Wallacea Plant Protection Journal
Vol. 2 No. 1 (2026)
Page: 26–33
DOI: https://doi.org/10.64128/wppj.v2i1.50533

Online ISSN 3090-5079

Published by Department of Plant Pest and Disease, Faculty of Agriculture, Hasanuddin University

Original Article

Potential of *Trichoderma* species against purple blotch disease and increase shallot yields

Ni Made D. Resiani [1], Sri Wahyuni Manwan [1,*], Ni P. Sutami [2], Asti Irawanti Azis [3], and Muhammad Iqbal Ardah [4]

[1] Research Centre for Horticulture and Crop Estate, National Research and Innovation Agency West Java, Indonesia
[2] Assessment Institute for Agricultural Technology – Bali, Indonesian Agency for Agricultural Research and Development (IAARD), Ministry of Agriculture, Denpasar, Bali, Indonesia
[3] Department of Plant Pest and Disease, Faculty of Agriculture, Hasanuddin University, Indonesia
[4] Agricultural Assembly and Modernization Agency – Bali, Ministry of Agriculture, Indonesia
[*] Correspondence: sriw024@brin.go.id

ARTICLE INFORMATION

Citation: Resiani, N. M. D., Manwan, S. W., Sutami, N. P., Azis, A. I., & Ardah, I. (2026). Potential of *Trichoderma* species against purple blotch disease and increase shallot yields. *Wallacea Plant Protection Journal, 2*(1), 26–33. https://doi.org/10.64128/wppj.v2i1.50533

Editor handling: M. Bayu Mario

Received : 07 April 2026
Revised : 16 August 2026
Accepted : 19 August 2026
Published : 22 August 2026

ABSTRACT

Purple blotch disease, caused by pathogenic fungi *Alternaria porri*, is an important foliar disease of shallot that can substantially reduce crop productivity. Biological control using *Trichoderma*-derived preparations offers a potential alternative to intensive reliance on synthetic fungicides. This study evaluated the effects of different concentrations of a *Trichoderma* sp. preparation on purple blotch development and yield performance of three shallot varieties under field conditions. The experiment was conducted in Tabanan Regency, Bali, Indonesia, from February to May 2020 using a factorial randomized block design. The treatments consisted of four concentrations of the *Trichoderma* preparation (0, 20, 40, and 60 mL L^{-1}) and three shallot varieties (Bima Brebes, Bali Karet, and Local Tabanan), with four blocks. Disease development and yield-related parameters were evaluated to determine the responses to *Trichoderma* concentration, shallot variety, and their interaction. The combination of 40 mL L^{-1} *Trichoderma* preparation and Bali Karet was associated with a low purple blotch severity of 11.55%. However, the highest dry bulb yield (14.10 t ha^{-1}) was recorded in the untreated Bali Karet control, whereas the 40 mL L^{-1} treatment in the same variety produced 13.89 t ha^{-1}. These findings indicate that suppression of purple blotch did not necessarily correspond to a proportional increase in bulb yield and that treatment responses were dependent on shallot variety. Therefore, the effectiveness of the *Trichoderma* preparation should be interpreted by considering both disease suppression and varietal yield response rather than defining a single concentration as universally optimal.

Keywords: *Alternaria porri*; Disease management; Shallot variety; Tabanan Regency

1. Introduction

Shallots (*Allium cepa* L.) are one of the horticultural commodities belonging to the Family Amaryllidaceae, classified as the most important spice vegetable (Jhala et al., 2017) and as a seasoning of local cuisine in various parts of the world. Shallots contain carbohydrates, vitamins A, B, and C (Wenli et al., 2019). The shallots extract contains several polyphenols such as gallic acid, apigenin, catechins, quercetin, tannic acid, and kaempferol which are well-known compounds that have antifungal activity (Sittisart et al., 2017) and are beneficial for health, serving as antibiotics, anticancer, antioxidant, and kidney protectors (Abdelrahman et al., 2017).

China is the world's largest producer of shallots, with production reaching 24,699,576 tons, followed by India at 22,071,000 tons and the United States at 3,284,420 tons (FAO, 2018). In Indonesia, total shallot production reached 1,815,445 tons, with Central Java Province contributing the highest share (611,165 tons), while Bali Province recorded a significantly lower production of 14,207 tons (BPS, 2020). The demand for shallots continues to increase annually, driven by population growth and the expansion of the food industry. Various efforts have been undertaken to enhance shallot production and productivity; however, pests and diseases remain major constraints. The most prevalent diseases affecting shallots are caused by *Fusarium oxysporum* and *Stemphylium vesicarium* (Gaikwad et al., 2014). Alternaria porri is one of the major pathogens causing purple spot disease in shallots (Setyadjit & Sukasih, 2015). This pathogen primarily infects leaves and flower stalks, leading to severe damage to above-ground plant parts. Under endemic conditions, the disease can result in complete crop failure (Haq et al., 2014). Yield losses due to *A. porri* infection have been reported to range from 2.5 to 87.8 % (Jalal et al., 2011).

