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Induction of Twisting Disease Resistance on Shallot (*Allium cepa* var. ascalonicum) Against Twisting Disease (*Fusarium oxysporum* f. sp. *cepae*) through Biopesticide Application

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Abstract. This study aimed to develop resistance in shallot (Allium cepa) against twisting disease caused by Fusarium oxysporum by applying microorganism-based biopesticides. By inducing resistance in shallots, the research sought to explore the pathogen-host interactions, understand infection mechanisms, and establish sustainable disease management strategies. Utilizing a biopesticide approach within an organic farming framework, this study aimed to assess the effectiveness of biopesticides in inducing plant defense mechanisms. The experimental design was non-factorial and followed a randomized block structure, consisting of four treatments with three replications each: (A) Chemical pesticide and fertilizer, (B) Biopesticide applied to seeds and plants, with chemical fertilizers on soil, (C) Soil sterilization with biopesticide and pesticide application on plants, and (D) Soil sterilization with biopesticide, with biopesticide applied to seeds and plants. Observations focused on disease intensity and salicylic and jasmonic acid levels in shallot bulbs. Results demonstrated that biopesticide application successfully reduced disease incidence and increased resistance, as shown by higher levels of salicylic and jasmonic acids in treated plants. The study concluded that biopesticides are promising for enhancing systemic resistance in shallots.

Keywords*:* biocontrol; induced resistance; jasmonic acid; organic farming; salicylic acid

INTRODUCTION

Plaosan District is one of the areas in Magetan Regency with the largest contributor to horticultural production in the form of shallots. Shallot (*Allium ascalonicum*) is one of the vegetable products with high commercial value in a wide range of applications from household to industrial (Safitri & Hasanah, 2019). However, in July 2022, the productivity of Shallot is predicted to be a failure because of its low productivity. The low productivity of Shallot depends on environmental factors(Fauzan, 2020). Factors that cause reduced productivity include reduced soil fertility, increased prevalence of plant-destroying organisms, microclimate changes, and poor seed quality (Hasyidan et al., 2021). Pathogens that afflicts bulbous plant is Fusarium wilt disease which is caused by the fungus Fusarium Oxysporum. The target is the root of the tuber. Pathogenic F. Oxysporum has many special forms with different pathogenic characteristics, depending on the infected plant (Gordon, 2017). Shallot may have a pathogenic race of F. Oxysporum f. sp. Cepae with different pathogenicity (Herlina et al., 2021). The fungus has been reported to have many specific forms depending on the infected host, each of which is divided into physiological races with characteristic pathogenic patterns in different host varieties (Fadhilah et al., 2014). In many plant species, fungi act as phytopathogens and cause root and stem rot, vascular wilt, and/or tuber rot, causing severe damage and financial losses (Xia et al., 2020). One of the most studied and economically significant genera of fungi in the world is Fusarium (Idean et al., 2012).

Twisting disease, caused by Fusarium oxysporum f.sp. cepae, significantly impacts shallot cultivation by reducing both yield quantity and quality. This fungal pathogen induces various detrimental effects on shallot plants, leading to decreased productivity with fewer and smaller bulbs, ultimately diminishing the overall harvest output. The disease also causes morphological abnormalities in bulbs, such as deformation and twisting, reducing their market value and consumer appeal (Kalman et al., 2020) ;

(Supyani et al., 2023). The assault of Fusarium oxysporum on the shallot's vascular system hinders water and nutrient uptake, resulting in stunted growth and diminished plant vigor. This compromised physiological state makes infected plants more vulnerable to secondary infections by opportunistic pathogens, exacerbating agricultural losses (Kalman et al., 2020). The persistence of Fusarium oxysporum in the soil post-infection poses a continuous threat to future crops, necessitating stringent disease management practices to mitigate its spread (Kalman et al., 2020). The economic consequences of Fusarium Basal extend beyond reduced yields and compromised quality, encompassing the financial burdens associated with disease control measures and the environmental impact of intensive fungicide application (Kalman et al., 2020). To address the multifaceted impact of twisting disease, comprehensive mitigation strategies are essential to safeguard the sustainability of shallot cultivation. Research has explored various approaches, including the use of biological control agents, such as Bacillus and mycorrhizal fungi, to manage Fusarium spp. infections and suppress twisted disease (Wibowo et al., 2022). Additionally, studies have investigated the application of salicylic acid to enhance the resistance of shallot cultivars to twisting disease (Wijoyo et al., 2020).

