Effects of Biocontrol Product Bio P60 and Liquid Organic Fertilizer on The Development of Fusarium Wilt and Yield of Shallot

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ABSTRACT

Shallot production is frequently threatened by Fusarium wilt. Chemical control has proven ineffective, highlighting the need for environmentally friendly alternatives such as the application of liquid organic fertilizer combined Bio P60. The study evaluated the effectiveness of the fertilizer and Bio P60 in controlling the disease and their impact on shallot growth and yield. A completely randomized block design with 16 treatments and three replicates was used, testing Bio P60 application (control, 20 mL per plant applied 1, 3, or 5 times) and the fertilizer (control, 3, 5, or 7 mL L^{-1}). Results showed that the five times application of Bio P60 significantly delayed the incubation period by 61.71%, suppressing disease incidence by 66.67% and reducing AUDPC by 69.84%. Bio 60 also increased plant height by 30.75%, number of leaves by 40.7%, number of bulbs by 75.6%, bulb fresh weight by 104.53%, blub dry weight by 51.1%, and total biomass compared to control. However, the fertilizer application has no significant effect on all variables, and no interaction was found between Bio P60 and the fertilizer. These findings suggest Bio P60 is an effective biocontrol agent for suppressing Fusarium wilt and improving shallot yield, offering a sustainable alternative to chemical treatments.

Keywords: Eco-friendly method; *Fusarium oxysporum*; *Pseudomonas fluorescens*; Shallot

INTRODUCTION

Shallots are a type of vegetable crop in incredible demand by the community and have great potential to be cultivated in Indonesia (Saptana et al., 2021). Shallots are utilized in different ways, including conventional pharmaceuticals, crude materials for the nourishment industry, and flavors (Moldovan et al., 2022). The dietary substance contained in 100 g of shallots is 39 calories, phosphorus 40 mg, iron 0.8 mg, protein 1.5 g, hydrate charcoal 0.3 g, fat 1.2 g, calcium 36 mg, and vitamin C 2 g (Sun et al., 2019). Indonesia's shallot production in 2023 is 1,985,233 tons, which is still low compared to the shallot production data for 2021, which is 2,004,590 tons (BPS, 2024). The low shallot production is caused by several factors, including bad weather that does not support plant development, wasteful utilization of production facilities, and plant pests and diseases (Manwan et al., 2020; Ortiz-Bobea et al., 2021).

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Plant pests and diseases reduce shallot yield (Rovicky et al., 2024). Fusarium wilt is a plant disease caused by *Fusarium oxysporum* f. sp. *cepae,* a primary disease in shallot plantations (Sakane et al., 2024). This disease can harm shallot plants. Twisting leaves are caused by shallots infected with Fusarium. Fusarium wilt may cause Indonesian shallot producing centers to lose at least 50% of their yield, according to Hadiwiyono et al. (2020). Harvest failure is another consequence of infected shallot plants (Sharma et al., 2024). Link first defined the genus Fusarium in 1809, citing the specific conidia that had a banana or canoe shape (Samiksha & Kumar, 2021). The most harmful species are Fusarium species (Ajmal et al., 2023). Soil-borne pathogens are another name for them.

Control of Fusarium wilt now depends on chemical fungicides (Tang et al., 2020; Baloch et al., 2021), along with measures such crop rotation (Theron et al., 2023) and fumigation (El-Aswad et al., 2023). Inappropriate utilize of chemical fungicides can hurt the environment and result in hurtful buildups in agrarian items, posturing a risk to human wellbeing (McDonald et al., 2019; Okagu et al., 2023). To address the inconvenient impacts of chemical fungicides, it is vital to investigate elective ecologically inviting control strategies, counting organic specialists (Bubici et al., 2019; Tang et al., 2020). One of the organic operators utilized to combat contagious and bacterial pathogens is the opposing microscopic organisms known as *Pseudomonas fluorescens*. One strain of the adversarial microscopic organisms, *P. fluorescens* P60, has illustrated viability in controlling a run of plant pathogens, especially those found within the soil. This has been watched in research facility, nursery, and field ponders (Bhetwal et al., 2021). *P. fluorescens* P60 created auxiliary metabolites with bioactive compounds. The fluid detailing for the opposing microscopic organisms is called Bio P60 (Soesanto et al., 2019). The item incorporates bioactive compounds in auxiliary metabolites gotten from *P. fluorescens* P60, which produces different compounds, counting anti-microbials, lytic chemicals, and siderophores.

