AGROTECH–FOOD SCIENCE, TECHNOLOGY AND ENVIRONMENT VOL. 4 NO. 1 (2025) P.66-71

AGROTECH
ISSN: 2773-4870 **eISSN:** 2821-3106
DOI: https://doi.org/10.53797/agrotech.v4i1.10.2025

Effect of Kelpak Plant Growth Regulator Soaking and NPK Fertilizer Dosage on the Germination and Growth of True Shallot Seedlings (*Allium cepa* L.)

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Received 03 May 2025; Accepted 12 June 2025; Available online 30 June 2025

Abstract: This study investigates the effect of Kelpak plant growth regulator (PGR) soaking and varying dosages of NPK fertilizer on the germination and growth of True Shallot Seeds (TSS) of *Allium cepa L*. The experiment was conducted from February 2 to May 3, 2024, in Bodag Hamlet, Bandungharjo Village, Grobogan Regency, Indonesia, using a Completely Randomized Block Design (CRBD) with two treatment factors and three replications. The first factor was Kelpak PGR soaking at four concentrations: 0, 1, 2, and 3 mL/L (J0–J3). The second factor was NPK Mutiara fertilizer application at rates of 0, 100, 200, and 300 kg/ha (K0–K3). Data were analyzed using analysis of variance (ANOVA) and least significant difference (LSD) at the 5% level. Parameters observed included germination rate, root length, plant height, leaf number, tuber number per plant, tuber weight per plant, and total yield per plot. The findings indicate that the combination of 1 mL/L Kelpak soaking (J1) and 300 kg/ha NPK application (K3) yielded optimal seedling growth and tuber development.

Keywords: Kelpak PGR, NPK fertilizer, germination, shallot, *Allium cepa* L.

1. Introduction

Shallots (*Allium cepa* L.) are a widely cultivated horticultural crop recognized for their pungent flavor and aromatic compounds, which play a crucial role in global cuisines. In Indonesia, shallots are not only central to traditional food practices but also serve as a valuable agricultural commodity that supports smallholder livelihoods and contributes significantly to national food security (Kumar et al., 2022).

The development of True Shallot Seed (TSS) technology has introduced a viable alternative to traditional vegetative propagation. TSS cultivation offers several agronomic advantages, including greater genetic uniformity, resistance to soil-borne diseases, and improved post-harvest handling. Despite its potential, TSS-based production systems remain underexplored, particularly in relation to the optimization of agronomic inputs such as plant growth regulators (PGRs) and mineral fertilization strategies.

Kelpak, a commercial seaweed extract derived from *Ecklonia maxima*, has emerged as a potent biostimulant due to its high content of auxins and cytokinins. Several studies have documented its positive effects on plant physiology. For instance, Hendarto et al. (2021) demonstrated that Kelpak application significantly enhanced root and shoot growth in shallots. Similarly, Nurhayati and Prayoga (2023) found that combining Kelpak with coconut water improved the vegetative development and bulb formation in garlic shallots. In a study on chili peppers, Azzahra et al. (2023) reported increased biomass and flowering when Kelpak was used alongside organic fertilizers. These findings suggest that Kelpak can modulate hormonal activity, stimulate cell division and elongation, and improve plant resilience under various environmental conditions.

Parallel to this, the role of NPK fertilizers comprising nitrogen (N), phosphorus (P), and potassium (K) is well established in supporting essential plant functions, including leaf expansion, root proliferation, and osmotic regulation (Nurhayati & Mustaqim, 2023). These macronutrients are critical for early plant development, especially in the establishment phase from seeds such as true shallot seeds (TSS). Optimal nutrient availability at this stage ensures the plant can allocate resources effectively for both shoot and root growth, setting the foundation for higher yield potential (Triadiawarman et al. 2022).

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In addition to fertilizers, the application of plant growth regulators (PGRs) such as Kelpak, a natural extract containing auxins and cytokinins has gained traction for its role in stimulating physiological responses in plants. Kelpak has been reported to improve seed germination, root elongation, and stress tolerance in various crops (Pepenfus et al., 2013). When used in seed priming or soaking treatments, Kelpak can enhance seed vigor and synchronize germination, which is crucial for achieving uniform growth in the field.

This study aims to evaluate the synergistic effect of Kelpak PGR soaking and varying doses of NPK fertilizer on the germination and early growth of shallots grown from TSS. The results are expected to guide farmers in adopting more efficient cultivation practices that enhance productivity and minimize input waste. By integrating biological and chemical approaches, this research seeks to contribute to sustainable shallot production through evidence-based input management.