The fusarium research community is looking into new crop protection methods since commercially significant food crops lack fungicide resistance and resistant varieties (Rampersad, 2020). The use of pesticides must be considered. Parent pesticides, their breakdown products, and metabolites can be harmful to the environment, ecosystems, and human health (Assey et al., 2021). Environmentally friendly control methods for effective and efficient plant disease management are important components of integrated control. The use of chemical-free biopesticides is an important component in the integrated management of plant diseases. One of the trade names for biopesticides is FOBIO and a common patent registration number is P00201200183 (Wiyatiningsih & Sukaryorini, 2010).

Further, the natural microorganisms used in this formulation were found in the root sphere of plants. Microorganisms that inhabit the roots of coconut plants, mangrove roots, sugarcane roots, and roots of Siwalan plants, honey, coconut water, and liquid milk can survive effectively as microorganisms that increase plant resistance to pathogen attack. Microbial suspensions in combination, composition, and the ratio of carrier media are yeast, phosphate solubilizing bacteria, Lactobacillus, Rhizobium, starch degrading bacteria, proteolytic bacteria, photosynthetic bacteria, ammonification bacteria, nitrifying bacteria (Wiyatiningsih & Sukaryorini, 2010). Plant-resistant compounds can be produced using other organisms that produce resistant compounds that can induce plant resistance to pathogens, but the use of biopesticides exhibits an immediate response to plant pathogens (Gwinn, 2018). However, according to research conducted by (Hasyidan, 2021), it is not well understood how salicylic acid (SA) and jasmonic acid (JA) signaling affect root pathogen resistance. Research conducted by (Hasyidan, 2021) has conducted research relating the use of biopesticides fobio with streptomyces sp. to control Moler's disease. Thus, it needs another research to determine and see the use of biopesticides to increase salicylic acid and jasmonic acid levels in order to reduce its susceptibility to infections of Shallot. Therefore, the purpose of this study is to evaluate the efficacy of using biopesticides to increase salicylic acid and jasmonic acid levels in Shallot to reduce its susceptibility to infections (Yastika et al., 2023).

In the context of shallots, research has shown promising results in inducing twisting disease resistance through the application of biopesticides formulated with plant extracts or beneficial microorganisms (Mullins et al., 2019). Experimental trials have demonstrated that these biopesticides can effectively prime shallot plants against Fusarium oxysporum f.sp. cepae infection (Mullins et al., 2019). The efficacy of biopesticides in inducing resistance in shallot plants is attributed to various mechanisms, including the activation of defense-related genes, the production of antimicrobial compounds, and the modulation of plant hormone signaling pathways (Mullins et al., 2019). Field trials conducted under natural disease pressure have further confirmed the effectiveness of biopesticide-treated shallot plants in reducing disease incidence and severity (Mullins et al., 2019). This induced resistance not only offers immediate protection against twisting disease but also holds potential for long-term disease management by enhancing the plant's intrinsic defense mechanisms (Mullins et al., 2019)). The use of biopesticides aligns well with the principles of sustainable agriculture, as these natural alternatives minimize adverse environmental impacts and promote ecological balance (Mullins et al., 2019). Unlike chemical fungicides, biopesticides are generally less harmful to non-target organisms and do not contribute to pesticide residue accumulation in the environment or food chain (Mullins et al., 2019). This underscores the importance of exploring biopesticides as a sustainable solution for disease management in agricultural systems. Studies have highlighted the significance of biological control agents and their bioactive compounds as viable alternatives to chemical pesticides in agriculture (Calvo-Garrido et al., 2019).