Expanded shallot generation is affected by inside components, such as plant hereditary qualities, and outside variables, such as soil and water reasonableness, climate, and intelligent with other living life forms (Zhang et al., 2022a). An increment in shallot generation can be upheld by utilizing natural fertilizers, such as NASA, which has been commercially accessible for this reason (Lasmini et al., 2019; Hayati, 2020). The fluid natural fertilizer could be a characteristic fertilizer made from extricates of characteristic fixings sourced from animals and poultry excrement, plants, and other natural materials. It is prepared utilizing ecologically neighborly innovation based on the Zero Emanation Concept guideline (Sopha & Lukman, 2019; Husen et al., 2022). NASA fluid natural fertilizer quickens plant development, diminishes bother assaults, has no hurtful impacts on plants or the environment, and is secure for people. The nutrient content of NASA liquid organic fertilizer is as follows: N 0.12%, P2O5 0.03%, K 0.31%, S 0.12%, and Cl 0.29% (Wanimbo & Tuhuteru, 2020; Serdani et al., 2023). The combined effect of Bio P60 and NASA has not been studied. A study assessed the effectiveness of NASA liquid organic fertilizer and Bio P60 in controlling Fusarium wilt and its impact on shallot growth and yield in plants. The benefits of this research ensure that the Fusarium wilt of shallots can be tackled organically.

MATERIALS AND METHOD

The research was conducted in Banjarsari Wetan Village, Sumbang Subdistrict, Banyumas Regency, with coordinates of 7°21'47" S 109°15'04" E, altitude of 220 m above sea level and tropical climate, and at the Plant Protection Laboratory, Faculty of Agriculture, Universitas Jenderal Soedirman for five months.

Preparation of Bio P60

Bio P60 production initiates by inoculating *P. fluorescens* P60 in as much as 1 test tube into 1 L of liquid King's B. incubated with shaking at 135 rpm at room temperature for 3 days (Han et al., 2012). Preparation of propagation media with 200 g of boiled catfish and 80 g of shrimp paste in 20 L of water. Filter and transfer to a sterile jerry can, then cool. After cooling, 40 mL of liquid *P. fluorescens* P60 was added to the media and shaken at 135 rpm at room temperature for 3 days. The density was calculated to be 10^9 cfu mL^{-1} (Wang et al., 2024).

Preparation of *Fusarium oxysporum* f.sp. *cepae*

The pathogenic organism *F. oxysporum* f.sp. *cepae* was disconnected from onion bulbs showing Fusarium shrivel side effects. The bulbs were surface sterilized with 70% alcohol, washed with sterile water three times, and dried on sterile filter paper. Next, the tubers were cut into small pieces, placed on PDA media in Petri dishes, and incubated at room temperature for 5 days (Kalman et al., 2020). To confirm *F. oxysporum* f.sp. *cepae*, the fungus was identified microscopically and compared with the literature (Sharma et al., 2024). The fungus was cultured in PDB liquid media by placing 2 plugs (diameter 1 cm) of *F. oxysporum* f.sp. *cepae* into a 250 mL Erlenmeyer flask filled with 125 mL of cold, sterile PDB and incubated with shaking at 135 rpm for 7 days at room temperature. The density of fungal microconidia was counted using a hemocytometer until it reached a density of 10^6 conidia mL^{-1}.

Preparation of growth media

The planting medium was a mixture of soil and manure (2: 1, w/w), and the mixture was pasteurized at 80 °C, then put into polybags (25 × 40 cm^2), and the number of polybags was 144. The bottom of the polybags was given some drainage holes (Haase et al., 2021).

Preparation of shallot seeds and planting

Seeds of the shallot variety Bima Brebes were prepared. The seeds were cut off the top 1/3 with a sterile knife and planted 1-2 cm deep, with the cut marks facing upwards, then covered with thin soil. Additional fertilizer, such as base fertilizer, was given in the form of TSP in the form of as much as 3 g per polybag (Purba et al., 2017).

