalonicum L.) are categorized as a strategic horticultural commodity with high economic value and are highly susceptible to environmental microclimate dynamics and cultivation management systems (Mardhiyah et al., 2024). Among the existing cultivar diversity, the introduced Bangkok variety offers a comparative advantage in its highly active vegetative meristem tissue division intensity. This adaptive trait directly impacts the high production capacity of the number of tillers and the multiplication of bulbs within each plant clump (Gisat et al., 2023). However, the actualization of the genetic potential of this Bangkok cultivar is largely determined by the stability of the reciprocal relationship between the capacity of the source organ, in the form of leaf surface area, to absorb solar radiation, and the volume of the sink organ during the initial phase of bulb initiation (Mardhiyah et al., 2024). The lack of adequate growing space and a deficit in essential macro-micronutrients during this critical period can inhibit cellular differentiation in tuber primordia. Consequently, organ morphology will only develop in a cylindrical, elongated manner without the optimal accumulation of assimilates (Mardhiyah et al., 2024).

The Effect of Spatial Planning and Plant Density on Vegetative Structure

Plant spacing is essentially a form of manipulation of vegetation canopy architecture to minimize friction and biophysical competition between individuals within the plot (Wahyudi et al., 2020). When planting is excessively dense, limited space triggers uneven interception of solar radiation due to mutual shading between plant canopies (Putra et al., 2021). This low-light microenvironment triggers a decrease in the red/far-red ratio of light, which is then captured by phytochrome photoreceptors (Putra et al., 2021). As a form of structural compensation, plants induce shade avoidance syndrome through massive auxin secretion in the apical region, thereby accelerating vertical cell elongation or triggering mild etiolation symptoms (Putra et al., 2021). Conversely, at low population densities (wide spacing), the loss of root intersection and canopy overlap allows individual plants to maximize water, air, and light absorption, which positively correlates with the increase in leaf number per clump (Wahyudi et al., 2020).

The Function of Essential Macronutrients (NPK) in the Physiological Mechanism of Bulbization

Accelerating the vegetative growth phase and optimizing yield components of horticultural crops requires a balanced supply of essential macronutrients, particularly nitrogen (N), phosphorus (P), and potassium (K) (Siregar & Nababan, 2022). Nitrogen plays a vital role as a constituent of chlorophyll, amino acids, and protein compounds that stimulate the expansion of the photosynthetic area of leaves (Gisat et al., 2023). Furthermore, the availability of energy supplies in the form of Adenosine Triphosphate (ATP), supported by Phosphorus metabolism, is transmitted to drive cell division and elongation in meristem tissue, both in the vegetative and generative phases (Gisat et al., 2023). Entering the final phase of cultivation, Potassium plays a crucial role as a regulator of cellular osmotic pressure and an activator for various starch-forming enzyme systems (Lestari & Wardana, 2021). The presence of Potassium facilitates the efficient translocation of photoassimilates (carbohydrates) from the leaf organ (source) to the target tuber organ (sink), thereby boosting cell density, volume, and total dry weight of tubers at harvest (Lestari & Wardana, 2021).

The Relationship between Population per Unit Area and Land Productivity Efficiency

In plant ecophysiology, there is a reverse polarity phenomenon between productivity performance per individual clump and total yield per unit area (Fikri et al., 2022). The use of a wide planting spacing configuration has been shown to be effective in producing maximum dry weight per clump because individual plant growth is free from the stresses of competition for nutrients and living space (Lestari & Wardana, 2021). However, dry biomass accumulation per hectare or per experimental plot is often highest in high-density planting schemes (Fikri et al., 2022). Increasing the population per effective unit area in dense cultivation systems can significantly offset the decrease in tuber weight per individual (Fikri et al., 2022). As long as macronutrient requirements are met at optimum levels to minimize soil nutrient deficit stress, high population integration can create optimal light use efficiency at the macro canopy level, resulting in a total yield of high economic value for the agribusiness industry (Fikri et al., 2022).