The development of fungicide resistance due to the characteristics of synthetic fungicides underscores the need for exploring natural alternatives like biopesticides (Calvo-Garrido et al., 2019). Biopesticides offer a promising avenue for managing pest resistance while reducing the reliance on conventional chemical control methods (Calvo-Garrido et al., 2019). The potential of biopesticides in pest management extends beyond fungal pathogens to include ticks, where products based on fungi like Beauveria and Metarhizium have shown efficacy in controlling tick populations (Sullivan et al., 2022). The development of mycoacaricides and mycoinsecticides based on these fungi highlights the diverse applications of biopesticides in pest control across different agricultural systems (Sullivan et al., 2022). Furthermore, the role of endophytic fungi in plant defense against pathogens has been a subject of interest, with studies emphasizing their biological control potential against various fungal plant pathogens (Akram et al., 2023). Endophytic fungi with antifungal properties have been identified as valuable allies in enhancing plant resistance mechanisms (Akram et al., 2023). This highlights the intricate interactions between plants and beneficial microorganisms in bolstering plant immunity against pathogen attacks (Akram et al., 2023). In the context of shallot cultivation, the negative impact of certain fungicide applications on biocontrol agents like Trichoderma harzianum has been documented, emphasizing the importance of considering the broader ecological implications of pesticide use in agricultural systems. Such findings underscore the need for sustainable pest management strategies that take into account the interactions between biocontrol agents and chemical inputs in agricultural practices (Mihiretu et al., 2024). The utilization of essential oils and plant extracts as biopesticides has also been explored for controlling seed-borne fungi, showcasing the potential of natural compounds in managing plant pathogens (Chrapačienė et al., 2022). Essential oils derived from plants like thyme, sage, and peppermint have demonstrated efficacy against fungal pathogens, offering sustainable alternatives to synthetic fungicides (Chrapačienė et al., 2022).

The aim of this research is to explore the potential of biopesticides derived from natural sources to induce resistance in shallot plants against twisting disease (*Fusarium* *oxysporum* f.sp. *cepae*), providing a sustainable and environmentally friendly alternative for disease management in agriculture.

METHODS

Research Design

This research is concluded as a quantitative experiment with a completely randomized design experiment. The study was conducted in Bulugunung Village, Plaosan District, Magetan Regency, from March to May of 2021. Analysis of the content of Salicylic Acid and Jasmonic Acid was carried out at the Plant Health Laboratory, Faculty of Agriculture, National Development University "Veteran" East Java.

The procedure of the experiment consists of Treatment 1 (A): without Fobio, Treatment 2 (B): Fobio applied to seeds and plants and chemical fertilizers, Treatment 3 (C): manure, soil sterilization with Fobio and pesticides. Pesticide application to plants, treatment 4 (D): Application of manure to the soil and soil sterilization with Fobio, and application of Fobio to seeds and plants with a dilution dose of 10 ml/L water with a suspension dose of 2 L. Incidence is the number of infected plants expressed in percentage of diseased plants.

Materials

The materials used in this study included shallot cultivars, as well as biopesticide formulations based on microorganisms derived from the rhizosphere of coconut, sugarcane, siwalan (Borassus flabellifer), coconut, and mangrove roots with the carrier medium for the biopesticide formulation in the form of potato extract, sugar, meat, and black sticky rice.

Analysis Technique

According to (Fauzan, 2020) systemic diseases are calculated using the **Equation 1**.

$I = a/(b) \times 100\%$ …..1)

Information:

I = Disease Intensity

a = Number of plants affected by the disease

b = Total number of plants

Observation data will be tested statistically with an analysis of variance. If the F test shows a significant effect, proceed with the subsequent trial, namely the Least Significant Difference (LSD) at the 5% absolute level. The mechanism of resistance of the pamelo citrus plant can be observed from the accumulation of the formation of salicylic acid and jasmonic acid compounds. The test sample used to determine the accumulation of salicylic and jasmonic acids in the shallot bulbs which showed some response after the application of the biopesticide formula. The accumulation of salicylic acid in plants is a response to Systemic Acquired Resistance (SAR) and the accumulation of jasmonic acid is a response to plant resistance by Induced Systemic Resistance (ISR). The accumulated concentration of salicylic acid and jasmonic acid was analyzed by gas chromatography method.