Application of treatments

The *F. oxysporum* f.sp. *cepae* suspension was inoculated by pouring into shallot seeds as much as 10 mL plant-1. Furthermore, two days after *F. oxysporum* f.sp. *cepae* inoculation, Bio p60 application was carried out by sprinkling it to plants as much as 20 mL plant-1 with a concentration

of 5 mL solution^{-1} and repeated according to the treatment. NASA liquid organic fertilizer was applied with a concentration according to the treatment and sprinkled as much as 40 mL plant^{-1} at the age of shallot plants 7, 17, 27, and 37 days after planting (Buton et al., 2019).

Research design

This study used a completely randomized design consisting of two factors. The first factor was the intensity of Bio P60 application, which was the control and Bio P60 watering of 20 mL plant^{-1} repeated 1, 3, and 5 times. The second factor was NASA liquid organic fertilizer, the control, and 3, 5, and 7 mL L^{-1} concentrations. The combined results of the two factors resulted in 16 treatment combinations, which were repeated 3 times, resulting in 48 experimental units. One experimental unit contained 3 plants, resulting in 144 plants (Piepho et al., 2022).

Variables observed

The variables observed were the incubation period with units of days after inoculation disease incidence using the formula (Nathawat et al., 2020): DI = (n ÷ N) ×100%, where: DI = Disease incidence (%); n = number of plant samples or plant parts that were damaged or considered damaged; N = number of plant samples or plant parts observed. The area under disease progress curve (AUDPC) was calculated by the formula (Alves & Del Ponte, 2021):

$$\text{AUDPC} = \frac{\left(\frac{I1+I2}{2} x\, T\right)+\left(\frac{I1+I2}{2} x\, T\right)+\left(\frac{I1+I2}{2} x\, T\right)+\left(\frac{I1+I2}{2} x\, T\right)}{n-1} \qquad (1)$$

Notes: I = Intensity of disease attack at different observations (I_1, I_2, ... I_n); T = Interval of observation interval; n = Number of observations. Plant growth and yield components observed were crop height, number of leaves, number of bulbs, crop fresh weight, bulb fresh weight, crop dry weight, and bulb dry weight.

Data Analysis

Data were analyzed with ANOVA at the 95% confidence level. If the analysis results show a significant effect, continue with DMRT (Duncan's Multiple Range Test) at a 5% error level (Midway et al., 2020).

RESULT AND DISCUSSION

Incubation Period

The observation of the incubation period of Fusarium wilt on shallot plants revealed that using Bio P60 could prolong the onset of disease symptoms and was noticeably different from the control (Table 1). Bio P60 applications of 1, 3, and 5 times can delay the incubation period of the fungal pathogen *F. oxysporum* f. sp. *cepae*. Compared to the control, the suppressive effects were observed at 50.81%, 55.18, and 61.71%. Bio P60 has been shown to reduce the incubation period of fungal pathogens. Bio P60 is a formulated product containing secondary metabolites from the antagonistic bacteria *P. fluorescens* P60. Cell-based antagonistic bacteria, *P. fluorescens,* suppressed pathogen development by producing antibiotic compounds like phenazine carboxylic acid (PCA), pyrrolnitrin, oomycin A, 2,4- diacetylphloroglucinol (Phl), and pyoluteorin (Plt) (Saeed et al., 2021; Raio, 2024).