2. Materials and Methods

2.1. Study Location and Duration

The experiment was conducted in an open field located in Bodag Hamlet, RT 04/RW 05, Bandungharjo Village, Toroh Subdistrict, Grobogan Regency, Central Java, Indonesia. The study took place from February to May 2024, during the wet season.

2.2. Plant Materials and Inputs

The experimental materials included *Allium cepa L.* True Shallot Seed (TSS), specifically the SANREN F1 variety. Inputs used in the study were Kelpak liquid plant growth regulator (PGR), NPK Mutiara fertilizer (16:16:16), and standard farming tools such as hoes, buckets, measuring tape, hand sprayers, scales, and writing instruments.

2.3. Experimental Design

The study employed a Randomized Completely Block Design (RCBD**)** with two treatment factors, each with four levels, and three replications. This resulted in 16 treatment combinations, repeated three times, totaling 48 experimental units.

- **Factor I** – Kelpak PGR Soaking Dosage (J):
  - J0: 0 mL/L (Control)
  - J1: 1 mL/L
  - J2: 2 mL/L
  - J3: 3 mL/L
- **Factor II** – NPK Mutiara Fertilizer Dosage (K):
  - K0: 0 kg/ha (Control)
  - K1: 100 kg/ha
  - K2: 200 kg/ha
  - K3: 300 kg/ha

2.4. Treatment Application

Seeds were soaked in Kelpak solution for 30 minutes prior to sowing according to treatment levels. NPK fertilizer was applied evenly according to the designated rates at planting time and repeated during vegetative growth stages as needed.

2.5. Parameters Measured

The study measured several key agronomic parameters to evaluate the influence of Kelpak PGR soaking and NPK fertilizer on the growth performance of True Shallot Seed (*Allium cepa* L.). The following measurements were conducted during the vegetative and harvest phases:

2.5.1 Germination Rate (%)

Germination rate was determined by counting the number of seeds that successfully sprouted within 14 days after sowing. A seed was considered germinated when the radicle protruded at least 2 mm. Germination percentage was calculated as:

$$\text{Germination Rate (\%)} = \frac{\text{Number of germinated seeds}}{\text{Total seeds sown}} \, x \, 100$$

2.5.2 Root Length (cm)

Root length was measured at the seedling stage using a standard ruler. Ten randomly selected seedlings from each plot were gently uprooted, and the length of the primary root was measured from the base of the stem to the root tip in centimeters (cm). The average was then calculated for each treatment.

2.5.3 Plant Height (cm)

Plant height was measured at 43 days after sowing (DAS), from the base of the stem (soil surface) to the tip of the longest leaf. Measurements were taken from ten randomly selected plants per plot, and the average was used for analysis.

2.5.4 Number of Leaves per Plant

The number of leaves was counted manually at the same stage (43 DAS). Only fully developed leaves were included in the count. Observations were made on ten randomly selected plants in each plot, and the mean value was calculated.

2.5.5 Number of Tubers per Plant

At harvest, the number of tubers was recorded for each plant by manually separating and counting the bulbs attached to the plant base. The count was averaged across ten representative plants per plot.

2.5.6 Tuber Weight per Plant (g)

Tuber weight was measured at harvest. Individual plants were carefully uprooted, and tubers were separated from shoots. The weight was measured using a digital balance (±0.01 g accuracy) and averaged over ten plants per plot.

2.5.7 Tuber Weight per Plot (g), Including Leaves

This parameter was assessed by weighing the total fresh biomass per plot, including tubers and aerial parts (leaves and stems), using a field scale. The recorded weight represented the cumulative yield performance per treatment plot and was used for yield extrapolation to a per-hectare basis.

2.6 Data Analysis

The data were analyzed using analysis of variance (ANOVA) in SPSS, and treatment means were compared using the least significant difference (LSD) test at a significance level of $p \leq 0.05$.

3 Results and Discussion

3.1. Germination Rate

The germination response of *Allium cepa* TSS to Kelpak PGR soaking and NPK fertilization is presented in Table 1. The highest germination rate (91.67%) was observed in the treatment with 3 mL/L Kelpak (J3) and 0 kg/ha NPK (K0). This suggests that auxin-rich PGRs like Kelpak can significantly enhance the physiological readiness of seeds for germination, even in the absence of additional macronutrients.

Table 1. Germination Rate of Shallot Seeds as Affected by Kelpak Soaking and NPK Fertilizer

Treatment	Germination Rate (%)
J3K0	**91.67**
J2K1	87.33
J1K2	87.67
J0K2	80.67
J1K0	81.00
Mean	82.44

Plant growth regulators such as Kelpak contain bioactive compounds including auxins that enhance cell division, improve seed coat permeability, and promote enzymatic activity involved in germination (Debitama et al., 2022). The enhanced performance in J3K0 implies that initial seed vigor can be significantly elevated through soaking in Kelpak alone.