RESULTS AND DISCUSSION

The purpose of inducing *Fusarium* resistance in shallot seeds using microorganism-based biopesticides is to enhance the plants' natural defense mechanisms, enabling them to resist infection and reduce disease impact. This approach not only minimizes reliance on chemical pesticides, which can lead to environmental harm and resistance in pathogens, but also promotes sustainable agriculture by utilizing natural, eco-friendly solutions for disease control.

Intensity of Disease

The findings of the calculation of the incidence of twisting disease are derived based on the observational data of the incubation period. The shallot cultivars are sprayed using fobio and other elements compared to the shallot that is not sprayed by fobio. The test is carried out five times to five shallot cultivars. The incidence is the number of infected plants expressed in percentage of diseased plants. The results of the treatment

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show in **Table 1**.

Table 1. Intensity of disease on shallot

Treatment	**Test (%)**						**Total**	**Mean**	**F**	**Sig**	**Description**
	1	2	3	4	5	6					
A :(Pesticide and Chemical Fertilizer Treatment)	0	0	0	0	0	0	0	0.00±0.00	0.667	0.582	Not Significant
B :(Biopesticide treatment applied to seeds and plants, and chemical fertilizers on soil)	0	1	0	0	0	0	1	0.17±0.41			
C :(Soil sterilization with biopesticides, and Pesticide application to plants)	0	0	0	0	0	0	0	0.00±0.00			
D :(Soil sterilization with biopesticide and biopesticide application in seeds and plants)	0	0	0	1	0	0	1	0.17±0.41			

Treatment (A): without Fobio, Treatment (B): Fobio applied to seeds and plants and chemical fertilizers, Treatment (C): manure, soil sterilization with Fobio and pesticides. Pesticide application to plants, treatment (D). Based on the results of the ANOVA test conducted to compare disease intensity among several groups, it was found that the F value is 0.667 and the significance (Sig.) value is 0.582. These values indicate that there is insufficient evidence to reject the null hypothesis (H0), which states that there are no significant differences in disease intensity among the groups. In other words, the differences in disease intensity among the tested groups are not statistically significant. This conclusion is supported by the low F value and the high p value, indicating that we fail to reject the null hypothesis. It can be concluded there are no significant differences in disease intensity among the tested groups.

Application of manure to the soil and soil sterilization with Fobio, and application of Fobio to seeds and plants with a dilution dose of 10 ml/L water with a suspension dose of 2 L. From the Table above, it is seen that the incidence of disease in treatments A and C was 0% while in treatments B and D was 0.167%. This proves that the use of chemical pesticides is faster in controlling the pathogenic fungus Fusarium oxysporum so that no plants are attacked by twisting disease compared to the use of biopesticides to control Plant Pest Organisms (OPT). There is a difference in the incidence of disease between treatments A and C with treatments B and D due to differences in the application of twisting disease control. The intensity of disease in pesticide-treated plants was 0%, but the intensity of disease applied to biopesticides was only 1%, there was no significant difference from pesticide application. Microorganisms contained in Fobio need to adapt to the new environment so it takes more time to control pathogenic fungi than chemical pesticides.

Salicylic Acid Levels

Based on the results of the ANOVA test conducted to compare salicylic acid levels among several groups, it was found that the F value is 23.622 and the significance (Sig.) value is 0.000. These values indicate that there is sufficient evidence to reject the null hypothesis (H0), which states that there are no significant differences in salicylic acid levels among the groups. In other words, the differences in salicylic acid levels among the tested groups are statistically significant. This conclusion is supported by the high F value and the very low p value, indicating that we reject the null hypothesis. Therefore, it can be concluded that there are significant differences in salicylic acid levels among the tested groups.

