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Optimizing Growth and Yield of Shallot by Different Water-soluble Fertilizer Package

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***Abstract*—** Proper nutrient management, particularly through fertigation using water-soluble fertilizers, is essential for optimizing the vegetative growth and yield of shallots. This study aimed to evaluate the effects of different water-soluble fertilizer packages on shallot growth and yield. Conducted under a rain shelter at MARDI Sintok, the experiment utilized three water-soluble NPK formulations—T1 (high concentration), T2 (intermediate concentration), and T3 (low concentration)—arranged in a randomized complete block design (RCBD). The results indicated that the fertilizer formulations significantly influenced plant height and bulb fresh weight, whereas the number of bulbs per plant was not significantly affected. The intermediate fertilizer formulation (T2) consistently produced superior results, achieving a maximum plant height of 62.7 cm and the highest bulb fresh weight of 287.16 g. The number of bulbs ranged from 4.3 to 4.7 per plant across all treatments, suggesting that bulb multiplication is more strongly regulated by genetic and environmental factors rather than variations in nutrient supply. In conclusion, balanced fertilization at moderate nutrient levels (T2) represents the most efficient nutrient strategy for maximizing shallot yield without the drawbacks of fertilizer over-application.

***Keywords*—** Shallot, Water-soluble fertilizer, Fertigation, Nutrient management, Bulb yield.

I. INTRODUCTION

Shallot (Allium cepa L. Aggregatum Group) is an important bulb vegetable cultivated for household consumption, food processing, and commercial trade. Its productivity and bulb quality are strongly influenced by water availability, soil fertility, cultivar, planting density, and nutrient-management practices. Because shallot produces an underground storage organ within a relatively short growing period, adequate and timely nutrient supply is essential for vigorous vegetative growth, bulb initiation, bulb enlargement, and final yield. Nitrogen (N), phosphorus (P), and potassium (K) are among the major nutrients required for shallot production. Nitrogen promotes leaf development and photosynthetic activity, phosphorus supports root growth and bulb initiation, while potassium contributes to carbohydrate transport, bulb enlargement, water regulation, and crop quality. However, excessive nitrogen may prolong vegetative growth and delay bulb maturity, whereas insufficient phosphorus or potassium can restrict bulb development and reduce marketable yield. Research on onion and shallot has shown that yield responses to nitrogen and phosphorus vary according to soil fertility, irrigation, cultivar, and environmental conditions (Gebretsadik & Dechassa, 2018; Júnior et al., 2016; Piri & Naserin, 2020).

Conventional fertilizer application may not always provide nutrients in synchrony with crop demand. Nutrients can be lost through leaching, runoff, volatilization, or fixation, particularly in sandy or low-organic-matter soils. In contrast, water-soluble fertilizers can be dissolved in irrigation water and applied in precise amounts and at appropriate crop-growth stages. This approach, commonly known as fertigation, supplies nutrients directly to the active root zone and allows the rate and timing of nutrient application to be adjusted according to crop requirements. Fertigation has been reported to improve fertilizer-use efficiency and marketable bulb yield compared with conventional soil application in onion production (Prabhakar et al., 2011; Kakade et al., 2015; Babu et al., 2018).

Several studies have demonstrated the potential of water-soluble fertilizer packages for improving the growth, yield, and quality of small onion. Vairavan et al. (2021) reported that soil-test-based application of water-soluble NPK combined with sulfur and liquid micronutrients improved plant growth, bulb characteristics, yield, and quality. In a related study, Vairavan et al. (2023) found that a 125% soil-test-based NPK treatment supplied through TNAU water-soluble fertilizers, together with sulfur and liquid micronutrients, produced greater nutrient uptake and nutrient-use efficiency than lower fertilizer rates. Similarly, Sutardi et al. (2022) found that the combined application of N, P, K, magnesium, and sulfur increased shallot bulb production in sandy-loam soil, demonstrating the importance of balanced and complete nutrient management. These findings suggest that fertilizer formulation, nutrient ratio, application method, and crop-growth stage may interact to influence shallot performance.

Water management must also be considered when evaluating water-soluble fertilizer packages. Onion-type crops have relatively high sensitivity to soil-moisture stress, particularly during bulb formation and enlargement. The Food and Agriculture Organization estimates that onion crops may require approximately 350–550 mm of water during the growing period, although actual requirements depend on climate, soil type, crop duration, and growth stage (FAO, 1984). Fertigation can therefore provide both water and nutrients in a coordinated manner; however, inappropriate fertilizer concentration, application frequency, or nutrient balance may cause nutrient losses, salt accumulation, or inefficient fertilizer use. Although previous studies have investigated individual nutrients, fertigation schedules, and selected water-soluble fertilizer formulations, limited information is available regarding the comparative performance of complete water-soluble fertilizer packages for shallot under specific local production conditions. Different packages may vary in NPK ratio, secondary nutrients, micronutrients, concentration, and application schedule. Therefore, evaluating these packages is necessary to identify a treatment that promotes optimum vegetative growth, efficient nutrient uptake, bulb development, yield, and economic production.