Table 1. Pathosystem components of Fusarium wilt of shallot plants

Treatments	Incubation period (dai)	Disease incidency (%)	AUDPC (% days)
NASA Liquid organic fertilizer			
Control	36.64 a	47.22 a	156.94 a
Con 3 mL	37.51 a	41.67 a	144.44 a
Con 5 mL	41.35 a	33.33 a	112.50 a
Con 7 mL	42.42 a	27.78 a	106.94 a
Bio P60			
Control	27.71 b	66.67 b	248.61 b
Bio P60 1x	41.79 a	35.55 a	109.71 a
Bio P60 3x	43.61 a	30.55 a	87.50 a
Bio P60 5x	44.81 a	22.22 a	74.99 a
Interaction of NASA x Bio P60			
Control	22.47 a	77.78 a	305.56 a
Bio P60 1x	42.53 a	33.33 a	94.44 a
Bio P60 3x	43.90 a	33.33 a	83.33 a
Bio P60 5x	37.67 a	44.44 a	144.43 a
Con 3 mL, Control	25.57 a	77.78 a	261.11 a
Con 3 mL, Bio P60 1x	44.13 a	22.22 a	83.33 a
Con 3 mL, Bio P60 3x	35.43 a	44.44 a	177.78 a
Con 3 mL, Bio P60 5x	44.90 a	22.22 a	55.55 a
Con 5 mL, Control	32.57 a	55.56 a	199.99 a
Con 5 mL, Bio P60 1x	37.40 a	44.44 a	155.55 a
Con 5 mL, Bio P60 3x	47.43 a	22.22 a	44.45 a
Con 5 mL, Bio P60 5x	48.00 a	11.11 a	50.00 a
Con 7 mL, Control	30.23 a	55.56 a	227.78 a
Con 7 mL, Bio P60 1x	43.10 a	22.22 a	105.55 a
Con 7 mL, Bio P60 3x	47.67 a	22.22 a	44.44 a
Con 7 mL, Bio P60 5x	48.67 a	11.11 a	50.00 a

Notes: Numbers in the same column followed by different letters indicate significant differences at the DMRT 5% error level; dai = days after inoculation.

In addition, *P. fluorescens* bacteria produce bioactive compounds in the secondary metabolites, such as the enzyme pectinase (Raio, 2024). The enzyme degrades the conidia wall of *F. oxysporum* f.sp. *cepae*, so that ruptures the cell fluid, causing the pathogenic fungus to die. This condition is causing a delay in the incubation period. Other factors include the adaptation of pathogenic fungi in new environments over time. The pathogenic fungi inoculated into the growing medium are produced in a laboratory under controlled conditions. When pathogenic fungi are introduced into the growing medium, they must acclimate to the new surroundings to flourish (Xiao et al., 2022). The inoculation of the pathogenic fungus F. oxysporum f.sp causes the emergence of disease symptoms. *cepae* despite the beneficial impact of the Bio P60 application.

On the other hand, the onset of Fusarium wilt symptoms was quicker in control plants compared

to Bio P60-treated plants. The fungus has adapted to the new environment, allowing it to develop without inhibiting factors (Nnadi & Carter, 2021). Symptoms of Fusarium wilt disease include alterations in the growth pattern of shallot plants. The growth of shallot plants becomes grooved and lopsided, and the color of the leaves turns yellow (Marianah et al., 2024). The disease symptoms appeared more quickly in control plants, partly due to the aggressiveness of the pathogenic fungus (El-Baky & Amara, 2021; Peng et al., 2021). This demonstrates that using Bio P60 can postpone the onset of Fusarium wilt symptoms, resulting in lower disease severity.

Disease incidence

Bio P60 at all dosages effectively reduces Fusarium wilt disease in shallot, as evident from the markedly varied results in Table 1. Bio P60 application of 1, 3, and 5 times can reduce disease incidence by 46.68, 54.18 and 66.67%, respectively, compared to the control. The greater the application doses of Bio P60, the higher the disease suppression. This condition aligns with the incubation period. The prevention of disease when using Bio P60 may be due to its role as a secondary metabolite of *P. fluorescens, which* can inhibit the growth of harmful fungi through its bioactive compounds. The hindrance of pathogenic parasites Various bioactive compounds is found within the secondary metabolites of *P. fluorescens*, which create lysis proteins and poisons, as detailed by Sharma et al. (2019). These secondary metabolites can affect plant resistance against pathogenic organisms, progressing plant development and defense mechanisms. Secondary metabolites are delivered utilizing water-soluble substances taken up by plant roots and conveyed all through the plant, where they can repress the development of pathogenic parasites (Soesanto et al., 2019; Zhou et al., 2023). The need of characteristic inhibitors in control plants comes about in a better infection rate. Concurring to Nnadi & Carter (2021), the quick emergence of Fusarium shrink indications within the control bunch is ascribed to the forcefulness of the pathogen in causing illness and the need of hindrance of pathogen development and advancement. Besides, the pathogen's compatibility with shallot plants comes about in prior side effect sign, leading to increased infection rate. *F. oxysporum* f.sp. *cepae* may be a soil-borne pathogen that taints shallot plants. The organism within the soil will adjust and create well after vaccination (Hadiwiyono et al., 2020). The development and improvement of soil-borne parasites are backed by natural conditions within the soil, especially soil dampness. This leads to quick contamination of plant roots by the organism, causing illness rapidly (Wang et al., 2019).