Table 2. ANOVA test of salicylic acid levels

Treatment	**Test (%)**						**Total**	**Mean**	**F**	**Sig**	**Description**
	1	**2**	**3**	**4**	**5**	**6**					
A :(Pesticide and Chemical Fertilizer Treatment)	1.76	1.65	1.46	1.4	1.76	1.56	9.59	1.60±0.15	23.62	0.000	Significant
B :(Biopesticide treatment applied to seeds and plants, and chemical fertilizers on soil)	1.98	2.15	2.17	1.76	2.03	1.90	11.99	2.00±0.16			
C :(Soil sterilization with biopesticides, and Pesticide application to plants)	1.47	1.39	1.46	1.51	1.54	1.39	8.76	1.46±0.06			
D :(Soil sterilization with biopesticide and biopesticide application in seeds and plants)	1.77	1.72	1.87	1.82	1.97	1.91	11.06	1.84±0.09			

The analysis of Salicylic Acid levels under different treatments reveals several significant differences. Comparing Treatment A with Treatment B, there is a statistically significant decrease in Salicylic Acid levels, with a mean difference of -0.40000 and a 95% confidence interval ranging from -0.5466 to -0.2534. Similarly, Treatment A also shows a significant decrease in Salicylic Acid levels compared to Treatment D, with a mean difference of -0.24500 and a confidence interval from -0.3916 to -0.0984. Conversely, when comparing Treatment B with Treatment C, there's a significant increase in Salicylic Acid levels, with a mean difference of 0.53833 and a confidence interval from 0.3917 to 0.6849. Treatment B also exhibits a significant increase in Salicylic Acid levels compared to Treatment D, with a mean difference of 0.15500 and a confidence interval from 0.0084 to 0.3016. Furthermore, Treatment C displays a significant decrease in Salicylic Acid levels compared to both Treatment B and Treatment D, with mean differences of -0.53833 and -0.38333, respectively. These findings suggest that different treatments exert distinct effects on Salicylic Acid levels, indicating potential avenues for further investigation or optimization of treatment protocols.

Jasmonic Acid Levels

Based on the results of the ANOVA test conducted to compare jasmonic acid levels among several groups, it was found that the F value is 15.165 and the significance (Sig.) value is 0.000. These values indicate that there is sufficient evidence to reject the null hypothesis (H0), which states that there are no significant differences in jasmonic acid levels among the groups. In other words, the differences in jasmonic acid levels among the tested groups are statistically significant. This conclusion is supported by the high F value and the very low p value, indicating that we reject the null hypothesis. Therefore, it can be concluded that there are significant differences in jasmonic acid levels among the tested groups.

Table 3. LSD test of salicylic acid levels

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Sig.	Description
A :(Pesticide and Chemical Fertilizer Treatment)	B	-0.400*	0.000	Significant
	C	0.138	0.063	Not Significant
	D	-0.245*	0.002	Significant
B :(Biopesticide treatment applied to seeds and plants, and chemical fertilizers on soil)	A	0.400*	0.000	Significant
	C	0.538*	0.000	Significant
	D	0.155*	0.039	Significant
C :(Soil sterilization with biopesticides, and Pesticide application to plants)	A	-0.138	0.063	Not Significant
	B	-0.538*	0.000	Significant
	D	-0.383*	0.000	Significant
D :(Soil sterilization with biopesticide and biopesticide application in seeds and plants)	A	0.245*	0.002	Significant
	B	-0.155*	0.039	Significant
	C	0.383*	0.000	Significant

*. The mean difference is significant at the 0.05 level.

Based on the results of the multiple comparisons using the Least Significant Difference (LSD) test for jasmonic acid levels among different treatments, several significant differences were found. Treatment A compared to Treatment B showed a significant mean difference of -0.14000 (p = 0.022), indicating that Treatment B had higher jasmonic acid levels than Treatment A. However, the mean difference between Treatment A and Treatment C was not significant (0.08333, p = 0.156). On the other hand, Treatment A compared to Treatment D showed a significant mean difference of -0.27000 (p = 0.000), indicating higher jasmonic acid levels in Treatment D. For Treatment B, the comparisons revealed that Treatment B had significantly higher jasmonic acid levels compared to Treatment A (0.14000, p = 0.022) and significantly higher levels compared to Treatment D (-0.13000, p = 0.032). Treatment B also showed a significant difference when compared to Treatment C, with a mean difference of 0.22333 (p = 0.001). Comparing Treatment C to other treatments, the mean difference with Treatment A (-0.08333, p = 0.156) was not significant, but significant differences were observed with Treatment B (-0.22333, p = 0.001) and Treatment D (-0.35333, p = 0.000), indicating higher jasmonic acid levels in Treatments B and D compared to Treatment C. Lastly, Treatment D compared to Treatment A showed a significant mean difference of 0.27000 (p = 0.000), and significant differences were also found when compared to Treatment B (0.13000, p = 0.032) and Treatment C (0.35333, p = 0.000), indicating that Treatment D had the highest jasmonic acid levels among the groups. Overall, the results indicate significant differences in jasmonic acid levels among the treatments, with Treatment D generally having the highest levels, followed by Treatments B, A, and C.

