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Comparative study between fungicides and some chemical inducers for controlling root rot incidence of green bean (*Phaseolus vulgaris* L.) under field conditions

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Abstract: Root rot disease caused by *Rhizoctonia solani* J.G. Kuhn and *Fusarium solani* (Mart.) Sacc. is a major problem restricting profitable farming of green bean (*Phaseolus vulgaris* L.). Under field conditions, some chemical inducers compared with chemical fungicides were evaluated for controlling bean root rot disease. Significant effect was observed for all applied treatments against disease incidence compared with control. Applied treatments of seed dressing plus foliar spray showed the highest reduction of root rot incidence followed by seed dressing then foliar spray. Salicylic acid as seed followed by foliar spray showed the highest suppressive effect against disease incidence followed by glutathione treatments. Furthermore, application of calcium silicate revealed higher effect against disease incidence compared with potassium and sodium silicate at both pre-, and post-emergence plant growth stages. Fungicidal treatments showed affect disease incidence in a lower extent compared with Plant Resistance Inducers (PRI). Treatment of Rizolex T50 followed by Topsin M70 was more effectively in controlling root rot than each fungicide alone. Such applied treatments could be useful for controlling root rot disease under field conditions

Key words: bean; fungicide alternatives; root rot; Rizolex T50; Topsin M70

Primerjalna raziskava fungicidov in kemičnih vzpodbujevalcev za nadzor koreninske gnilobe pri fižolu (*Phaseolus vulgaris* L.) v razmerah na prostem

Izvleček: Koreninska gniloba, ki jo povzročata glivi *Rhizoctonia solani* J.G. Kühn in *Fusarium solani* (Mart.) Sacc. je glavni omejujoči dejavnik za donosno pridelavo stročjega fižola(*Phaseolus vulgaris* L.). V razmerah poljskega poskusa so bili primerjani učinki kemičnih vzpodbujevalcev in kemičnih fungicidov v njihovi sposobnosti nadzora koreninske gnilobe. V primerjavi s kontrolo so bili opaženi značilni učinki vseh obravnavanj proti bolezni. Obravnavanja s kapsuliranimi semeni in foliarnimi pršili so pokazala največje zmanjšanje gnilobe, tem so sledila obravnavanja s kapsuliranimi semeni in nato obravnavanja s foliarnimi pršili. Salicilna kislina kot sredstvo obdelave semen in kot naknadno foliarno pršilo je imela največji učinek na zaviranje bolezni, temu je sledilo obravnavanje z glutationom. Nadalje je bila uporaba kalcijevega silikata bolj učinkovita pri zatiranju bolezni v primerjavi s kalijevim in natrijevim silikatom v obravnavanjih pred in po vzniku rastlin. Obravnavanja s fungicidi so pojav bolezni bolj zmanjšala kot tista z alternativnimi sredstvi. Obravnavanje s fungicidom Rizolex T50 in nato s fungicidom Topsinn M70 je bilo bolj učinkovito pri nadzoru gnilobe kot uporabi posameznih fungicidov. Našteta obravnavanja bi torej lahko bila koristna za nadzor fižolove gnilobe v poljskih razmerah.

Ključne besede: fižol; alternativni fungicidi; koreninska gniloba; Rizolex T50; Topsin M70

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1 INTRODUCTION

Soilborne plant pathogens are considered the main problems in agricultural production all-over the world that they affected seriously on plant stand causing great losses in produced yield. Therefore, growing plants are exposed to invasion by various soilborne pathogens during their different growth stages starts from seed sowing up to maturity. Bean (Phaseolus vulgaris L.) is one of food legume species that widely cultivated for domestic use, exportation, and it has considerable importance for human food especially in developing countries (Baudoin et al., 2001). Certain fungi could attack bean plants causing root rot, wilt and leaf spot diseases which greatly influenced plant stand and subsequently yield production. Root rot disease caused by particular soilborne pathogens have an effect on emerged seedlings and may be occurs earlier when seeds are attacked during their emergence causing pre-emergence infection leading to the need of re-sowing the missed hills or dead plants.

The most harmful soilborne fungi causing root rot disease of bean are Fusarium solani Sacc., Sclerotium rolfsii Sacc. and Rhizoctonia solani J.G. Kühn (Abdel-Kader, 1997; El-Mougy et al., 2007). A high buildup of root rot pathogen inoculums due to successive cultivation on the same land could leads to causes serious yield losses. Therefore, control of this disease is considered important especially in new reclaimed soil where green bean is wide prevalence crop in Egypt.