This study aims to evaluate the effects of different water-soluble fertilizer packages on the growth and yield of shallot. Specifically, it seeks to determine the fertilizer package that produces the best plant growth, bulb characteristics, total yield, and marketable yield. The results may provide a basis for improving nutrient-management recommendations and developing a more efficient fertilizer program for shallot production.

II. METHODOLOGY

A. Locations and Experimental Materials

This experiment was conducted in the rain shelter structure at Malaysia Agricultural Research and Development Institute, Sintok, Kedah (6.488305, 100.482) from Mac 2026 to May 2026. The planting materials used in this study was shallot (Allium cepa) var. BAW1. Uniformed-sized onion bulbs were used as the planting material in this study.

B. Treatments and Experimental Design

This experiment consisted of three water-soluble NPK rate treatments arranged in a randomized complete block design (RCBD) with four replications. The replications used were represented as a block to reduce the errors and interferences in the field. Each of the replicates consisted of twelve plants with divided into four plants/ polybag. The total numbers of plants were used in this study is 144. Three different AB fertilizer formulation was applied in this experiment with different fertilizer compositions. The descriptions of the treatments used in this study were followed as table 1.0.

Table 1. *Application of different fertilizer formulation on shallot.*

Fertilizer component	T1 (g)	T2 (g)	T3 (g)
Stock A			
Calcium nitrate	1150	766.67	383.33
Iron (Fe)	19	12.67	6.33
Stock B			

Potassium nitrate	660	440	220
Magnesium sulphate	403	268.67	134.33
Mono-potassium phosphate	222	148	74
Manganese	1.7	1.13	0.57
Boron	3.3	2.2	1.1
Copper	0.2	0.13	0.07
Zinc	1.5	1.0	0.5
Ammonium molybdate	0.2	0.13	0.07

Each fertilizer formulation treatments were mix together according to the specific amount of fertilizer for both fertilizer stock A and B.

C. Plant maintenances and Treatment Application

Bulbs of the BAW 1 variety were trimmed by removing approximately 10% of their upper portion before being planted in a growing medium consisting of burnt rice husk. Four bulbs were planted in each polybag. During the establishment stage, the bulbs were irrigated with 3 L of water per day using a drip irrigation system. Between 15 and 30 days after planting (DAP), once all bulbs had sprouted, the fertigation treatments were applied manually at a rate of 2 L per polybag per day. From 31 to 50 DAP, the fertigation volume was reduced to 1 L per polybag per day. During 51 to 60 DAP, the fertigation volume was further reduced to 500 mL per polybag per day. Irrigation was completely withheld from 61 to 70 DAP to facilitate bulb maturation before harvest. The bulbs were harvested at the end of the experimental period and labelled according to their respective treatment groups. After data collection, the harvested bulbs were cured by air-drying under a rain shelter structure with 100% light transmission. Pest and disease management, including pesticide applications, was carried out as required throughout the growing period.

D. Data collection

Growth performance was evaluated based on three selected parameters: plant height, number of bulb divisions, and fresh bulb weight. plant height was measured using a measuring tape at 30 and 50 days after planting (DAP). The number of bulb divisions was determined manually at 50 DAP by counting the total number of divisions produced per bulb. Fresh bulb weight was measured at 75 DAP following harvest using a digital weighing balance.

E. Data collection

All the data taken was computed using statistical analysis software (SAS) version 9.4 (SAS Institute Inc., Cary, NC). GLM procedure was used to do analysis of variance and mean comparisons were calculated using Least Significant Difference (LSD) at $P \leq 0.05$.

III. RESULTS AND DISCUSSIONS

The fertilizer formulations significantly influenced plant height and bulb fresh weight of shallot, whereas the number of bulbs per plant was not significantly affected (Table 2). Among the three formulations, T2 (Formulation 2) consistently produced superior growth and yield performance compared to T1 and T3. For plant height, shallots treated with T2 achieved the greatest height (62.7 cm), which was significantly higher ($P \leq 0.05$) than T1 (53.5 cm) and T3 (57.3 cm). The increase in plant height under T2 represented an improvement of 17.2% and 9.4% compared with T1 and T3, respectively. No significant difference was observed between T1 and T3, indicating that the intermediate fertilizer formulation was more effective in promoting vegetative growth than either the higher or lower nutrient concentrations.