Area Under Diseases Progress Curve (AUDPC)

The application of Bio P60 brought about in essentially diverse AUDPC values for Fusarium shrink in shallot plants, as appeared in Table 1. All Bio P60 applications effectively decreased the AUDPC esteem of Fusarium shrivel on shallot plants compared to the control. Bio P60 applications of 1, 3, and 5 times decreased AUDPC values by 55.87, 64.8, and 69.84%, separately, compared to the control. This adjusts with the information on the incubation period and plant infection rate. The more Bio P60 is connected, the more prominent the concealment of illness. The Bio P60 application decreases AUDPC, coming about in lower values than the control since the secondary metabolites in Bio P60 can hinder the improvement of the pathogen *F. oxysporum* f.sp. *cepae* (Maurya et al., 2024). The littler the AUDPC esteem, the way better the malady concealment (Bock et al., 2022). The moor

Table 2. Application of Bio P60 and NASA liquid organic fertilizer on the growth and yield components of shallots

Treatments	Crop height (cm)	Number of leaves	Frech weight of crop(g)	Fresh weight of bulb (g)	Number of bulbs	Dry weight of crop (g)	Dry weight of bulb (g)
NASA Liquid organic fertilizer							
Control	41.09 a	44.35 a	107.99 a	69.94 a	10.24 a	54.83 a	50.17 a
3 mL	43.06 a	49.14 a	103.31 a	70.28 a	10.33 a	54.08 a	49.75 a
5 mL	43.54 a	52.92 a	139.53 a	90.90 a	11.53 a	74.01 a	67.91 a
7 mL	44.76 a	51.34 a	121.50 a	85.14 a	11.34 a	64.40 a	58.96 a
Bio P60							
Control	35.48 b	39.36 b	72.06 b	47.01 b	7.09 b	37.78 a	33.89 b
1x	43.93 a	51.48 a	13.88 a	90.86 a	13.00 a	71.65 a	66.73 a
3x	46.65 a	51.53 a	12.17 a	82.25 a	10.90 a	62.69 a	56.67 a
5x	46.39 a	55.38 a	139.23 a	96.14 a	12.45 a	75.21 a	69.50 a
Interaction of NASA x Bio P60							
Control	30.63 a	31.90 a	49.43 a	27.00 a	4.57 a	19.43 a	17.23 a
1x	43.93 a	50.57 a	136.53 a	86.20 a	13.70 a	68.80 a	62.80 a
3x	47.07 a	47.13 a	128.00 a	86.67 a	12.47 a	67.67 a	60.97 a
5x	42.73 a	47.80 a	118.00 a	79.90 a	10.23 a	63.43 a	59.67 a
3 mL, Contrl	36.07 a	38.57 a	64.13 a	44.80 a	6.80 a	34.53 a	32.23 a
3 mL, 1x	45.83 a	55.43 a	138.43 a	92.53 a	14.20 a	75.23 a	69.90 a
3 mL, 3x	42.63 a	50.20 a	86.43 a	62.10 a	9.20 a	44.20 a	41.10 a
3 mL, 5x	47.70 a	52.37 a	124.23 a	81.67 a	11.10 a	62.37 a	55.77 a
5 mL, Contrl	36.33 a	42.87 a	85.77 a	61.90 a	7.90 a	50.33 a	45.53 a
5 mL, 1x	41.70 a	50.67 a	143.23 a	96.03 a	12.10 a	80.67 a	74.43 a
5 mL, 3x	48.77 a	58.00 a	168.57 a	93.90 a	11.23 a	74.13 a	65.90 a
5 mL, 5x	47.37 a	60.13 a	160.57 a	111.77 a	14.90 a	90.90 a	85.77 a
7 mL, Contrl	38.90 a	44.10 a	88.90 a	54.33 a	9.10 a	46.80 a	40.57 a
7 mL, 1x	44.23 a	49.23 a	117.33 a	88.67 a	12.00 a	61.90 a	59.77 a
7 mL, 3x	48.13 a	50.80 a	125.67 a	86.33 a	10.70 a	64.77 a	58.70 a
7 mL, 5x	47.77 a	61.23 a	154.10 a	111.23 a	13.57 a	84.13 a	76.80 a

Notes: Numbers in the same column followed by different letters indicate significant differences at the DMRT 5% error level.