The present research focuses on comparing the use of fungicides and natural compounds that are capable to control root rot incidence. The objective of this study was evaluate some chemical fungicides and chemical inducers as alternatives to fungicide application to achieve effective management against the incidence of green bean root rot disease when used as seed dressing and/or foliar spray under natural field conditions.

2 MATERIALS AND METHODS

2.1 TESTED MATERIALS:

Green bean seeds (Phaseolus vulgaris 'Giza 3') kindly obtained from Vegetables Crop Research Department, Agricultural Research Centre, Giza, Egypt. The tested chemicals potassium silicate, calcium silicate, glutathione, salicylic acid and sodium silicate purchased from Al-Gamhoria Company Ltd. for chemicals and medicinal instruments, Cairo, Egypt. Meanwhile, the fungicides Rizolex-T 50 WP (20 % Tolclophos-methyl and 30 % Thiram) Sumi Agro Co. and Topsin M70 WSB (thiophanate-methyl 70 %) Martin's Co. purchased from local market.

2.2 FIELD EXPERIMENTS:

A field located at Al-Nubaria region, Beheira governorate, Egypt was chosen for this experiment. This field is well known by the authors to be characterized with semi homogeneous distribution with root rot pathogens mainly *Fusarium solani*, *Sclerotium rolfsii* and *Rhizoctonia solani* as naturally heavily infested soil. In addition, at prior growing season to the present study, samples of growing bean plants showing root rot disease symptoms were collected and subjected to isolation trails for the causal organisms.

The present field experiment was carried out for two successive growing seasons (March and September, 2019) to evaluate the efficacy of some chemical inducers and fungicides applied as seed dressing and/or foliar spray against root rot incidence. The experimental field contains plots (6 × 7 m), each included 12 rows with 35 holes. In all plots green bean seeds of ´Giza 3` were sown at the rate of three seed/hole. Seed dressing was carried out before sowing, meanwhile foliar spray was applied twice, the first was at the two true leaves age of emerged seedlings and the second after 15-day interval. All treated plants were sprayed using 20 l sprayer for each plot.

2.3 APPLICATIONS TO THE EXPERIMENTAL FIELD

For the two cultivation seasons the same proposed treatments were designed as follows:

a) Seed treatment at the rate of 3 g kg^{-1}
T1- potassium silicate
T2- calcium silicate
T3- glutathione
T4- salicylic acid
T5- sodium silicate
T6- Rizolex T50

b) Seed treatment at the rate of 3g l^{-1} + foliar spray at the rate of 3 g l^{-1}
T7- potassium silicate + potassium silicate
T8- calcium silicate + calcium silicate
T9- glutathione + glutathione
T10- salicylic acid + salicylic acid
T11- sodium silicate + sodium silicate
T12- Rizolex T50 (3 g l^{-1}) + Topsin M70 (3 g l^{-1})

c) Foliar spray at the rate of 3 g l^{-1}
T13- potassium silicate
T14- calcium silicate
T15- glutathione
T16- salicylic acid
T17- sodium silicate
T18- Topsin M70
T19- untreated control

2.4 DISEASE AND YIELD ASSESSMENT

Three plots as replicates were used for every specific treatment as well as untreated control. All plots were conducted in completely randomized block design. The traditional agricultural practices, that is, soil plowing, fertilization, irrigation, etc., were followed at all experimental plots. Monitoring and scouting for diseases incidence in all cultivated plots were preformed weekly (El-Mougy and Abdel-Kader et al., 2018). At all applied treatments and control as well the percent of pre-emergence root rot disease incidence was recorded after 15 days from sowing date as numbers of emerged seedlings referring to the numbers of sown seeds. Meanwhile, the percentage of post-emergence disease infection were recorded after 15, 30 and 45 days as numbers of diseases plants referring to the numbers of emerged seedlings. Percentage of healthy survivals was calculated as the numbers of survival plants referring to the numbers of sown seeds. Accumulated yield was determined as fresh pods (kg/plot) for each particular treatment at the end of growing season. The increase of obtained yield in relative to comparison treatment was also calculated.

2.5 STATISTICAL ANALYSIS

The obtained data subjected to analysis of variance using IBM SPSS software version 14.0. Mean separation performed using Duncan's Multiple Range Test at $p \leq 0.05$ by the MSTAT-C software

3 RESULTS

The fungi isolated from the bean plants showing root rot symptoms were identified as *Fusarium solani* and *Rhizoctonia solani*. The results showed that all applied treatments had announced effects against root rot incidence compared with the control (Table 1).