The salicylic acid and jasmonic acid in Shallot reach different levels after being sprayed and not sprayed with biopesticides. These differences happen because the different treatment in Treatment A, B, C, and D. Figure 1 shows the difference in salicylic acid content.

From **Table 1**, it can be assumed that the observation of disease intensity and response to plant growth that the application of

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biopesticides stimulated the development of resistant shallot cultivars. The plant resistance mechanism in Shallots cultivars is thought to be induced ISR (Induced Systemic Resistance). In addition, upon exposure to the pathogen, the plant developed resistance due to the endogenous salicylic acid level (Abbaspour & Ehsanpour, 2016). By lowering the prevalence of illness, salicylic acid can help plants develop resistance. However, there does not seem to be a connection between fresh bulb weight, plant development rate, or the overall accumulation of dry weight (Wijoyo et al., 2020). An integrated management strategy should be employed to treat illnesses brought on by Fusarium (Jiménez-díaz & Jiménez-gasco, 2011). Therefore, from the results of the research conducted, it is determined that the application of biopesticides can reduce the incidence of disease.

Table 4. ANOVA test of jasmonic acid levels

Treatment	Test (%)						Total	Mean	F-Sig.		Description
	1	2	3	4	5	6					
A: (Pesticide and Chemical Fertilizer Treatment)	0.75	0.91	0.81	0.84	0.87	0.90	5.08	0.85± 0.06	15.17	0.000	Significant
B: (Biopesticide treatment applied to seeds and plants, and chemical fertilizers on soil)	0.87	0.93	0.99	1.05	1.11	0.97	5.92	0.99± 0.09			
C: (Soil sterilization with biopesticides, and Pesticide application to plants)	0.68	0.73	0.78	0.83	0.81	0.75	4.58	0.76± 0.06			
D: (Soil sterilization with biopesticide and biopesticide application in seeds and plants)	1.1	0.9	0.9	0.9	1.2	1.3	6.7	1.12± 0.16			

These findings suggest that JA and its signaling pathway plays significant roles in rice defense against hemibiotrophic and biotrophic pathogens. Numerous earlier reports back up these findings (Kanno et al., 2012). Various effects have been reported with SA and related compounds. SA is a major phenylpropanoid compound that has anti-pathogen effects, probably under other stress conditions (Ojha & Narayan, 2012). Salicylic acid (SA) controls resistance to necrotizing infections that feed on dead host cells negatively and positively to bio-nutrient pathogens that receive nutrients from living host cells (Klessig et al., 2018). The microorganisms in fobio biopesticides may boost plants' resilience to disease attacks (Fitriana et al., 2020). Applications of fobio can raise the salicylic acid in Shallot. Treatment with the combination of fobio contains sufficient amounts of salicylic acid. Plant resistance to fusarium is also enhanced by salicylic and jasmonic acids. Two phytohormones, jasmonic acid (JA) and salicylic acid (SA) are crucial for activating plants' pathogen defense mechanisms (Tamaoki et al., 2013).

The application of biopesticides has been shown to stimulate the development of resistant shallot cultivars by inducing systemic resistance mechanisms in plants (Grady et al., 2019). Specifically, the use of biopesticides has been linked to the activation of Induced Systemic Resistance (ISR) in shallot cultivars, enhancing their ability to resist diseases (Grady et al., 2019) This resistance mechanism is further supported by the role of endogenous salicylic acid levels in plants, which have been found to increase upon pathogen exposure, aiding in the development of resistance (Grady et al., 2019). Salicylic acid has been identified as a key player in reducing the prevalence of diseases in plants, contributing to their overall resilience (Grady et al., 2019). While salicylic acid plays a crucial role in enhancing plant resistance, it is important to note that factors such as fresh bulb weight, plant development rate, and the accumulation of dry weight may not be directly influenced by salicylic acid levels (Abdelrahman et al., 2020). Therefore, while salicylic acid contributes to disease resistance, its impact on other growth parameters in shallot cultivars may be limited (Abdelrahman et al., 2020). To effectively manage diseases like Fusarium in shallots, an integrated management strategy is recommended (Omoba et al., 2022)