METHODOLOGY

Time and Location

This field research was conducted from January to March 2026. The testing location was Tambak Wirang Hamlet, Sidowarek Village, Pelemahan District, Kediri Regency, East Java Province, Indonesia. Geographically, this managed agroecosystem area is located in a lowland typology with an estimated barometric elevation of approximately 120 meters above sea level (asl).

Materials and Experimental Design

The primary biological material evaluated was shallot (Allium ascalonicum L.) seed bulbs from the Bangkok Thailand variety, which had undergone a post-harvest dormancy phase of approximately three months to ensure uniform germination. The primary macronutrient input was supplied using Phonska NPK compound fertilizer with a nutrient ratio of 15:15:15. Pest control was applied preventively and curatively using a commercial pesticide package including the herbicide Goal, insecticides (Prevathon 50 SC and Demolis), fungicides (Antracol 70 WP and Cabrio), the bactericide Agrep, and the additional adhesive-leveling agent Borer.

This experiment was designed using a Randomized Block Design (RBD) Factorial pattern combining two treatment factors with three block replications.

The first factor was the graduated dose of Phonska NPK compound fertilizer (D), divided into four quantity levels: D0: No fertilizer application with PHONSKA fertilizer (15:15:15), D1: Plants were fertilized with PHONSKA (15:15:15) at a dose of 400 kg ha-1, D2: Plants were fertilized with PHONSKA (15:15:15) at a dose of 600 kg ha-1, D3: Plants were fertilized with PHONSKA (15:15:15) at a dose of 800 kg ha-1.

The second factor was the spatial configuration of plant spacing engineering (J), consisting of three levels of population density: J1: Plant spacing 20 x 10 cm. (130 plant holes), J2: Planting distance 20×15 cm. (100 plant holes), J3: Planting distance 20×20 cm. (80 plant holes) The interaction of the two factors above resulted in 12 treatment combinations (D0J1 to D3J3) which were randomly placed in the experimental units in each growth block.

Research Implementation

The planting area construction began with the creation of 36 experimental plots with architectural dimensions of 200 cm x 200 cm. The spacing between plots was set at a constant 30 cm, and the boundaries between replication blocks were separated by 50 cm. The soil was mechanically cultivated to achieve a crumbly texture, air-dried for five days, and then covered with silver-black plastic mulch (MHP) to mitigate extreme evaporation and suppress pre-emergent weed invasion.

Before planting, one-third of the seed tubers were cut transversely to stimulate synchronized bud dormancy breaking. NPK Phonska nutrient application was applied fractionally (split) in two stages: 50% of the dose at 14 days after planting (DAP) and the remaining 50% at 28 days after planting using a scattering method along the perimeter of the plants, followed by soil hilling (pendangiran). Micro-irrigation was carried out twice daily (morning and afternoon) during the early vegetative critical phase using a manual watering system, and the intensity was reduced to every four days when the plants entered the storage organ maturation phase. Replanting of plants experiencing mortality was limited to a maximum of 7 days after planting using homogeneous border stock. Total destructive harvesting was initiated at 65 days after planting when the leaf stand showed signs of natural senescence, indicated by 75% wilting of the stem collar and visualization of the tuber epidermis, which had developed a deep red sheen.

Observation Variables

Agronomic data collection was classified into two periodic analysis procedures:

Non-Destructive Observation: Conducted longitudinally (in situ) during the late vegetative phase (35 and 42 days after planting) by taking random representative plant samples per treatment plot. Parameters included:

- Plant Height (cm): Measured from the base of the vertical root collar to the tip of the tallest leaf.
- Number of Leaves per Clump (leaf): Quantitative calculation of the total number of functionally active photosynthetic leaves.

Post-harvest Destructive Observation (65 days after harvest): Production performance evaluation is conducted after the tuber biomass is cleared of soil residue, including:

- Number of Tubers per Clump (fruit): The density of storage organs formed per individual unit.
- Wet Tuber Weight per Clump (gm): The fresh mass of commodity tuber organs per sample clump, measured using a precision digital scale.
- Wet Tuber Weight per Plot (Kg): Estimated gross productivity of harvested biomass per net treatment plot area (m2).

