Enhancing of shallot (Allium cepa L. var. ascalonicum) yield through soil organic carbon improvement by blotong compost application

by Christa Dyah Utami

Enhancing of shallot (*Allium cepa* L. var. *ascalonicum*) yield through soil organic carbon improvement by blotong compost application

Edi Siswadi[1], *Gallyndra Fatkhu* Dinata[1], *Christa Dyah* Utami[1], *Abdurrahman* Salim[1], and *Fadil* Rohman[1]

[1] Department of Agricultural Production, Politeknik Negeri Jember, Indonesia

Abstract. Shallots (*Allium cepa* L. var. *ascalonicum*) are one of the most important commodities. The decline in productivity is not only related to fluctuations in planting area, but also to a decline in soil fertility, which is largely due to a lack of organic matter returning to the soil. National data shows that 72% of agricultural land contains less than 2% soil organic carbon, which is classified as low. This study aims to increase soil organic carbon content and shallots productivity through the application of blotong compost. This study evaluated four technology packages: (i) consisting of 30 tons per hectare of blotong compost combined with PGPR; (ii) 30 tons per hectare of blotong compost alone; (iii) PGPR alone; and (iv) as a control without the application of blotong compost or PGPR. The treatments were analyzed using LSD. The results showed that the application of 30 tons per hectare of blotong compost significantly increased the soil's organic carbon content, which in turn increased the growth and yield of shallots. These findings highlight the potential of blotong compost as an organic amendment to restore soil fertility and support a sustainable shallot production.

1. Introduction

Shallots (*Allium cepa* L. var. ascalonicum) are one of Indonesia's strategic horticultural commodities due to their high economic value and steadily increasing market demand throughout the year. Domestic consumption of red onions in 2023 reached 858,396 tons, with per capita consumption per week at 0.55 ounces. East Java is the largest contributor to national shallot consumption, with a 56.46% share. However, shallot production in East Java has stagnated from 2021 to 2023, with a production decline of 3.37% [1].

Corresponding author: edi_siswadi@polije.ac.id

Shallot production faces various obstacles, particularly a decline in soil fertility due to intensive use of chemical fertilizers, repeated soil cultivation, and minimal return of organic matter to the land. These conditions have caused many shallot fields to experience a decline in soil organic carbon content, which has led to a decrease in the soil's ability to provide nutrients, retain moisture, and support optimal bulb formation.

Soil organic carbon is a key indicator of soil fertility that greatly determines the productivity of horticultural crops. Soils with low organic carbon content tend to have unstable structures, low cation exchange capacity, decreased microorganism activity, and suboptimal fertilizer use efficiency. In shallots, which require loose, nutrient-rich soil with good aeration, low organic matter content can inhibit bulb enlargement, thereby reducing yields. Ideally, the organic carbon content that supports maximum plant growth and production is 5% [2]. Low soil organic carbon content can affect various aspects of the physical, chemical, and biological properties of the soil, which ultimately has a negative impact on plant growth and production.

One way to increase soil organic carbon is through the application of organic materials, such as compost. Bagasse, which is solid waste from sugar cane processing in the sugar industry, is a very abundant source of organic material in sugar cane growing areas. After composting, blotong contains organic carbon, nitrogen, phosphorus, potassium, and a number of microelements that can improve the physical, chemical, and biological properties of soil. Several studies have shown that blotong compost can increase cation exchange capacity, improve aggregate structure, and increase water retention in various types of soil. However, its use in high-value horticultural commodities, including shallots, is still relatively rare.

Although a number of studies have evaluated the use of various organic sources such as manure, biochar, straw, and general compost on shallots, research specifically examining blotong compost as a source of soil organic carbon enhancement in shallot plants is still very limited. In addition, most previous studies only assessed plant growth or yield responses, without linking them to changes in soil organic carbon content as a mechanistic variable explaining the increase in yield. Variations in blotong dosage in previous studies have also not provided consistent recommendations, as they did not focus on onion plants and were not analyzed in the context of improving soil quality. Thus, there is still a research gap in understanding the mechanism by which blotong compost can increase shallot yields through increased soil organic carbon. This study aims to increase soil organic carbon content and shallots productivity through the application of blotong compost

18

2. Materials and Methods

The study was conducted from June to September 2025 on research installation of the Politeknik Negeri Jember using one way anova, and continued with the LSD test with the following treatments This study evaluated four technology packages: (i) consisting of 30 tons per hectare of blotong composts combined with Plant Growth Promoting Rhizobacteria (PGPR); (ii) 30 tons per hectare of blotong composts only; (iii) PGPR only; and (iv) as a control without the application of blotong composts or PGPR. The research was conducted as follows:

1. Increase in soil C-Organic through the addition of blotong compost, Trichoderma, manure as well as PGPR

The shallot cultivation area was treated with blotong compost and PGPR. This stage focused on the use of blotong compost, which had been researched previously by researchers. The blotong fertilizer innovation was carried out by adding bacteria from sugarcane roots (PGPR) and soil exploration bacteria. PGPR (Plant Growth Promoting Rhizobacteria) is a group of beneficial bacteria that colonize the soil 1–2 mm around the root zone and promote plant growth both directly and indirectly [3]. Blotong fertilizer was applied by scattering it around the plants at a rate of 30 tons/ha. In one container of the sprinkler, Application of *Trichoderma* according to [4][5], and 1 liter of PGPR bacteria and 18 liters of water are added [6]. The PGPR application is carried out once every two weeks from when the plants are 2 months old until two weeks before harvest, at a concentration of 25 ml/liter. The PGPR contains Acetobacter sp. 3.3 x 10^8 CFU/ml, Lactobacillus sp. 2.3 x 10^7 CFU/ml, Pseudomonas sp. 2 x 10^7 CFU/ml, Rhizobium sp. 1.22 x 10^9 CFU/ml, N-fixing bacteria 1.11 x 10^{11} CFU/ml, and Phosphate-solubilizing bacteria 1.74 x 10^8 CFU/ml.

2. Soil Chemical Analysis.

Soil fertility was assessed through soil organic carbon analysis using a series of methods. The four treatments were sampled using a homogeneous sampling method. Assessments were conducted periodically, resulting in 16 observation samples for each analysis. The analysis to be conducted is soil organic carbon analysis.

3. Shallot production analysis.

Evaluating the growth and yield of shallots from the vegetative to the generative stage.

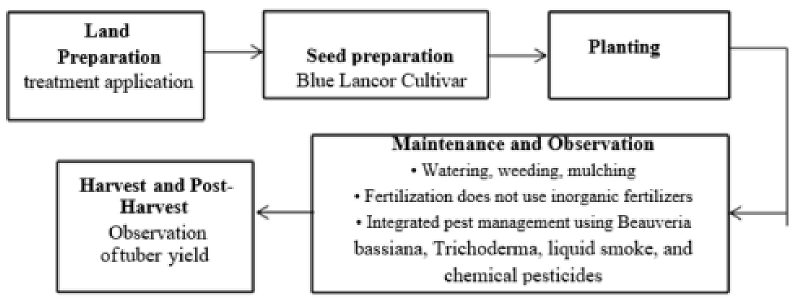

Fig. 1. Experimental Procedure.

3 Result and Discussion

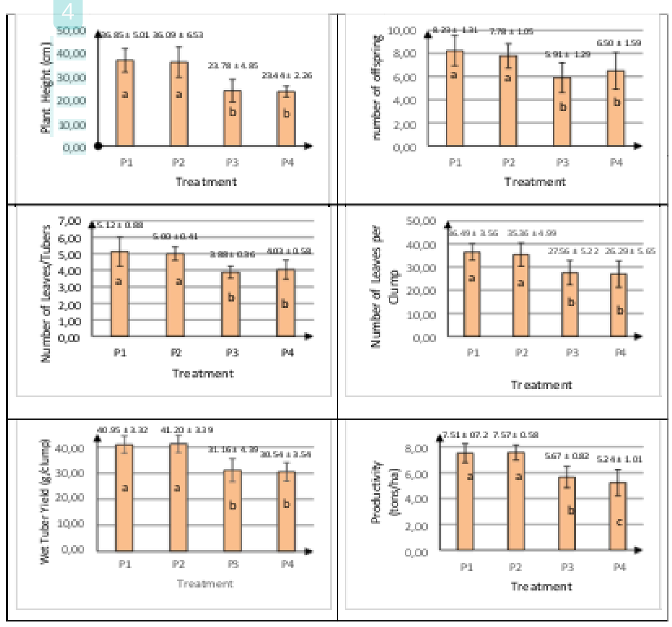

Fig. 2. Average of plant performances

The effects of treatments P1, P2, P3, and P4 on plant growth parameters and crop yield are shown in the diagram above, indicating significant variations between treatments. The ANOVA test followed by the LSD comparison test shows that different letters indicate significant differences at the specified significance level ($p < 0.05$). Plants treated with P1 (36.85 cm) and P2 (36.09 cm) had average heights that were not significantly different ("a"). On the other hand, P3 (27.78 cm) and P4 (23.44 cm) had significantly lower heights ("b"). Treatments P1 (8.23) and P2 (7.98) produced the highest number of offspring ("a"). Meanwhile, P3 (6.58) and P4 (6.50) produced fewer offspring ("b"). Number of leaves per clump. P1 (40) and P2 (37.56) were higher than P3 (27.56) and P4 (29.16), with P1 and P2 not significantly different from each other, but both significantly different from P3 and P4.