3.2. Plant Height

Table 2 displays the effect of treatments on shallot plant height at 43 days after sowing (DAS). The tallest plants (19.40 cm) were recorded under J3K0 (3 mL/L Kelpak, 0 kg/ha NPK). This growth enhancement is likely attributed to Kelpak's auxin and cytokinin content which stimulate elongation of shoot tissues.

Table 2. Plant Height at 43 DAS under Different Kelpak and NPK Treatments

Treatment	Plant Height (cm)
J3K0	**19.40**
J0K0	19.00
J0K1	18.50
J3K2	17.80
J2K1	17.47
Mean	17.44

Despite the absence of fertilizer, J3K0 outperformed other treatments, indicating that early application of PGRs plays a dominant role during the vegetative phase. However, in field practice, a combination with adequate fertilization is still vital for sustained growth beyond initial stages.

3.3. Number of Leaves

Leaf production varied slightly across treatments (Table 3). The highest number of leaves (7.67 per plant) was observed in both J0K2 and J0K3, suggesting that NPK fertilizer has a greater effect on leaf development than Kelpak alone.

Table 3. Effect of Treatments on Number of Leaves

Treatment	Number of Leaves
J0K2	**7.67**
J0K3	**7.67**
J2K3	7.33
J2K2	7.33
J1K1	7.00
Mean	6.94

Since leaves are the primary site of photosynthesis, their number and health directly impact biomass production. The positive response under J0K2 and J0K3 underscores the importance of balanced nutrient availability, particularly nitrogen and potassium, which are crucial for cell division and chlorophyll synthesis.

3.4. Tuber Yield per Plot

The total yield of shallots per plot was significantly influenced by both Kelpak soaking and NPK fertilizer application (Table 4). The highest yield per plot was achieved with the combination of 3 mL/L Kelpak and 300 kg/ha NPK fertilizer (J3K3), producing an average of 463.67 grams.

Table 4. Effect of Treatments on Tuber Weight per Plot

Treatment	Tuber Weight (g)
J3K3	**463.67**
J0K3	461.00
J3K0	443.67
J1K3	441.67
J2K2	430.00
Mean	402.94

This result suggests a synergistic effect between the highest dose of PGR and complete macronutrient supply. The availability of nitrogen supports vegetative growth, phosphorus aids in root and bulb development, while potassium improves bulb quality and water regulation.

The outcome also highlights that while Kelpak alone (J3K0) can enhance yield to an extent, maximum productivity is achieved when complemented with NPK fertilization. These findings are in line with previous studies indicating that combined organic and inorganic inputs often yield the best agronomic results (Simanjuntak et al., 2013; Azzahra et al., 2023).

3.5. Estimated Yield per Hectare

Based on a planting density of 160,000 plants per hectare, and an average tuber weight of 11.96 grams per plant, the estimated yield reaches approximately 1.91 tons per hectare. While this is slightly below the expected commercial yield of 2–4 tons/ha for TSS shallots, environmental constraints such as excessive rainfall during the study period likely impacted crop performance.

Heavy rainfall and associated waterlogging during the growth period led to suboptimal bulb development and yellowing of leaf tips, typical stress symptoms in shallot cultivation. Nevertheless, the recorded yield under experimental conditions remains promising, especially considering the optimization potential with better weather control and integrated nutrient management.

4 Conclusion

The application of Kelpak plant growth regulator (PGR) and NPK Mutiara fertilizer demonstrated a significant impact on the germination, vegetative growth, and yield performance of shallots grown from True Shallot Seed (*Allium cepa* L.). Among the treatment combinations, 1 mL/L Kelpak soaking paired with 300 kg/ha NPK fertilizer (J1K3) produced the most favorable results across multiple parameters, including root development, number of tubers, and tuber weight per plant. While Kelpak independently enhanced seed germination and early vegetative traits, optimal productivity was achieved when complemented with adequate nutrient input through NPK fertilization. Although the yield observed was slightly below commercial benchmarks due to climatic constraints, the findings affirm that integrating biostimulants like Kelpak with balanced fertilization can substantially improve the agronomic performance of TSS-based shallot cultivation. These findings underscore the importance of precise input management in optimizing shallot productivity and provide practical recommendations for enhancing smallholder farming systems. For future research, it is recommended to investigate the interaction of Kelpak with organic nutrient sources and to assess its efficacy under diverse agroecological conditions through multi-season and multi-location trials to validate its broader applicability and sustainability in different production systems.

Acknowledgement

The authors would like to express their gratitude to the Universitas Slamet Riyadi for their support in providing both facilities and financial assistance for this research.

Conflict of Interest

The authors declare no conflicts of interest.

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