Looking at the condition, it is necessary to control the pathogens. In the field, a common practice is to use chemical pesticides excessively. Farmers are forced to spray very high amounts of chemical pesticides on shallot crops for the sustainability of their crops. The use of high-dose chemical pesticides will affect the health and due to pollution. To minimize or avoid side effects, effective and environmentally friendly means of control are required. Integrated pest and disease management (IPM) is the solution. Biological control is one of the components in IPM. Biological control with the use of antagonistic microorganisms is a way of control that is environmentally friendly and sustainable. There are many species of fungi and bacteria have the potential as biocontrol agents to control various diseases (Janisiewicz et al., 2011). *Trichoderma* is one of the most widely used fungal biocontrol agents. *Trichoderma* is a fungus that lives freely everywhere and highly interactive in the root and soil environment. In addition, Mycorrhiza is also used to improve the quality of shallots bulbs (Golubkina et al., 2019). *T. harzianum* can effectively control pathogen *A. porri* and increases shallot bulbs (Prakasam & Sharma, 2012). This study aims to obtain the optimum dose of *Trichoderma* sp. in the combination of *Trichoderma* sp. and varieties for integrated management of *A. porri* and to improve shallot yields in Bali.

2. Materials and Methods

2.1. Study Site and Experimental Period

The field experiment was conducted in Subak Biaung, Pemanis Kaje Village, Penebel District, Tabanan Regency, Bali, Indonesia, from February to May 2020.

2.2. Materials and Tools

The materials used in the field experiment included planting materials of three shallot varieties (Bima Brebes, Bali Karet, and Local Tabanan), a *Trichoderma* sp. preparation, trichocompost, inorganic fertilizers, dolomite, silver-black plastic mulch, and water. Standard field equipment was used for land preparation, crop maintenance, treatment application, data collection, and documentation.

Planting materials of the Bima Brebes variety were obtained from shallot seed producers in Brebes, Central Java, Indonesia. Bali Karet planting materials were obtained from shallot seed producers in Songan Village, Kintamani, Bangli Regency, Bali, Indonesia, whereas Local Tabanan planting materials were obtained from local farmers in Tabanan Regency, Bali, who traditionally cultivate this shallot variety.

The *Trichoderma* sp. material evaluated at different concentrations in the field experiment was obtained from the Biological and Botanical Pesticide Laboratory, Technical Implementation Unit (UPT) for Plantation Crop Protection, Bali Province. The experimental treatments consisted of 0 (TR0), 20 (TR1), 40 (TR2), and 60 mL L^{-1} (TR3) of the *Trichoderma* preparation, with TR0 representing the untreated control without application of the tested *Trichoderma* preparation. Biohorvic, obtained from the Indonesian Center for Agricultural Biotechnology and Genetic Resources Research and Development, Bogor, Indonesia, was also available as a comparative *Trichoderma*-based preparation. However, it was not designated as TR0 in the factorial treatment structure described in this study.

2.3. Research Design

The field experiment was arranged in a factorial randomized complete block design (RCBD) with two experimental factors: *Trichoderma* sp. dose and shallot variety. The first factor consisted of four *Trichoderma* sp. doses: TR0 (0 mL L^{-1}), TR1 (20 mL L^{-1}), TR2 (40 mL L^{-1}), and TR3 (60 mL L^{-1}). The second factor consisted of three shallot varieties: V1 (Bima Brebes), V2 (Bali Karet), and V3 (Local Tabanan). The factorial combination of the two factors resulted in 12 treatment combinations. The experiment consisted of four blocks, established according to field position to account for spatial variability in growing conditions across the experimental area. Within each block, the 12 treatment combinations were randomly assigned to the experimental plots. Thus, the experiment comprised 48 experimental units (4 *Trichoderma* doses × 3 varieties × 4 blocks). Each experimental unit consisted of 10 shallot clumps, resulting in a total of 480 clumps. Data were analyzed using a two-way analysis of variance (ANOVA).

2.4. Implementation Method

The implementation of activities in the field begins with the selection and preparation of land including cleaning of used rice saplings, followed by soil processing and pretense and basic fertilization. The land is processed and splattered using tractors and hoes. Depth of processing about 30 cm, then sprinkled organic fertilizer (Trichocompos) with a dose of 5 tons per hectare and agricultural lime as much as 100 kg/ha and inorganic fertilizer 1/3 part. The mound is made 120 cm wide with a length along with the natural map. The average height of the mound becomes 35–40 cm, the distance between mounds is 50 cm. Drainage measuring 40 cm with a depth of unloading 20 cm. Mulch silver-mounted along with the mound. Mulch is 10 m long and 120 cm wide. Before planting, holes were made in silver mulch as deep as 3 cm with a spacing of 20 × 20 cm.

Shallot seeds are cut into 1/4 part if there is no sign of prospective roots, uniform seed size weighing 5 g, soaking with the biological agency (10–15 mL L^{-1} of water) for 30 minutes before planting. Shallot seedlings are planted in the morning to avoid the heat of the sun during the day which can cause the seedlings to wither. The next treatment is embroidery and continued maintenance. Embroidery is done on plants that do not grow or whose growth is not good. The insert material is taken from the seedlings of the rejuvenated reserve plants that are the same growth as plants in the field. Weeding is done manually by removing weeds to avoid competition in obtaining nutrients from the soil. Supplementary fertilization 1 (15 DAP), follow-up 2 (35 DAP), each 1/3 parts through flush. Application of *Trichoderma* sp. is carried out weekly according to the treatment, starting 2 weeks after planting an interval of a week to 2 weeks before harvest. Harvesting is done when the shallots are 60 DAP (75% yellowing and crushing upper leaves). Harvesting is done by plucking the plant to its roots, withered, dried, tied, and stored.