Table 2: *Effect of different fertilizer formulation on plant height, number of bulb and bulb fresh weight of shallot*

Treatments	Plant height (cm)	Number of bulb	Bulb fresh weight (g)
T1 – Formulation 1	53.5b	4.7	211.13b
T2 – Formulation 2	62.7a	4.3	287.16a
T3 – Formulation 3	57.3b	4.3	241.32ab

Means with the different letters in each column indicate significant differences at 95% probability level according to LSD

A similar trend was observed for bulb fresh weight. The highest bulb fresh weight was recorded in T2 (287.16 g), followed by T3 (241.32 g) and T1 (211.13 g). Bulb fresh weight under T2 increased by 36.0% and 19.0% relative to T1 and T3, respectively. Statistical analysis revealed that T2 produced significantly heavier bulbs than T1, while T3 exhibited intermediate performance and was not significantly different from either T1 or T2. These findings suggest that Formulation 2 provided a more favourable nutrient balance for assimilate accumulation and bulb development. In contrast, the number of bulbs per plant ranged from 4.3 to 4.7 bulbs and was not significantly affected by fertilizer formulation. T1 recorded the highest bulb number (4.7 bulbs), whereas both T2 and T3 produced 4.3 bulbs per plant. The absence of significant differences indicates that bulb formation in shallot may be more strongly regulated by genetic factors and environmental conditions rather than by variations in nutrient supply within the range tested. Overall, the results demonstrate that the intermediate fertilizer formulation (T2) was the most effective treatment for enhancing vegetative growth and increasing bulb yield without significantly affecting bulb multiplication.

The superior performance of T2 in promoting plant height and bulb fresh weight indicates that an optimal balance of macro- and micronutrients is essential for efficient shallot growth and bulb development. Based on Table 1, T2 contained moderate concentrations of calcium nitrate, potassium nitrate, magnesium sulphate, mono-potassium phosphate, and essential micronutrients, which collectively supplied sufficient nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and trace elements required for physiological processes.

The significant increase in plant height observed under T2 can be attributed to the adequate supply of nitrogen and potassium. Nitrogen is a major component of chlorophyll, amino acids, proteins, and nucleic acids, thereby promoting cell division and leaf expansion. Potassium, meanwhile, plays an important role in enzyme activation, stomatal regulation, and photosynthate translocation. The balanced availability of these nutrients in T2 likely enhanced photosynthetic efficiency and biomass accumulation, resulting in greater vegetative growth. In contrast, the lower nutrient concentration in T3 may have limited nutrient availability, while the excessive nutrient concentration in T1 may have caused nutrient imbalance or reduced nutrient use efficiency (Kurniawan et al., 2020). Calcium and magnesium also contributed to the improved performance observed in T2. Calcium is essential for cell wall formation, membrane stability, and root development, whereas magnesium is the central atom in chlorophyll molecules and is directly involved in photosynthesis. The balanced supply of these nutrients in T2 may have supported stronger plant growth and improved assimilate production (Sopha et al., 2021).

Bulb fresh weight was highest under T2, suggesting that moderate nutrient levels favoured the partitioning of photosynthates towards bulb development. Bulb enlargement depends largely on the translocation and accumulation of carbohydrates from leaves to storage organs. Potassium is known to enhance carbohydrate synthesis and transport, while phosphorus plays an important role in energy transfer through ATP formation. Therefore, the balanced NPK composition in T2 likely increased the efficiency of assimilate translocation to bulbs, resulting in greater bulb fresh weight (Ritung et al., 2022). The lack of significant differences in bulb number among treatments indicates that bulb multiplication was less responsive to fertilizer composition than bulb enlargement.

Shallot bulb formation is strongly influenced by varietal characteristics, photoperiod, and environmental factors, while nutrient availability mainly affects the size and weight of bulbs rather than the number produced. Similar findings have been reported in previous studies where nutrient management significantly improved bulb yield and biomass accumulation but had limited effects on bulb number (Ritung et al., 2022;). Overall, the present findings suggest that Formulation 2 provided the most suitable nutrient balance for shallot cultivation, promoting superior vegetative growth and bulb yield compared with both higher (T1) and lower (T3) fertilizer concentrations. These results indicate that balanced fertilization, rather than excessive nutrient application, is essential for maximizing shallot productivity

IV. CONCLUSION

Balanced fertilization at moderate nutrient levels (T2) is more effective for shallot production than either excessive (T1) or deficient (T3) rates, because it optimizes nitrogen, phosphorus, potassium, calcium, and magnesium supply for both vegetative growth and bulb enlargement. This balance enhances photosynthesis, assimilate translocation, and bulb fresh weight, while bulb number remains largely governed by variety and environment rather than fertilizer dose. Overall, Formulation 2 represents the most efficient nutrient strategy for maximizing shallot yield without over-application of fertilizer.

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