Data Analysis

The data obtained from the observations in each F-test using the variable method were entered into a table for the F-test using the Analysis of Variance (ANOVA) method with the following test criteria:

- If Ftable 5% < Fcount < Ftable 1%, then H1 is accepted at the significant level, indicating a significant effect.
- If Fcount > Ftable 1%, then H1 is accepted at the 1% significant level, indicating a highly significant effect.
- If Fcount < Ftable 5%, then H0 is accepted and H1 is rejected.

If an interaction occurs between the treatment combinations (H1 is accepted), a 5% BNT comparison test is conducted to compare the average values of the treatment combinations to determine which values are significantly different or the same. If no interaction occurs, the 5% BNT test is conducted on the average results of the single treatment that has an effect on the observed variable.

RESULTS *AND* DISCUSSION

Plant Height (cm)

Analysis of variance (ANOVA) results confirmed a significant interaction ($p<0.05$) between the combination of NPK Phonska compound fertilizer doses and plant spacing manipulation on the height of Bangkok shallots in the final vegetative phase (35 and 42 days after planting). Based on the results of the 5% Least Significant Difference (LSD) post-hoc test (Table 1), optimum plant height performance was consistently documented in the D3J1 treatment combination (NPK Phonska 800 kg ha^{-1} + 20 × 10 cm plant spacing), with vertical heights of 42.30 cm (35 days after planting) and 47.40 cm (42 days after planting).

Table 1. Average Plant Height (Cm) of Bangkok Red Onion Varieties Due to the Interaction of Phonska NPK Doses and Planting Distance at 35 and 42 Days After Planting

Treatment Combination	Plant Height 35 days after sowing (cm)	Plant Height 42 days after sowing (cm)
D0J1 (0 kg ha^{-1} + 20 × 10 cm)	36,60 a	42,47 c
D0J2 (0 kg ha^{-1} + 20 × 15 cm)	35,00 a	41,07 a
D0J3 (0 kg ha^{-1} + 20 × 20	33,07 a	38,83 a

cm)		
D1J1 (400 kg ha⁻¹ + 20 × 10 cm)	38,47 ef	44,20 f
D1J2 (400 kg ha⁻¹ + 20 × 15 cm)	37,43 cd	43,20 cde
D1J3 (400 kg ha⁻¹ + 20 × 20 cm)	36,73 a	42,50 cd
D2J1 (600 kg ha⁻¹ + 20 × 10 cm)	39,70 g	45,40 g
D2J2 (600 kg ha⁻¹ + 20 × 15 cm)	37,93 def	43,70 ef
D2J3 (600 kg ha⁻¹ + 20 × 20 cm)	37,87 de	43,43 def
D3J1 (800 kg ha⁻¹ + 20 × 10 cm)	42,30 i	47,40 i
D3J2 (800 kg ha⁻¹ + 20 × 15 cm)	40,90 h	46,37 h
D3J3 (800 kg ha⁻¹ + 20 × 20 cm)	38,90 fg	44,63 g
BNT 5%	**1,02**	**0,95**

Note: Numbers accompanied by the same letter in the same column are not significantly different in the 5% BNT test.

The phenomenon of plant height in the dense population treatment (J1: 20 × 10 cm) is rooted in morphological compensation mechanisms due to interspecific competition for growing space. High plant density induces reciprocal shading between shoots, which degrades the red/far-red light intensity ratio received by plant phytochrome photoreceptors. This condition triggers shade avoidance syndrome in the form of aggressive biosynthesis of the phytohormone auxin, thereby spurring the elongation of stem cells (moderate etiolation) in order to capture solar radiation vertically (Putra et al., 2021). This vegetative growth pattern was accelerated synergistically by determining the optimum NPK Phonska dose of 800 kg ha^{-1}. The availability of high doses of Nitrogen (N) nutrients stimulates the expansion of the ATP energy supply for apical meristem cell division, resulting in superior visualization of plant height (Gisat et al., 2023).