2.5. Data Collection and Disease Assessment

Data collected during the experiment included purple blotch disease incidence (%), maximum plant height (cm), maximum number of leaves per clump, number of bulbs per clump, bulb diameter (mm), fresh bulb weight per clump (g), estimated fresh bulb yield (t ha^{-1}), dry bulb weight per clump (g), and estimated dry bulb yield (t ha^{-1}). In addition, the relationships between *Trichoderma* sp. concentration and disease incidence and shallot yield were evaluated using regression analysis.

Purple blotch disease incidence was determined as the proportion of plants exhibiting symptoms of *A. porri* infection relative to the total number of plants assessed. Disease incidence was calculated using the following equation (1):

$$DI = \frac{A}{B} \times 100\% \quad (1)$$

where, DI is disease incidence (%), A is number of affected plants according to scoring, and B is number of plants observed.

2.6. Data Analysis

The data obtained in this study were analyzed by using analysis of variance (ANOVA). If the treatment causes a difference to the observed variable, it is followed by the Duncan's multiple range test (DMRT) at the 5% significant level (Gomez & Gomez, 1995).

3. Results

The responses of the measured variables differed among the treatment combinations. Maximum plant height did not show a significant treatment response, whereas significant differences were detected for *A. porri* disease incidence and several growth- and yield-related parameters, including the maximum number of leaves per clump, number of bulbs per clump, bulb diameter, fresh bulb weight per clump, estimated fresh bulb yield, dry bulb weight per clump, and estimated dry bulb yield (Tables 1–6). The observed responses generally varied according to the combination of *Trichoderma* sp. concentration and shallot variety. During the experimental period, air temperature ranged from 25 to 29 °C, while relative humidity ranged from 75 to 90%.

A significant interaction between *Trichoderma* sp. concentration and shallot variety was detected for *A. porri* disease incidence at 21 and 28 days after planting (DAP) (Table 1). At 21 DAP, disease incidence ranged from 7.19% to 15.61% across the treatment combinations. The numerically highest incidence was recorded in TR1V1 (15.61%), whereas the lowest was recorded in TR3V2 (7.19%). Disease incidence in TR3V2 and TR0V2 was 53.94% and 50.22% lower, respectively, than the value recorded in TR1V1.

At 28 DAP, disease incidence ranged from 8.28% to 18.30%. TR1V1 had the numerically highest incidence (18.30%), although it was not significantly different from TR0V1 (16.62%), TR2V1 (15.96%), TR3V1 (15.23%), and TR1V3 (13.28%). The numerically lowest incidence was observed in TR0V2 (8.28%). However, this value did not differ significantly from TR1V2 (10.91%), TR2V2 (9.73%), TR3V2 (9.85%), TR0V3 (11.74%), TR1V3 (13.28%), TR2V3 (11.67%), and TR3V3 (11.06%). Numerically, the incidence recorded in TR0V2 was 54.75%, 50.18%, 48.12%, 45.65%, and 37.65% lower than those recorded in TR1V1, TR0V1, TR2V1, TR3V1, and TR1V3, respectively (Table 1).

A significant interaction between *Trichoderma* sp. application and shallot variety was observed for *A. porri* disease incidence at both 35 and 42 days after planting (DAP) (Table 2). At 35 DAP, the highest disease incidence was recorded in TR1V1 (19.06%), which did not differ significantly from TR0V1 (17.51%), TR2V1 (15.98%), and TR3V1 (15.65%). In contrast, the lowest incidence was observed in TR3V2 (10.07%), although it was statistically comparable to TR2V2 (11.26%), TR0V2 (11.52%), TR1V2 (13.75%), TR0V3 (12.77%), TR1V3 (13.27%), TR2V3 (12.58%), and TR3V3 (12.13%). Compared with TR1V1, disease incidence was 47.17%, 40.92%, and 39.56% lower in TR3V2, TR2V2, and TR0V2, respectively.

At 42 DAP, the highest disease incidence was again recorded in TR1V1 (19.33%), which was not significantly different from TR0V1 (17.64%), TR2V1 (16.36%), and TR3V1 (17.75%). The lowest incidence was recorded in TR2V2 (11.55%), but this value did not differ significantly from TR0V2 (11.88%), TR1V2 (13.79%), TR3V2 (11.64%), TR0V3 (12.89%), TR1V3 (14.77%), TR2V3 (12.62%), and TR3V3 (12.42%). Disease incidence in TR2V2 was 40.25% lower than that recorded in TR1V1 (Table 2).