AUDPC esteem in plants treated with Bio P60 may be ascribed to secondary metabolites that seem restrain the pathogen *F. oxysporum* f.sp. *cepae* and influence plant resistance (Anjali et al., 2022).

In differentiate, the tall AUDPC values within the control plants adjusted with the brooding period and illness rate. In controlled situations, parasitic pathogens can effectively create and taint crops due to the need of components that inhibit their development, beside the nearness of aggressive pathogens (Jian et al., 2024). The pathogenic organism *F. oxysporum* f.sp. *cepae* may be a term commonly utilized in plant pathology to allude to a particular shape of the organism that taints certain plant species. The quick foundation of infection indications within the have plant shows compatibility with the pathogenic organism, driving to tall illness rate and AUDPC values (Bock et al., 2022). The quick incubation period and high disease rate contribute to the speedy malady.

Crop height

Plant stature shown critical contrasts when Bio P60 was connected compared to the control, but there was no critical distinction between distinctive Bio P60 applications (Table 2) improvement, affecting the AUDPC esteem. The highest shallot plant height was observed when Bio P60 was applied 3 times, followed by Bio P60 applications 5 times and 1 time, resulting in heights of 31.48, 30.75, and 23.82% compared to the control. The decreased plant height in the control group results from the plants infected by the pathogen *F. oxysporum* f.sp. *cepae* causing insufficient plant growth and can lead to mortality in shallot plants. This follows the opinion of Lal et al. (2024) that plants affected by Fusarium wilt will collapse and die in advanced attacks.

The application of NASA liquid organic fertilizer and the interaction between Bio P60 and NASA were not significantly different (Table 2) but tended to increase the height of shallot plants compared to the control. The presence of NASA is believed to enhance the nutrient content in the soil, particularly macro-nutrients like N, benefiting plant growth. The element N is recognized as essential for the growth of leaves, stems, and roots in the vegetative stage (Ye et al., 2022). The growth enhancement in plants treated with Bio P60 is attributed to the secondary metabolites of *P. fluorescens* P60, which produces antibiotics that suppress Fusarium wilt and generate growth hormones for plants. *P. fluorescens* is a bacterium that falls under the category of plant growth-promoting rhizobacteria (PGPR), according to Saeed et al. (2021). *P. fluorescens* P60 produces growth hormones, including IAA, in its secondary metabolites that promote plant growth (Sah et al., 2021). IAA hormone, an endogenous auxin, contributes to cell enlargement, inhibits side shoot growth, stimulates abscission, aids in xylem and phloem network formation, and influences root development and elongation, ultimately promoting increased plant growth (Zhang et al., 2022b; Mishra et al., 2023).

Number of leaves

The results indicated significant differences in the number of leaves for the Bio P60 application, with no significant differences observed between different Bio P60 applications. The highest increase in leaf quantity, up to 40.7%, was achieved by applying Bio P60 five times, as shown in Table 2. No significant difference was observed in the NASA application and interaction with Bio P60. However, the NASA treatment tended to increase the number of leaves compared to the control. It is believed that the presence of growth regulators and macro- and micro-nutrients in NASA can stimulate the growth and yield of shallots. According to Wanimbo & Tuhuteru (2020), NASA provides a comprehensive mix of macro- and micro-nutrients, which can enhance crown growth and leaf count in plants.

The abundance of leaves in the Bio P60 treatment is attributed to *P. fluorescens,* a biological PGPR agent that enhances shallot growth by synthesizing auxin (Khoso et al., 2024). Leaves, being crucial vegetative organs responsible for photosynthesis, play a vital role in plant function (Wang et al., 2021). *P. fluorescens* possesses the capability to degrade phosphate. Adequate phosphorus is crucial for optimal plant growth and development, increasing the number of shallot leaves (Li et al., 2023).