Number of Leaves per Clump (pieces)

In contrast to plant height, analysis of variance indicated that there was no significant interaction effect ($p>0.05$) between the two factors on the accumulation of leaf number. However, both the single factor Phonska NPK dosage and variations in planting distance had a very significant influence ($p<0.01$) independently (Table 2).

Table 2. Average Number of Leaves Per Clump (Leaves) Due to the Single Effect of NPK Phonska Dosage and Planting Distance at 35 and 42 Days After Planting

Faktor Perlakuan Tunggal	Jumlah Daun 35 hst (helai)	Jumlah Daun 42 hst (helai)
Dosis NPK Phonska (D)		
D0 (0 kg ha^{-1})	32,47 a	40,06 a
D1 (400 kg ha^{-1})	35,28 b	42,69 b
D2 (600 kg ha^{-1})	36,30 c	43,67 c
D3 (800 kg ha^{-1})	38,30 d	45,54 d
BNT 5% (D)	**0,57**	**0,60**
Jarak Tanam (J)		
J1 (20 × 10 cm)	34,36 a	41,75 a
J2 (20 × 15 cm)	35,57 b	42,92 b
J3 (20 × 20 cm)	36,83 c	44,30 c
BNT 5% (J)	**0,49**	**0,52**

Note: Numbers accompanied by the same letter in the same column and treatment do not show a significant difference in the 5% BNT test.

The significant increase in leaf quantity following D3 application (800 kg ha^{-1}) reflects optimal sufficiency of essential nutrients for cellular metabolism in Bangkok shallots. A balanced supply of macronutrients stimulates the Krebs cycle and oxidative phosphorylation, which facilitate carbon assimilation and the formation of new leaf primordia in vegetative meristems (Siregar & Nababan, 2022). Conversely, regarding plant spacing, the highest leaf performance was achieved in sparse plots (J3: 20 × 20 cm). The absence of significant competition under low population levels minimizes root and canopy overlap, allows water and soil nutrient uptake to occur without biophysical limitations, and maximizes sunlight interception per individual clump to support the formation of photosynthetic organs (Wahyudi et al., 2020).

Yield Components: Number of Bulbs, Dry Weight of Bulbs per Hill, and Dry Weight of Bulbs per Plot

Post-harvest yield component parameters (65 days after planting), including the number of bulbs per hill, dry weight of bulbs per hill, and dry weight of bulbs per plot, showed a highly significant interaction response ($p<0.01$) between the compound fertilizer application treatment and spatial engineering of plant spacing (Table 3).

Table 3. Average Number of Bulbs (Fruits), Dry Weight of Bulbs Per Clump (G), and Dry Weight of Bulbs Per Plot (Kg) of Bangkok Variety Red Onions at Harvest (65 Days After Planting)

Combination of Treatments	**Number of Tubers (fruits)**	**Dry Weight / Cluster (g)**	**Dry Weight /Plot (kg)**
D0J1 (0 kg ha^{-1} + 20 × 10 cm)	12,53 a	52,13 a	6,78 de
D0J2 (0 kg ha^{-1} + 20 × 15 cm)	14,00 a	53,60 a	5,36 a
D0J3 (0 kg ha^{-1} + 20 × 20 cm)	15,07 bc	57,67 c	4,61 a
D1J1 (400 kg ha^{-1} + 20 × 10 cm)	16,07 cd	54,40 a	6,81 de
D1J2 (400 kg ha^{-1} + 20 × 15 cm)	16,43 de	63,03 d	6,30 c
D1J3 (400 kg ha^{-1} + 20 × 20 cm)	17,87 fg	64,47 de	5,16 a
D2J1 (600 kg ha^{-1} + 20 × 10 cm)	16,87 def	55,93 bc	7,22 e
D2J2 (600 kg ha^{-1} + 20 × 15 cm)	17,53 f	63,13 d	6,31 c
D2J3 (600 kg ha^{-1} + 20 × 20 cm)	18,70 g	66,30 de	5,30 a
D3J1 (800 kg ha^{-1} + 20 × 10 cm)	17,23 ef	56,83 bc	**7,85 f (19,63 t ha^{-1})**
D3J2 (800 kg ha^{-1} + 20 × 15 cm)	19,90 h	66,50 e	6,65 cd
D3J3 (800 kg ha^{-1} + 20 × 20 cm)	**21,30 i**	**70,30 f**	5,52 c
BNT 5%	**1,03**	**3,25**	**0,39**

Note: Numbers accompanied by the same letter in the same column are not significantly different in the 5% BNT test.