Application of *Trichoderma* sp. and shallot varieties showed significant interactions with the average maximum number of leaves and number of bulbs per clump (Table 3). The highest maximum number of leaves as shown in the TR0V3 combination treatment (36.73 strands) which was not significantly different from the TR1V3 combination treatment (35.75 leaves); TR2V3 (36.25 strands); and TR3V3 (36.20 strands) and the lowest was in the treatment combination TR1V2 (17.05 strands); TR2V2 (17.33 strands); and TR3V2 (17.75 strands). The combination treatment TR0V3 (36.73 strands) was able to give a maximum number of leaves 115.43% higher than the treatment TR1V2 (17.05 strands) (Table 3). The highest number of bulbs per clump as shown in the combination treatment TR0V3 (10.70 cloves) was not significantly different from the combination treatment TR1V3 (9.30 cloves); TR2V3 (10.00 cloves); and TR3V3 (10.15 cloves) (Table 3). The lowest number of bulbs per clump as shown in the combination treatment TR1V2 (3.80 cloves) which was not significantly different from the combination treatment TR2V2 (4.70 cloves); TR3V2 (4.70 cloves); TR0V2 (6.10 cloves); TR0V1 (6.95 cloves); TR1V1 (5.20 cloves); TR2V1 (6.55 cloves); and TR3V1 (5.95 cloves). Treatment TR0V3 (10.70 cloves) was able to increase the number of bulbs per clump by 181.58% higher than the combination treatment TR1V2 (3.80 cloves) (Table 3).

The highest diameter of bulbs per clump was indicated in the combination treatment TR0V2 (3.27 mm) which did not differ markedly from the combination treatment TR2V2 (3.17 mm) and the lowest in the combination treatment TR1V1 (1.56 mm) which did not differ markedly from the combination treatment TR0V1 (1.72 mm); TR2V1 (1.73 mm); TR3V1 (1.69 mm); TR0V3 (2.11); and TR1V3 (1.97 mm). TR2V2 treatment (3.17 mm) was able to increase the diameter of bulbs by 103.20% compared to the combination treatment TR1V1 (1.56 mm) (Table 4).

Table 1. Effect of *Trichoderma* sp. and varieties of shallots against the average attack of purple blotch disease aged 21 and 28 days after planting (DAP).

Treatment	21 DAP						28 DAP*					
	V1		V2		V3		V1		V2		V3	
TR0	13.66	abc	7.77	fg	10.34	def	16.62	ab	8.28	f	11.74	bcdef
TR1	15.61	a	9.77	f	13.19	abcde	18.30	a	10.91	def	13.28	abcde
TR2	14.39	ab	7.83	f	10.95	cdef	15.96	abc	9.73	ef	11.67	bcdef
TR3	13.53	abcd	7.19	g	10.57	cdef	15.23	abcd	9.85	ef	11.06	cdef
CV (%)	17.86						11.44					

Note: The numbers followed by the same letter do not differ significantly on the 5% DMRT test. TR0= 0 mL L^{-1} *Trichoderma* sp.; TR1= 20 mL L^{-1} *Trichoderma* sp.; TR2= 40 mL L^{-1} *Trichoderma* sp.; TR3= 60 mL L^{-1} *Trichoderma* sp.; V1=Bima Brebes; V2= Bali Karet; V3=Local Tabanan. *Data analyzed after transformation into Arcsin $\sqrt{\%}$.

Table 2. Effect of *Trichoderma* sp. and varieties of shallots against the average attack of purple blotch disease aged 35 and 42 days after planting (DAP).

Treatment	35 DAP						42 DAP					
	V1		V2		V3		V1		V2		V3	
TR0	17.51	ab	11.52	e	12.77	cde	17.64	abc	11.88	e	12.89	de
TR1	19.06	a	13.75	cde	13.27	cde	19.33	a	13.79	bcde	14.77	bcde
TR2	15.98	abc	11.26	e	12.58	cde	16.36	abcd	11.55	e	12.62	de
TR3	15.65	abcd	10.07	e	12.13	de	17.75	ab	11.64	e	12.42	de
CV (%)	16.49						17.49					

The numbers followed by the same letter do not differ significantly on the 5% DMRT test. TR0= 0 mL L^{-1} *Trichoderma* sp.; TR1= 20 mL L^{-1} *Trichoderma* sp.; TR2= 40 mL L^{-1} *Trichoderma* sp.; TR3= 60 mL L^{-1} *Trichoderma* sp.; V1=Bima Brebes; V2= Bali Karet; V3=Local Tabanan.

Table 3. Effect of *Trichoderma* sp. and varieties of shallots against the average maximum number of leaves and the number of bulbs per clump.

Treatment	Maximum number of leaves (sheet)						Number of bulbs per clump (clove)					
	V1		V2		V3		V1		V2		V3	
TR0	27.49	e	22.58	fgh	36.73	a	6.95	e	6.10	e	10.70	a
TR1	20.95	fghi	17.05	i	35.75	abcd	5.20	e	3.80	e	9.30	abcd
TR2	24.97	ef	17.33	i	36.25	ab	6.55	e	4.70	e	10.00	abc
TR3	23.15	efg	17.75	i	36.20	abc	5.95	e	4.70	e	10.15	ab
CV (%)	11.02						14.62					

The numbers followed by the same letter do not differ significantly on the 5% DMRT test. TR0= 0 mL L^{-1} *Trichoderma* sp.; TR1= 20 mL L^{-1} *Trichoderma* sp.; TR2= 40 mL L^{-1} *Trichoderma* sp.; TR3= 60 mL L^{-1} *Trichoderma* sp.; V1=Bima Brebes; V2= Bali Karet; V3=Local Tabanan.