Applied treatments of a seed dressing + foliar spray showed lower root rot disease incidence followed by seed dressing alone, and then foliar spray alone. Moreover, the effects of the fungicide applications were lower than those of the chemical inducers and followed similar trend as the applied methods mentioned above. The results also indicate that the application of salicylic acid as a seed and/or foliar spray showed the highest reduction in root rot incidence followed by the glutathione treatments. The percentage of pre- and post-emergence root rot was recorded as 5.3 %, 8.0 % [T4]; 5.5 %, 6.5 % [T10] and 15.6 %, 21.0 % [T16] followed by 7.3 %, 12.6 % [T3]; 7.5 %, 9.6 % [T9] and 14.3 %, 27.0 % [T15] when compared with the 30.0 %, 57.3 % of the untreated control treatment [T19]. Moreover, the pre- and post-emergence potassium silicate [T1], [T7] applications showed greater disease reduction when compared with the calcium [T2[, [T8] and sodium silicate [T5], [11].

For the seed dressing, seed dressing + foliar spray, and foliar spray treatments disease reduction was calculated as 70.0 %, 73.8 % [T2]; 72.0 %, 80.8 % [T8] and 38.0 %, 46.5 % [14] in relation to the control treatment [T19], respectively. Meanwhile for the same applied treatments disease reductions of 61.3 %, 74.6 % [T1]; 60.0 %, 82.0 % [T7] and 21.6 %, 38.9 % [T13] were identified. Likewise, for treatments [T5], [T11], and [T17] the percentages of root rot disease reduction were 60.0 %, 69.4 %; 56.6 %, 75.0 %, 30.0, and 41.8 % at pre-, and post-emergence growth stages, in respective order.

The fungicidal treatment data showed that the combination of two fungicides applied as a seed dressing + foliar spray resulted in lower disease incidence when compared with the seed dressing and foliar spray, in descending order (Table 1). The percentage of root rot incidence for [T12] was 9.5 % and 10.6 % with disease reduction of 68.3 % and 81.5 % at the pre-, and post-emergence growth plant stages, respectively. Furthermore, for the [T6] treatment, disease incidence and reduction were recorded as 9.6 %, 14.6 %, and 68.0 %, 74.5 % for both plant growth stages in parallel, respectively. Meanwhile a higher root rot incidence of 27.3 %, 40.0 % and its lower reduction of 9.0 %, 30.1 % were recorded when Topsin M70 [18] was applied only as a foliar spray, although it significantly differed when compared with the untreated control [T19].

The results also revealed that applied treatments increased plant survival when compared with the untreated control (Table 1). The highest percentage of plant survival recorded with the seed dressing + foliar spray was followed by seed dressing then foliar spray treatments, respectively. The highest percentages of plant survival were 88.0 %, 81.9 %, and 81.5 % with the [T10], [T9], and [T8] treatments, followed by 86.6 %, 78.6 %, and 77.3 % with the [T4], [T3], and [T2] treatments, and 63.3 %, 58.6 %, and 50.6 % with the [T16], [T15], and [T14] treatments. The other applied chemical inducer treatments ranged between 37.5 % with the [T13] treatment to 77.6 % with the [T7] treatment for plant survival. For the fungicide applications there was 79.8 %, 75.6 %, and 32.6 % survival with the [T12] Rizolex T50 WP + Topsin M70 WSB followed by [T6] Rizolex-T50 WP and [T18] Topsin M70 WSB, respectively which was significant when compared with 12.6% for the [T19] control treatment.

In contrast, the data indicated that the obtained decreases in root rot disease incidence due to the current applied treatments resulted in an increase in plant survival which was subsequently reflected in the accumulated product yield.

The green pod yields from the beans showed similar tendencies to the reduction in disease incidence identified in Table 1 and Fig. 1. The highest obtained yields recorded were 27.8, 26.2, and 24.6 kg/plot with an increase over the control calculated as 78.2 %, 67.9 %, and 57.6 % for the [T10], [T9], and [T8] treatments which included a seed dressing + foliar spray treatments, respectively. There were moderate yield increases of 70.5 %, 55.1 %, and 42.9 % for the [T4], [T3], and [T2] treatments which involved seed dressing. Percentages of 71.7 %, 50.0 %, and 36.5 % indicated lower increases in the produced yields and were recorded for the [T16], [T15], and [T14] treatments which involved foliar sprays. The rest of the applied chemical treatments revealed a yield increase between 12.8 % for [T13] with a foliar spray and 44.8 % for [T7] with a seed dressing + foliar spray.