Number of leaves/tubers – This parameter indicates that the four treatments did not differ significantly statistically (values ± approximately 5.0–5.1), so treatment P had no significant effect on this parameter. Wet tuber yield per clump. P1 (43.05 g) and P2 (41.20 g) showed the highest yields and were not significantly different from each other. P3 (31.16 g) and P4 (30.35 g) were much lower and significantly different from P1/P2. Productivity (tons/ha). P1 (7.51 tons/ha) and P2 (7.57 tons/ha) showed the highest productivity with the letter "a". P3 (5.24 tons/ha) and P4 (5.27 tons/ha) were in the lower group ("b").

Looking at the diagram above, it is clear that P1 shows high results in all observation parameters, both vegetative and generative, followed by P2. The high growth of shallot plants shows a relatively good trend when using (i) Technology Package 1, which consists of 30 t ha^{-1} of compost combined with Plant Growth Inhibiting Bacteria (PGPR) and (ii) Technology Package 2, which consists of 30 tons per hectare of blotong compost compared to (iii) Technology Package 3, which consists of PGPR alone; and (iv) Technology Package 4, as a control without the addition of blotong compost or PGPR. These growth differences may be due to several factors, including environmental conditions, light availability, nutrient availability, and the treatment applied to the soil. The treatment applied to the soil, including the addition of blotong compost and PGPR, or the addition of blotong compost alone, affected the growth of shallots compared to treatments that only used PGPR or no treatment. The plants had the same factors, but if the environment and treatment applied were different, they would produce different growth results[7].

Cell division increases the number of leaves by forming apical meristems, whose cells actively divide by mitosis, forming leaf primordia that later develop into new leaves [8][1]. Meanwhile, an increase in the number of cell divisions refers to the result of the cell division process. Growth is characterized by an increase in cell size or number, resulting in an increase in tissue and organ size, which in turn forms new living organisms. Plant growth can be used as a measure of a plant species' suitability to its environment. The maximum number of offspring occurs when plants have good genetic traits and are exposed to favorable environmental conditions that are suitable for plant growth and development [9].

Similarly, crop yields will correspond to the results seen in the vegetative growth parameters of the plants. A supportive environment has a significant impact on plant growth and crop yield [10]. Treatments P1 and P2, with the addition of blotong compost, were able to improve the physical properties of the soil by providing organic binding agents, increasing water retention capacity, improving aeration, reducing soil mass density, and increasing the overall elasticity and resistance of the soil [11].

Increasing soil organic carbon is one of the main mechanisms in improving soil quality. Blotong compost, as solid organic waste from the sugar industry, contains lignocellulose, minerals, and easily decomposable organic fractions. These contents play a role in increasing organic C content, improving soil structure, increasing water holding capacity, and providing energy for beneficial microorganisms [12].

The results of the study show that treatments P1 and P2 had higher growth and yield values for shallots compared to P3 and P4. This pattern indicates that the increase in organic carbon through the addition of compost is optimal, not linear. At low to moderate doses (P1–P2), organic carbon increases at a rate that supports active mineralization, decomposition, and soil microbial activity. This is consistent with [13], who argue that moderate increases in organic matter can improve aeration, increase nutrient availability, and reduce environmental stress on roots.

C-organic from blotong compost improves soil structure and increases the availability of aeration pores. These conditions are an ideal habitat for rhizosphere bacteria, especially PGPR groups, which are generally aerobic [5]. When the PGPR population increases, a number of physiological mechanisms begin to work, including: phytohormone production (IAA, GA, cytokinin), phosphate solubilization, K and micronutrient mobilization, non-symbiotic nitrogen fixation, and induction of plant systemic resistance (ISR). Thus, the increase in growth in P1–P2 was not only due to the nutrient content of the composted manure, but also due to increased microbial activity that strengthened root function and plant physiology.

Conversely, at high doses (P3 and P4), the decline in growth may be due to increased soil density caused by the fine fraction of blotong, high moisture content, and the potential immobilization of nitrogen when decomposers balance the C/N ratio [14]. These conditions cause nutrient uptake to be disrupted and aerobic microbial activity to decline.