A significant interaction between *Trichoderma* sp. concentration and shallot variety was observed for fresh bulb weight per clump and estimated fresh bulb yield per hectare (Table 5). Fresh bulb weight per clump ranged from 20.07 to 79.67 g across the treatment combinations. The highest numerical value was recorded in TR2V2 (79.67 g), followed by TR0V2 (78.48 g) and TR3V2 (72.34 g). However, TR2V2 did not differ significantly from TR0V2, TR3V2, TR1V2 (65.40 g), TR0V3 (67.91 g), TR2V3 (67.88 g), or TR3V3 (66.88 g). In contrast, the lowest numerical value was recorded in TR1V1 (20.07 g), which was statistically comparable to TR0V1 (26.49 g), TR2V1 (26.34 g), and TR3V1 (25.98 g).

A similar response pattern was observed for estimated fresh bulb yield per hectare. The highest numerical yield was recorded in TR2V2 (19.92 t ha^{-1}), although it was not significantly different from TR0V2 (19.62 t ha^{-1}), TR3V2 (18.08 t ha^{-1}), TR1V2 (16.35 t ha^{-1}), TR0V3 (16.98 t ha^{-1}), TR2V3 (16.97 t ha^{-1}), or TR3V3 (16.72 t ha^{-1}). The lowest numerical yield was recorded in TR1V1 (5.02 t ha^{-1}), which did not differ significantly from TR0V1 (6.62 t ha^{-1}), TR2V1 (6.59 t ha^{-1}), and TR3V1 (6.50 t ha^{-1}) (Table 5).

Table 4. Effect of *Trichoderma* sp. and varieties of shallots against the average diameter of bulbs per clump.

Treatment	Diameter of bulb per clump (mm)					
	V1		V2		V3	
TR0	1.72	efgh	3.27	a	2.11	defg
TR1	1.56	gh	2.51	cd	1.97	efgh
TR2	1.73	efgh	3.17	ab	2.14	de
TR3	1.69	efgh	2.80	bc	2.14	de
CV (%)	13.00					

The numbers followed by the same letter do not differ significantly on the 5% DMRT test. TR0= 0 mL L^{-1} *Trichoderma* sp.; TR1=20 mL L^{-1} *Trichoderma* sp.; TR2=40 mL L^{-1} *Trichoderma* sp.; TR3= 60 mL L^{-1} *Trichoderma* sp.; V1=Bima Brebes; V2= Bali Karet; V3=Local Tabanan.

Table 5. Effect of *Trichoderma* sp. and varieties of shallots against the average weight of fresh bulbs of shallots per clump and per hectare.

Treatment	Fresh bulb weight per clump (g)						Fresh bulb weight per hectare (ton)					
	V1		V2		V3		V1		V2		V3	
TR0	26.49	i	78.48	ab	67.91	abcd	6.62	i	19.62	ab	16.98	abcd
TR1	20.07	i	65.40	abcdefg	57.655	cdefghi	5.02	i	16.35	abcdefg	14.41	defgh
TR2	26.34	i	79.67	a	67.88	abcde	6.59	i	19.92	a	16.97	abcde
TR3	25.98	i	72.34	abc	66.88	abcdef	6.50	i	18.08	abc	16.72	abcdef
CV (%)	18.73						18.73					

The numbers followed by the same letter do not differ significantly on the 5% DMRT test. TR0= 0 mL L^{-1} *Trichoderma* sp.; TR1=20 mL L^{-1} *Trichoderma* sp.; TR2=40 mL L^{-1} *Trichoderma* sp.; TR3= 60 mL L^{-1} *Trichoderma* sp.; V1 = Bima Brebes; V2 = Bali Karet; V3 = Local Tabanan.

Table 6. Effect of *Trichoderma* sp. and shallot varieties on the average dry-bulb weight of shallots per clump and hectare.

Treatment	Dry bulb weight per clump (g)						Dry bulb weight per hectare (ton)					
	V1		V2		V3		V1		V2		V3	
TR0	20.90	i	56.41	a	53.58	abcd	5.22	h	14.10	a	13.40	abcd
TR1	15.75	i	52.59	abcdefg	49.84	abcdefgh	3.94	h	13.15	abcdef	12.46	abcdefgh
TR2	20.78	i	55.55	ab	53.47	abcde	5.20	h	13.89	ab	13.37	abcde
TR3	20.51	i	53.68	abc	52.72	abcdef	4.92	h	13.42	abc	12.98	abcdefg
CV (%)	19.99						20.33					

The numbers followed by the same letter are not significantly different in the 5% DMRT test. TR0= 0 mL L^{-1} *Trichoderma* sp.; TR1=20 mL L^{-1} *Trichoderma* sp.; TR2=40 mL L^{-1} *Trichoderma* sp.; TR3= 60 mL L^{-1} *Trichoderma* sp.; V1=Bima Brebes; V2=Bali Karet; V3=Local Tabanan.