Number of bulbs

The number of shallot bulbs produced significantly varied with Bio P60 applications but not with Bio P60 intensities (Table 2). The highest number of bulbs was observed when using Bio P60

once, then with Bio P60 applied 5 times, and lastly with Bio P60 applied 3 times. The increase in the number of bulbs compared to the control was 83.35, 75.6, and 53.74%, respectively. The application of NASA and the interaction of Bio P60 with NASA did not have a significant effect, but they did lead to a higher number of tubers than the control. Liquid organic fertilizers are more effective than solid fertilizers because they are readily available and easily taken up by plants (Tian et al., 2022). The bulbs are believed to be linked with the number of leaves; more leaves generally result in a higher yield of tubers. The high number of leaves in the Bio P60 treatment is due to the secondary metabolites of *P. fluorescens* P60 contains growth-stimulating hormones such as IAA, auxin, gibberellin, and cytokinin (Gupta et al., 2023). This ability is evident in its impact on the parameters linked to the function of every hormone. Cytokinin and gibberellin promote plant growth by stimulating cell division and elongation, ultimately affecting the development of shallot bulbs (Barbosa & Dornelas, 2021).

Bulb fresh weight

The results indicated that all Bio P60 applications resulted in a significant difference in bulb fresh weight compared to the control. However, there was no significant difference between the Bio P60 applications themselves. This suggests that more applications can enhance bulb weight in shallots. The highest bulb fresh weight was observed when Bio P60 was applied 5 times, resulting in a 51.1% increase in fresh bulb weight. The interaction application of Bio P60 and NASA showed no significant difference but tended to increase the fresh weight of the bulbs compared to the control (Table 2). The increased tuber weight when using Bio P60 5 times is believed to be caused by the secondary metabolites of *P. fluorescens* P60, which contains bioactive compounds, specifically growth hormones. The findings of a study conducted by Soesanto et al. (2019) demonstrated that using Bio P60 led to a 68.07% increase in fresh weight of pakcoy plants compared to the control. This is attributed to the plant regulator properties of Bio P60 secondary metabolites, particularly growth hormones like IAA. The application of NASA increases the fresh weight of bulbs compared to the control. NASA increases nutrient availability and uptake by shallot plants, which also contain growth regulators, promoting plant growth and high bulb production (Tian et al., 2022). The low fresh bulb weight in the control treatment is believed to be linked to the high intensity of the disease. This is consistent with the incubation period and high disease incidence in the control, preventing plant growth and leading to bulb rot. This aligns with the statement of Lal et al. (2024). In young plants, Fusarium wilt leads to death. In adult plants, symptoms include smaller bulb size and rotting. This will impact the fresh weight of the bulbs.

Bulb dry weight

The dry weight of bulbs showed no significant difference when NASA was applied or in the interaction between Bio P60 and NASA. The only noticeable distinction was observed in the Bio P60 application, as shown in Table 2. The heaviest bulb dry weight was achieved by applying Bio P60 five times, resulting in a weight of 69.5 g, a 51.24% increase compared to the control. All Bio P60 applications showed a significant difference in the dry weight of shallot bulbs compared to the control. However, there were no significant differences between Bio P60 applications, which is

consistent with the results for the fresh weight of the bulbs. Dry weight increases as the fresh weight of bulbs increases at the same drying temperature. The dry weight of the bulbs increases as a result of applying Bio P60 due to the secondary metabolites of *P. fluorescens* P60 in Bio P60 contain bioactive compounds in the form of growth hormones, such as IAA and cytokinin (Gupta et al., 2023). The cytokinin hormone impacts the yield of shallot plants (Barbosa & Dornelas, 2021). Using Bio P60 (Table 2) results in a higher yield of fresh bulb shallots. This is attributed to the impact of growth hormones on secondary metabolites and the prevention of the pathogenic fungus *F. oxysporum* f.sp. *cepae* attack Data on the dry weight of bulbs is utilized for more precise measurements compared to data on the fresh weight of bulbs. The freshness of bulbs is influenced by various factors, particularly water content and tissue structure, especially when using quantitative data (Levinsh, 2023). The dry weight of the tuber represents the true yield weight in comparison to the fresh weight of the tuber (Huang et al., 2019).