Table 1: Average efficacy of some chemical inducers and fungicides against bean root rot incidence during two growing seasons under field conditions

	Root rot diseases incidence (%)				
	Pre-emergence**	Red.* (%)	Post-emergence**	Red.* (%)	Plant survivals (%)
			Seed dressing		
[T1] Potassium silicate	11.6 ± 0.8 cd	61.3	14.5 ± 1.9 de	74.6	73.8 ± 1.0 f
[T2] Calcium silicate	9.0 ± 0.5 e	70.0	15.0 ± 1.0 de	73.8	77.3 ± 1.1f
[T3] Glutathione	7.3 ± 0.5 f	75.6	12.6 ± 0.5 e	78.0	78.6 ± 2.0 f
[T4] Salicylic acid	5.3 ± 0.7 g	82.3	8.0 ± 1.5 fg	86.0	86.6 ± 1.2 g
[T5] Sodium silicate	12.0 ± 2.4 cd	60.0	17.5 ± 0.8 d	69.4	70.5 ± 1.7 f
[T6] Rizolex-T50	9.6 ± 0.8 e	68.0	14.6 ± 1.4 de	74.5	75.6 ± 1.9 f
			Seed dressing + Foliar spray		
[T7] Potassium silicate	12.0 ± 1.1 cd	60.0	10.3 ± 1.6 f	82.0	77.6 ± 1.1f
[T8] Calcium silicate	8.4 ± 0.8 ef	72.0	11.0 ± 1.7 e	80.8	81.5 ± 1.7 g
[T9] Glutathione	7.5 ± 0.8 f	75.0	9.6 ± 2.8 f	83.2	81.9 ± 1.7 g
[T10] Salicylic acid	5.5 ± 0.8 g	81.6	6.5 ± 2.6 g	88.6	88.0 ± 0.4 g
[T11] Sodium silicate	13.0 ± 1.1 cd	56.6	14.3 ± 2.3 de	75.0	72.6 ± 0.8 f
[T12] Rizolex-T50 + Topsin M70	9.5 ± 2.9 e	68.3	10.6 ± 1.0 f	81.5	79.8 ± 1.5 f
			Foliar spray		
[T13] Potassium silicate	23.5 ± 2.4 ab	21.6	35.0 ± 1.5 ab	38.9	37.5 ± 0.8 b
[T14] Calcium silicate	18.6 ± 2.3 b	38.0	30.6 ± 2.0 b	46.5	50.6 ± 2.0 d
[T15] Glutathione	14.3 ± 2.7 c	52.3	27.0 ± 1.3 bc	52.8	58.6 ± 1.0 d
[T16] Salicylic acid	15.6 ± 1.2 c	48.0	21.0 ± 0.6 c	63.3	63.3 ± 0.5 e
[T17] Sodium silicate	21.0 ± 0.6 ab	30.0	33.3 ± 3.3 ab	41.8	45.6 ± 1.2 c
[T18] Topsin M70	27.3 ± 0.4 a	9.0	40.0 ± 0.3 ab	30.1	32.6 ± 0.8 b
[T19] Control	30.0 ± 1.5 a	-	57.3 ± 1.3 a	-	12.6 ± 1.8 a

* Red. = Reduction
** Pre-emergence calculated after 15 days from seed sowing
*** post-emergence calculated after 45 days from seedlings emergence
Means ± standard deviations within a column followed by the same letter are not significantly different by Duncan multiple range test at $p < 0.05$