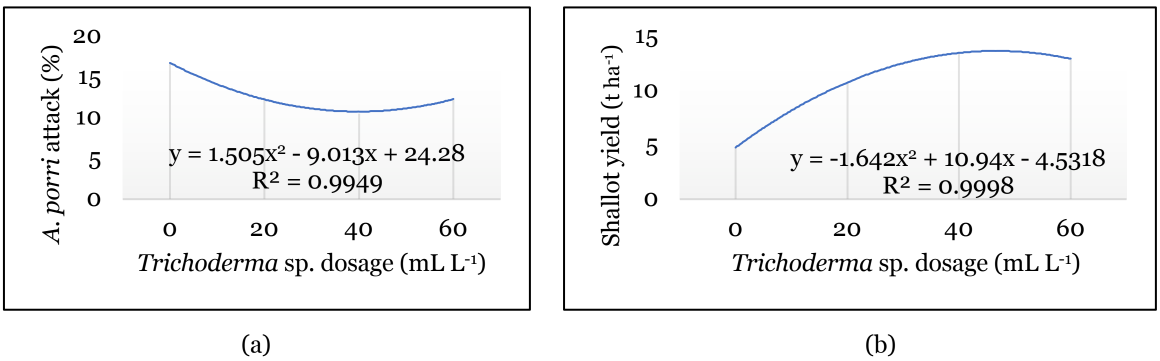

Figure 2. Relationships between *Trichoderma* sp. concentration and (a) purple blotch disease incidence and (b) dry bulb yield of shallot. Values represent marginal means across the three shallot varieties.

A significant interaction between *Trichoderma* sp. concentration and shallot variety was observed for dry bulb weight per clump and estimated dry bulb yield per hectare (Table 6). Dry bulb weight per clump varied among the treatment combinations, with the highest numerical value recorded in TR0V2 (56.41 g). However, this value was not significantly different from those recorded in TR1V2 (52.29 g), TR2V2 (55.55 g), TR3V2 (53.68 g), TR0V3 (53.58

g), TR1V3 (49.84 g), TR2V3 (53.47 g), and TR3V3 (52.72 g). In contrast, the lowest numerical dry bulb weight was recorded in TR1V1 (15.75 g), which did not differ significantly from TR0V1 (20.90 g), TR2V1 (20.78 g), and TR3V1 (20.51 g). A similar pattern was observed for estimated dry bulb yield per hectare. The highest numerical yield was recorded in TR0V2 (14.10 t ha^{-1}), followed by TR2V2 (13.89 t ha^{-1}) and TR3V2 (13.42 t ha^{-1}). Nevertheless, the yield recorded in TR0V2 did not differ significantly from those of TR1V2 (13.15 t ha^{-1}), TR2V2 (13.89 t ha^{-1}), TR3V2 (13.42 t ha^{-1}), TR0V3 (13.40 t ha^{-1}), TR1V3 (12.26 t ha^{-1}), TR2V3 (13.37 t ha^{-1}), and TR3V3 (12.98 t ha^{-1}). The lowest numerical yield was observed in TR1V1 (3.94 t ha^{-1}), which was statistically comparable to TR0V1 (5.22 t ha^{-1}), TR2V1 (5.20 t ha^{-1}), and TR3V1 (4.92 t ha^{-1}) (Table 6).

The results of the regression analysis obtained a correlation of doses *Trichoderma* sp. to the *A. porri* attack showed a quadratic relationship with the equation of regression line $y = 1.505x^2 - 9.013x + 24.28$, with a coefficient of determination (R^2) = 99.49%. Inferred dose of *Trichoderma* sp. 40.2 mL L^{-1} of water is the optimum dose of *A. porri* attack with *A. porri* attack of 7.42% (Figure 2).

Regression analysis showed a quadratic pattern between *Trichoderma* sp. concentration and both purple blotch disease incidence and dry bulb yield (Figure 2). Disease incidence tended to decrease from the untreated control to the intermediate *Trichoderma* concentrations, followed by a slight increase at the highest concentration tested (Figure 2a). Conversely, dry bulb yield showed an increasing trend toward the intermediate concentrations, followed by a slight decline at the highest concentration (Figure 2b). The quadratic models showed a close fit to the observed treatment means (R^2 = 0.9949 for disease incidence and R^2 = 0.9998 for dry bulb yield). However, because significant interactions between *Trichoderma* sp. concentration and shallot variety were detected, these regression patterns should be interpreted as overall descriptive trends across the tested concentrations rather than as evidence of a single optimum concentration applicable to all shallot varieties.