Table 5. LSD test of jasmonic acid levels

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Sig.	Description
A :(Pesticide and Chemical Fertilizer Treatment)	B	-0.140*	0.022	Significant
	C	0.083	0.156	Not Significant
	D	-0.270*	0.000	Significant
B :(Biopesticide treatment applied to seeds and plants, and chemical fertilizers on soil)	A	0.140*	0.022	Significant
	C	0.223*	0.001	Significant
	D	-0.130*	0.032	Significant
C :(Soil sterilization with biopesticides, and Pesticide application to plants)	A	-0.083	0.156	Not Significant
	B	-0.223*	0.001	Significant
	D	-0.353*	0.000	Significant
D :(Soil sterilization with biopesticide and biopesticide application in seeds and plants)	A	0.270*	0.000	Significant
	B	0.130*	0.032	Significant
	C	0.353*	0.000	Significant

*. The mean difference is significant at the 0.05 level.

Such a strategy should encompass various approaches to combat illnesses caused by Fusarium, ensuring a comprehensive and effective control method (Omoba et al., 2022). Research has indicated that the application of biopesticides, such as Fobio, can significantly reduce disease incidence in shallot cultivars (Elvira et al., 2023). In fact, the use of Fobio biopesticide has been found to be as effective in disease suppression as chemical fungicides, highlighting its potential as a sustainable and eco-friendly alternative for disease management in shallots (Elvira et al., 2023). Additionally, combining True Seed Shallot (TSS) with salicylic acid application has been proposed as a method to enhance the resistance of shallot cultivars to diseases like twisted disease caused by Fusarium (Wijoyo et al., 2020). This integrated approach shows promise in improving the resilience of shallot plants against common pathogens (Wijoyo et al., 2020). Furthermore, the incorporation of resistant cultivars with fungal antagonist-based biological control agents has been shown to reduce the growth of Fusarium oxysporum mycelium and increase the diameter of shallot bulbs, emphasizing the importance of utilizing multiple strategies for disease management in shallots. Identifying shallot genotypes with resistance to specific diseases, such as anthracnose, presents an opportunity to develop cultivars that are inherently more resilient and can serve as an effective control measure (Kawung et al., 2023).

Understanding the morphological and chemical resistance mechanisms of shallots to pathogens like Colletotrichum gloeosporioides is essential for breeding programs aimed at enhancing disease resistance in shallot cultivars (Maharijaya et al., 2023). In addition to disease resistance, optimizing growth characteristics and productivity in shallots is crucial for sustainable cultivation practices. Utilizing fertilizers, growth regulators like gibberellins, and appropriate planting techniques can significantly impact shallot productivity (Elvira et al., 2023). Moreover, studying the flowering ability and genetic diversity of shallot varieties is essential for developing improved cultivars with desirable traits. Enhancing the growth of shallots through the application of potassium fertilizers and manure can lead to improved yields, although the response to such treatments may vary depending on various factors (Grady et al., 2019).