Crop fresh weight

There was a significant difference in crop fresh weight with the application of Bio P60, as shown in Table 2. The data analysis results indicated that applying Bio P60 five times was the most effective, resulting in a 48.24% increase in crop fresh weight compared to the control. The application of NASA liquid organic fertilizer and the interaction between Bio P60 and NASA showed no significant differences. The increased crop weight when using Bio P60 is believed to be a result of the secondary metabolites produced by *P. fluorescens* P60 not only suppresses pathogens but also promotes plant growth. *P. fluorescens* is a PGPR bacterium that produces IAA, cyanide acid (HCN), siderophores, and phosphate solubilizing compounds beneficial for plant growth (Li et al., 2023; Khoso et al., 2024). *P. fluorescens* can indirectly supply crucial plant nutrients like nitrogen, phosphate, sulphur, and potassium, along with iron and ions (Sah et al., 2021). The availability of nutrients affects the number of leaves on shallot plants, which impacts the number of shallot tillers or bulbs. The increase in leaves resulted in more shallot bulbs and higher production (Rahmawati & Ladewa, 2023).

NASA application showed a slight increase in plant fresh weight compared to the control treatment. This is likely due to NASA's ability to supply plants with both macro- and micro-nutrients. The nutrients in NASA have a balanced content of macro- and micro-nutrients. Plant growth depends on plants' capacity to uptake macro- and micro-nutrients from the nutrient solution (Kumar et al., 2021). According to Levinsh (2023), the plant body's water content significantly affects plants' fresh weight. Applying NASA liquid organic fertilizer at the correct concentration can enhance plant nutrients, light, and water absorption, promoting optimal growth and influencing organ development (Liu et al., 2024).

Crop dry weight

Crop dry weight varied significantly with Bio P60, as shown in Table 2. The most noteworthy edit dry weight was watched by applying Bio P60 five times, coming about in a 49.77% increment compared to the control. The affect of applying Bio P60 on edit dry weight is accepted to be caused by a secondary metabolite delivered by *P. fluorescens*, particularly siderophores. Siderophores can

tie iron (Fe^{3+}) to create siderophore-iron bonds, which plants can get to whereas remaining blocked off to pathogens (Xie et al., 2024). The investigate conducted by Timofeeva et al. (2022) shows that siderophores help in making iron accessible for plants, advancing plant development. Iron is pivotal for plant nourishment, photosynthesis, respiration, and defense against pathogens.

NASA application and the interaction between Bio P60 and NASA had no critical impact. This adjusts with the investigate conducted by Oktaviani et al. (2020), which found that treating NASA concentration on shallot plants did not have a noteworthy affect on any of the parameters watched. The need of interaction between Bio P60 and NASA is likely due to NASA's imperfect dosing, coming about in an uneven affect on the two medicines. On the off chance that one calculate includes a more grounded impact than others, its impact is prioritized. In the event that each figure includes a particular nature of impact and work, it'll result in a relationship that does not altogether bolster plant development (Xiaoqin et al., 2022). This investigate appears that controlling the Fusarium shrivel of shallots can be done utilizing auxiliary metabolites determined from *P. fluorescens* P60. The secondary metabolites can control other plant infections (Muarifah et al., 2023). Fusarium wilt is one of the most important diseases of shallot and is difficult to control by any means. However, the results of this study prove that Fusarium wilt can be overcome organically.

CONCLUSION

The application of Bio P60 was able to suppress Fusarium wilt in shallots. The best application was in the Bio P60 treatment 5 times which was able to delay the incubation period by 61.71%, suppress the disease intensity by 66.67% and reduce the AUDPC value by 69.84%, which was able to increase growth and yield components such as plant height by 40.7%, number of leaves by 30.75%, number of bulbs by 83.35%, bulb fresh weight by 51.1%, bulb dry weight by 51.24%, plant fresh weight by 48.24% and plant dry weight by 49.77% compared to the control. The application of NASA liquid organic fertilizer has not been able to significantly affect the development of Fusarium wilt and shallot growth and yield. There is no interaction between the application of Bio P60 and NASA on the development of Fusarium wilt and shallot growth and yield. Fusarium wilt of shallots can be overcome organically, and it provides hope for the community to overcome Fusarium wilt disease organically.

AUTHORS CONTRIBUTIONS

LS and WSS designed and conceived the experiments. AMY and EM experimented. LS, AMY, and WSS contributed to the preparation of samples and interpretation of the results. The manuscript was primarily composed by LS and MWRS. All authors provided critical feedback and contributed to developing the research, analysis, and manuscript.

COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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