4. Discussion

The Bima Brebes variety is a shallot variety that was tested for the first time at the research site so it has not adapted well. The adaptation of local varieties is better than other local varieties adapted at the same environment. The variety can be said to be adaptive if it can grow well in its distribution area, with high production (Meliala, 2011). The results of this study also refer to Kareem et al. (2011) research who found that the development of *A. porri* disease increased with increasing plant age up to a certain age (Kareem et al., 2011). Climate such as temperature and humidity also support the development of *A. porri* disease in the study area. The average temperature and humidity ranged between 25–29 °C and 75–90% RH. The environmental factors, especially temperature and humidity, influenced the development of purple onion spots under field conditions (Ansar & Dabbas, 2012). Temperature ranges of 25.50–28 °C and 26.5–27.2 °C and RH 88–76% and 80–78% support the incidence of the disease. The *A. porri* infection of shallots occurred in the temperature range of 15–35 °C, with maximum infection at 25 °C and relative humidity for disease progression occurs in the range of 75–100% RH with an optimum RH of 95% (Kareem et al., 2011). There was an interaction between the treatment of *Trichoderma* sp. and varieties on the number of leaves, number of bulbs, bulb diameter, fresh bulb weight per clump and hectare, and dry bulb weight per clump and hectare (Table 3–6). This condition is probably caused by the application of *Trichoderma* treatment in addition to genetic factors from the plant itself. The *Trichoderma* is a filamentous fungus that has high economic value because it acts as a biocontrol or biological pesticide agent, inhibiting the growth of phytopathogenic fungi that can damage various kinds of plants (Hanhong, 2011). The application of *Trichoderma* spore suspension in the field was successful against antagonistic pathogens by reducing the appearance of purple spots (Janisiewicz et al., 2011).

The *Trichoderma* spp. is a common resident of the rhizosphere as a biocontrol against soil-borne plant pathogens. Antagonistic activity of *Trichoderma* can be through the mechanism of host cell wall lysis, antibiosis, parasitism, competition, secretion of chitinolytic enzymes, mycoparasitism, and production of inhibitory compounds and produce several secondary metabolites with biological activity (Fotoohiyan et al., 2015; Shehata et al., 2018). The *Trichoderma* is not only capable of producing antimicrobials, but also producing fungal substances that can stimulate plants to produce self-defense metabolites (Vinale et al., 2012). *Trichoderma* can cause an overall increase in production. The components of the growth and yield of onions vary, possibly due to genetic factors of each shallot variety. The development and growth of a plant are largely determined by plant genetic factors (Fotoohiyan et al., 2015). In addition to genetic factors, the growing environment, especially the humidity and temperature around the plant, also affects the growth components and plant yields. Each plant requires an optimal temperature within a certain range (Maruapey, 2012). The genetic factors are one of the factors causing the diversity of plant appearances in addition to environmental factors (Amin et al., 2013).

The results of the regression analysis obtained a correlation of doses *Trichoderma* sp. to the *A. porri* attack showed a quadratic relationship. Likewise, the results of the regression analysis obtained a correlation of doses *Trichoderma* sp. to the results of dried bulbs of shallots per hectare. It is mean the higher the dose of *Trichoderma* sp. given up to a certain point will suppress *A. porri* and increase the yield of shallot then will decrease.

5. Conclusion

Trichoderma sp. and varieties have a significant effect on the *A. porri* and yield of shallots. There was an interaction between *Trichoderma* sp. and shallot varieties in suppressing *A. porri* attack and shallot yields. The highest *A. porri* attack was shown in the combination of 20 mL L^{-1} SM of *Trichiderma* sp. and Bima Brebes, but not significantly different from other treatment doses SM of *Trichoderma*. The highest dry bulb weight per hectare was indicated in Bali Karet variety. The optimum dose of

Trichoderma sp. to suppress attack of *A. porri* was 40.2 mL L^{-1} of water with *A. porri* attack of 7.42%. The optimum dose of *Trichoderma* sp. to the yield of dry shallot per hectare is 46.6 mL L^{-1} of water with a yield of 17,081 t ha^{-1}.

Author Contributions: **Ni Made D. Resiani:** Investigation, Data curation Writing – original draft, Writing – review & editing. **Sri Wahyuni Manwan:** Conceptualization, Methodology, Validation, Supervision, Investigation, Writing – original draft, Writing – review & editing. **Ni P. Sutami:** Investigation, Data curation. **Asti Irawanti Azis:** Methodology, Validation, Writing – original draft, Writing – review & editing. **Muhammad Iqbal Ardah:** Formal analysis, Visualization, Writing – original draft, Writing – review & editing. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: Thanks are conveyed to the Agricultural Research and Development Agency of the Ministry of Agriculture, the Center for Research and Assessment, the Head of the Bali Agricultural Technology Study Center for the funding, so that this activity can take place and the farmer groups implement it for their assistance so that this activity goes according to plan.

Conflicts of Interest: The authors declare no conflicts of interest.

References

Abdelrahman, M., Mahmoud, H. Y. A. H., El-Sayed, M., Tanaka, S., & Tran, L. S. (2017). Isolation and characterization of Cepa2, a natural alliospiroside A, from shallot (*Allium cepa* L. Aggregatum group) with anticancer activity. *Plant Physiology and Biochemistry*, *116*, 167–173. https://doi.org/10.1016/j.plaphy.2017.05.006

Amin, A. W. B., Kuswanto, K., & Soegianto, A. (2013). Respon lima varietas jagung (*Zea mays* L.) pada aplikasi pyraclostrobin. *Jurnal Produksi Tanaman*, *1*(1), 80–85.

Ansar, M., & Dabbas, M. R. (2012). Influence of abiotic environmental factors on purple blotchdisease (*Alternaria porri* Eliss CIF.) of onion. *International Journal of Agricultural Sciences*, *8*(1), 171–173.

BPS. (2020). *Produksi bawang merah di Provinsi Bali*. https://bali.bps.go.id/id/statistics-table/2/MzMyIzI=/produksi-bawang-merah-provinsi-bali-menurut-kabupaten-kota.html

FAO. (2018). *Produksi bawang merah dunia*.