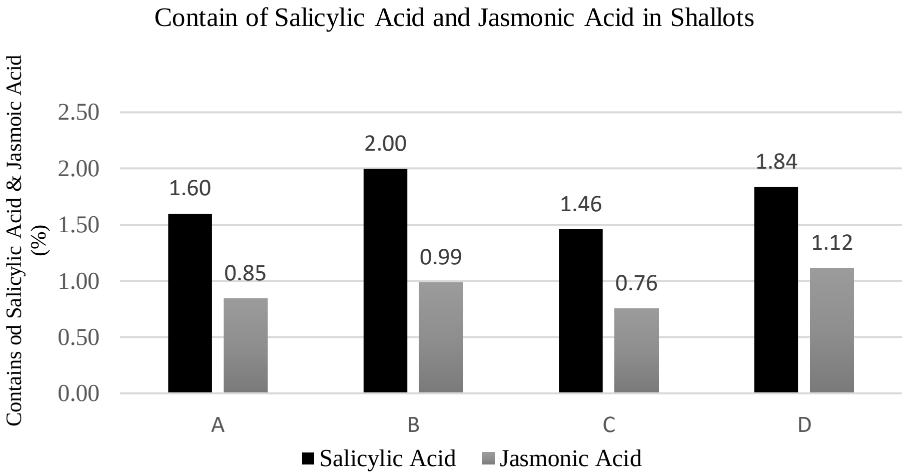

Figure 1. Salicylic acid and jasmonic acid content in shallots in different treatment

Using botanical biopesticides, such as essential oils and plant extracts, presents a sustainable approach to pest management in agriculture, aligning with the need to transition towards organic agroecological practices for long-term agricultural sustainability (Purba et al., 2020). Furthermore, exploring the beneficial effects of arbuscular mycorrhizal fungi and Trichoderma on diseased shallots highlights the potential of harnessing beneficial microorganisms for enhancing plant growth and disease suppression (Fitriana et al., 2020).

Conducting phenotypic evaluations and genetic profiling of shallot genotypes can aid in identifying varieties adapted to specific environments, contributing to the development of resilient cultivars suited for different growing conditions (Klessig et al., 2018). The application of biopesticides, the manipulation of salicylic acid levels, and the integration of various disease management strategies are essential for enhancing disease resistance in shallot cultivars. By understanding the mechanisms underlying plant resistance, optimizing growth conditions, and utilizing sustainable agricultural practices, it is possible to cultivate resilient shallot varieties with improved productivity and disease resistance.

Significantly, the use of biopesticides to seeds and plants and chemical fertilizers can produce the salicylic acid and jasmonic acid in shallots. This leads to reduction of pathogenic F. oxysporum. When the pathogenic F. oxysporum can be reduced, the productivity of shallots can also be increased. Therefore, in order to avoid the productivity failure of Shallots in Plaosan District, Magetan Regency, every seed and chemical fertilizer needs to be sprayed with folio biopesticides.

CONCLUSION

Fobio has a good impact on the resistance level of shallots to fusarium oxysporum, but the impact of changes after administration is visible. The salicylic and jasmonic acid levels in shallot plants are quite good with the addition of Fobio. The presence of salicylic acid and jasmonic acid may increase shallot resistance to Fusarium oxysporum attack. Based on the findings, utilizing Fobio as a biopesticide in shallot cultivation practices is recommended to enhance resistance against Fusarium oxysporum. Continuous monitoring of shallot plants post-administration of Fobio is advised to assess any changes in resistance levels, allowing for adjustments in application rates or frequencies as needed. Recognizing the significance of salicylic acid and jasmonic acid in enhancing shallot resistance, strategies should be implemented to optimize the levels of these signaling molecules, potentially through targeted nutrient management or bio-stimulant applications. Further research is warranted to elucidate the mechanisms underlying Fobio's impact on salicylic acid and jasmonic acid levels in shallot plants, informing the development of more targeted disease management strategies. Field trials should be conducted to validate the efficacy of Fobio in real-world agricultural settings, integrating its use into an overall integrated pest management approach for shallot cultivation. By implementing these recommendations, growers can effectively enhance shallot resistance to Fusarium oxysporum, ultimately improving crop health and productivity.

Based on these findings, it is recommended to adopt Fobio as a biopesticide in shallot farming practices to strengthen resistance against *Fusarium oxysporum*. Continuous monitoring of treated shallot plants is advised to observe any changes in resistance levels, allowing for precise adjustments to application rates or frequency as necessary. Recognizing the role of salicylic and jasmonic acids in boosting resistance, strategies should also focus on optimizing these defense molecules, potentially through specific nutrient management or bio-stimulant enhancements. Further studies are essential to understand how Fobio affects salicylic and jasmonic acid pathways in shallots, which could guide the refinement of biopesticide formulations. Additionally, field trials in varied environmental conditions would help validate Fobio's efficacy within an integrated pest management approach, supporting broader application in sustainable shallot cultivation.

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