The application of 5% BNT showed that the highest quantity of tubers (21.30) and the highest individual dry weight of the clump (70.30 g) were concentrated in the D3J3 combination (800 kg ha^{-1} + 20 × 20 cm). Low spatial density minimizes root intersection, optimizing the absorption capacity of dissolved nutrient ions. The availability of potassium (K) from high-dose compound fertilizer acts as an osmoregulator and activator of starch-synthesizing enzymes. This intensifies the rate of translocation of photosynthetic assimilates (carbohydrates) from the source organ (leaf) to the sink organ (bulb), which in turn increases the cellular volume and density of the Bangkok onion bulb (Lestari & Wardana, 2021). Conversely, nutrient reduction triggers failure of bulb initiation, causing the organ to remain cylindrical without accumulating food reserves (Mardhiyah et al., 2024).

Interestingly, the evaluation results of the total yield per unit area showed a reversed polarity. The absolute highest dry weight of tubers per plot was won by the D3J1 treatment combination (800 kg ha^{-1} + 20 × 10 cm) with a yield weight of 7.85 kg per efficient plot (equivalent to 19.63 tons ha^{-1}). Although the performance per individual clump in the dense spacing treatment (J1) was below the performance range of the sparse plot (J3), the surge in leaf area index and the exponential multiplication of the population per effective land unit (130 holes per plot compared to only 80 holes in J3) were able to compensate for the massive decrease in weight per clump. The synergy between balanced macronutrient application and high density induces the achievement of maximum light use efficiency at the canopy level of the plantation, resulting in optimal dry biomass aggregation per hectare and high economic value for industrial agribusiness scale (Fikri et al., 2022).

CONCLUSIONS AND RECOMMENDATIONS

1. There was a significant interaction between the combination of Phonska NPK fertilizer dosage and plant spacing manipulation on plant height acceleration (35 and 42 days after planting), the accumulation of bulbs per hill, the dry weight of bulbs per hill, and the dry weight productivity of bulbs per plot in the Bangkok variety of shallots.
2. The single factors of Phonska NPK dosage and plant spacing manipulation had a very significant independent effect on leaf quantity per hill at 35 and 42 days after planting, with the highest number of leaves produced by the application of 800 kg ha^{-1} of Phonska NPK (38.30–45.54 leaves) and a wide plant spacing of 20 × 20 cm (36.83–44.30 leaves).
3. The combination of 800 kg ha^{-1} of NPK Phonska and a wide spacing of 20 × 20 cm (D3J3) produced the best individual production component with an average number of tubers of 21.30 and the highest dry weight of tubers of 70.30 grams per clump.
4. The combination of 800 kg ha^{-1} of NPK Phonska and a dense spacing of 20 × 10 cm (D3J1) produced the highest area productivity with a dry weight of tubers per plot reaching 7.85 kg (equivalent to 19.63 tons ha^{-1}), making it the most efficient treatment combination for maximizing total yield.

FURTHER STUDY

1. For agribusiness practitioners and farmers focused on maximizing total yield per hectare, it is recommended to implement cultivation technology using a combination of 800 kg ha^{-1} of NPK Phonska fertilizer with a dense planting distance of 20 cm x 10 cm.
2. For seed cultivation (propagating premium-quality seed tubers with large tubers), it is recommended to use a combination of 800 kg ha^{-1} of NPK Phonska fertilizer with a loose planting distance of 20 cm x 20 cm.

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