Fotoohiyan, Z., Rezaee, S., Bonjar, G. H. S., Mohammadi, A., & Moradi, M. (2015). Induction of systemic resistance by *Trichoderma harzianum* isolates in pistachio plants infected with *Verticillium dahliae*. *Journal of Nuts*, *6*(2), 95–111.

Gaikwad, K., Jadhav, S. U., & Kakulte, V. R. (2014). Management of fungal diseases of onion (*Allium cepa* L.) by using plant extract. *International Journal of Life Science and Pharma Research*, *4*(2), 28–30.

Golubkina, N., Zamana, S., Seredin, T., Poluboyarinov, P., Sokolov, S., Baranova, H., Krivenkov, L., Pietrantonio, L., & Caruso, G. (2019). Effect of selenium biofortification and beneficial microorganism inoculation on yield, quality and antioxidant properties of shallot bulbs. *Plants*, *8*(4), 102. https://doi.org/10.3390/plants8040102

Gomez, K. A., & Gomez, A. A. (1995). *Prosedur statistik untuk penelitian pertanian*. UI Press.

Hanhong, B. (2011). *Trichoderma* species as abiotic and biotic stress quenchers in plants. *Research Journal of Biotechnology*, *6*(3), 73–79.

Haq, I, U., Zaman, Z., Habib, A., Javed, N., Khan, S, A., Iqbal, M., & Ihsan, J. (2014). Assessment of yield losses caused by purple blotch disease in onion (*Allium cepa* L.) and its management. *Pakistan Journal of Phytopathology*, *26*(02), 225–232.

Jalal, R., Bagheri, S. M., & Moghimi, A. (2011). The effect of Iranian shallot or garlic aqueous extracts on learning, memory and serum biochemical variables in fructose-fed wistar rats. *Iranian Journal of Basic Medical Sciences*, *14*(3), 284–289. https://doi.org/10.22038/ijbms.2011.5007

Janisiewicz, W. J., Pimenta, R. S., & Jurick, W. M. (2011). A novel method for selecting antagonists against postharvest fruit decays originating from latent infections. *Biological Control*, *59*(3), 384–389. https://doi.org/10.1016/j.biocontrol.2011.07.015

Jhala, P., Meena, M. K., & Mali, B. L. (2017). Impact of abiotic factors and age of host plant on purple blotch of onion caused by *Alternaria porri* (Ellis) and estimation of yield losses. *Journal of Plant Development Sciences*, *9*(5), 447–451.

Kareem, M. A., Murthy, K. V. M. K., Hasansab, A. N., & Waseem, M. . (2011). Effect of temperature, relative humidity and light on lesion length due to *Alternaria porri* in onion. *Bioinfolet*, *9*(3), 264–266.

Maruapey, A. (2012). Pengaruh pupuk kalium terhadap pertumbuhan dan produksi berbagai jagung pulut (*Zea mays* var. Ceratina L). *Agrikan: Jurnal Agribisnis Perikanan*, *5*(2), 33–45. https://doi.org/10.29239/j.agrikan.5.2.33-45

Meliala, B. A. (2011). *Uji adaptasi beberapa varietas bawang merah (Allium ascalonicum) pada musim hujan*. Universitas Sumatera Utara.

Prakasam, V., & Sharma, P. (2012). *Trichoderma harzianum* (Th-3) a potential strain to manage the purple blotch of onion (*Allium cepa* L.) caused by *Alternaria porri* under North Indian plains. *Journal of Agricultural Science*, *4*(10). https://doi.org/10.5539/jas.v4n10p266

Setyadjit, & Sukasih, E. (2015). Effect of addition of filler on the production of shallot (*Allium cepa Var. Ascalonicum* L.) powder with drum dryer. *Procedia Food Science*, *3*, 396–408. https://doi.org/10.1016/j.profoo.2015.01.044

Shehata, A., Mohammed, A., Mosa, A., & Ali, M. (2018). Evaluation of some fungicides and biocontrol agents for controlling of Alternaria rot on citrus fruits. *Arab Universities Journal of Agricultural Sciences*, *26*(2), 691–699. https://doi.org/10.21608/ajs.2018.16001

Sittisart, P., Yossan, S., & Prasertsan, P. (2017). Antifungal property of chili, shallot and garlic extracts against pathogenic fungi, *Phomopsis* spp., isolated from infected leaves of para rubber (*Hevea brasiliensis* Muell. Arg.). *Agriculture and Natural Resources*, *51*(6), 485–491. https://doi.org/10.1016/j.anres.2018.03.005

Vinale, F., Sivasithamparam, K., Ghisalberti, E. L., Ruocco, M., Woo, S., & Lorito, M. (2012). *Trichoderma* secondary metabolites that affect plant metabolism. *Natural Product Communications*, *7*(11). https://doi.org/10.1177/1934578X1200701133

Wenli, S., Mohamad, H. S., & Qi, C. (2019). The insight and survey on medicinal properties and nutritive components of shallot. *Journal of Medicinal Plants Research*, *13*(18), 452–457. https://doi.org/10.5897/JMPR2019.6836