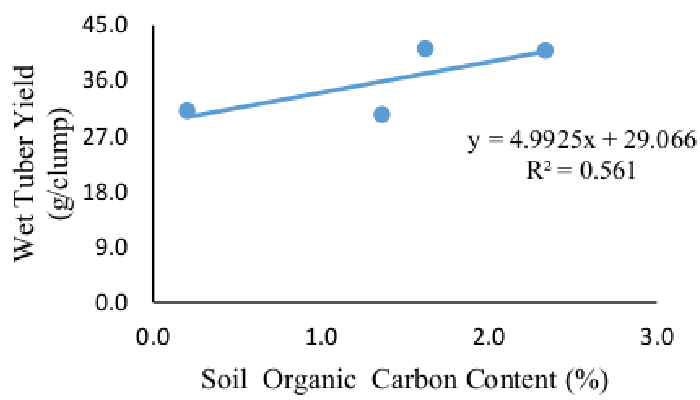

Fig. 3. The relationship between increasing soil carbon and wet tuber yield

The trend line equation is $y = 4.9925x + 29.066$, with a coefficient of determination (R^2) = 0.561. This means that for every 1% increase in soil organic carbon content, wet tuber yield increases by approximately 4.99 g per clump. The positive slope indicates a positive correlation between soil organic carbon and wet bulb yield—as soil organic carbon increases, bulb yield also tends to increase. However, an R^2 value of 0.561 indicates a moderate correlation, meaning that approximately 56.1% of the variation in wet bulb yield can be explained by soil organic carbon content, while the rest is influenced by other factors. An R^2 value of 0.561 indicates that 56.1% of the variation in shallot tuber yield can be explained by soil organic carbon content. Although the relationship is not entirely strong, this upward trend shows that organic matter from blotong compost plays a significant role in increasing crop productivity. These results are in line with [13], who stated that organic carbon is an important component that improves soil structure, increases cation exchange capacity (CEC), and provides an energy source for soil microorganisms that support plant growth.

Based on the graph above the relationship between soil organic carbon and wet tuber yield soils with higher organic carbon content tend to support better plant growth and yield, likely because organic matter improves soil structure, nutrient availability, and water retention. However, since the correlation is moderate rather than strong, other environmental or management factors also play significant roles in determining the wet tuber yield. The addition of PGPR can reduce plant sensitivity to drought stress. Pseudomonas Pb04 dominantly suppresses the effects of drought stress during the vegetative growth phase, while Bacillus Pb03 has a more dominant effect on drought stress occurring during the tuber initiation, tuber development, and ripening phases [15].

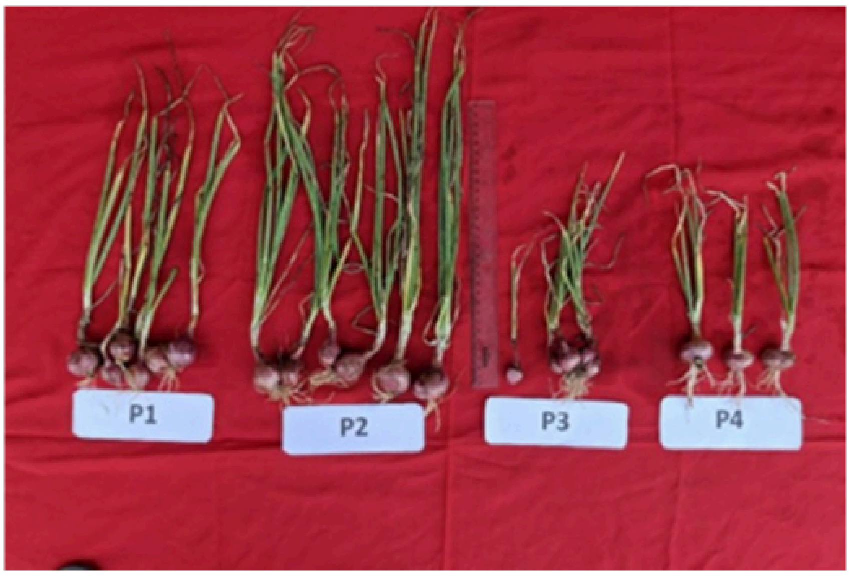

Fig. 4. Plant performance

4. Conclusion

The treatment of technology packages produced significantly different results in various parameters, namely plant height, number of tillers, number of leaves per bulb, and number of leaves per clump. The results of the study showed differences between treatments in several parameters of shallot growth. Treatment P1 proved to be the most consistent in increasing vegetative components, namely the number of tillers, number of leaves per bulb, and number of leaves per plant with good stability. Treatment P2 ranked in the middle with fairly high results and relatively good stability, especially in terms of the number of tillers and the number of leaves per bulb. Meanwhile, P3 and P4 were less supportive of increasing the number of tillers and leaves, and showed high result variability. Thus, P1 (technology package 1) can be recommended as the best treatment to support shallots productivity vegetatively, while P2 has the potential to be an alternative with adequate result stability.

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PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7