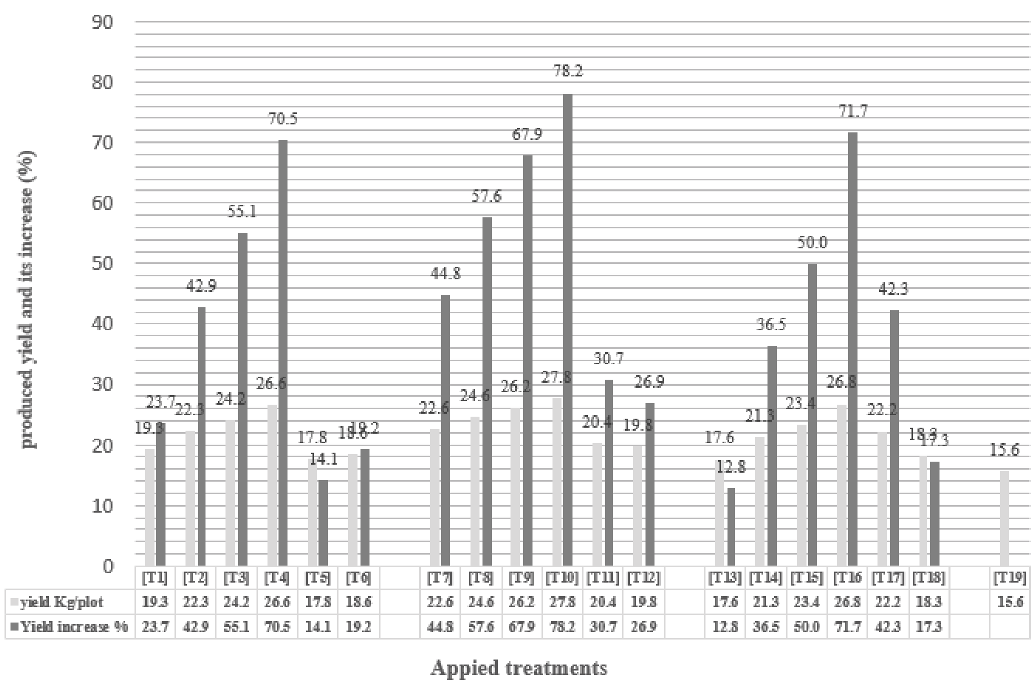

Fig. 1: Average accumulated yield of bean plants and its increase (%) in response to application of some chemical inducers and fungicides at two growing seasons under field conditions

For the fungicidal applications, yield was increased by 26.9 % for [T12] in response to the application of Rizolex T50 WP as a seed dressing followed by a foliar spray with Topsin M70 WSB. Meanwhile yield increases of 19.2 % and 17.3 % were recorded for [T6] and [T18] with the Rizolex T50 WP seed dressing and Topsin M70 WSB foliar spray, respectively.

4 DISCUSSION

In the current study the fungi isolated from the collected bean plants that showed root rot symptoms were identified as *Fusarium* sp. and *Rhizoctonia solani* Root rot disease of green caused by *F. solani* and *R. solani* has been previously reported (Abdel-Kader, 1997, El-Mougy et al., 2007, El-Mougy and Abdel-Kader, 2018). Additionally, common bean, cowpea, and faba bean, which are suitable pathogen hosts, are regularly grown in the study field, thus, it is assumed that there is an increasing population of the soilborne root rot pathogen as these crops are considered suitable hosts. This investigation aimed to evaluate the use of chemical inducers as fungicide alternatives when compared with chemical fungicides applied as seed dressing and/or foliar sprays to control the incidence of green bean root rot disease under field conditions. The obtained results revealed that the applied chemical inducers as well as the fungicidal treatments were all highly effective at reducing disease incidence and increasing yield. In this regard, salicylic acid treatments as a seed dressing and/or foliar spray had high efficacy against root rot incidence and yield increase. These results are in accordance with those of previous studies (El-Mougy et al., 2019). El-Mohamady et al. (2017) reported on the use of chemical inducers, such as chitosan (CH), salicylic acid (SA), and humic acid (HA) for the control of bean root rot caused by *Fusarium solani* and *Rhizoctonia solani* under both greenhouse and field conditions. They found that soaking bean seeds in CH 1.0 g/l^{-1} + SA 5% followed by foliar applications at half of this concentration, caused a superior reduction in both damping-off and root rot incidence when compared with their other applied treatments. In addition, Anderson (1988) reported that salicylic acid as a phenolic compound acts as a regulator key of the internal coding network in plants under either abiotic or biotic stress. It plays a major role in the plant resistance functions against pathogens as it promotes the production of pathogenesis-related proteins (PRPs). Furthermore, salicylic acid was accountable for the aggregation of phytoalexins in viable plant tissues. Mandel et al. (2009) stated that external or internal operators might ultimately affect the host plant physiology, leading to the fast and harmonic activation of defense-genes in plants which were susceptible to parasite infections. However, Jabnoun et al. (2015) reported that systemic acquired resistance for controlling tomato fungal diseases could be induced by using salicylic acid and chitosan as chemical inducers. Likewise, several workers reported yield increases when chemical inducers or fungicides were applied (El-Mougy et al. 2007, El-Mohamady and Abd-El-Baky, 2008, Abd-El-Kareem et al., 2013, Abdel-Kader et. al., 2014, El-Mohamady et al., 2017, El-Mougy et al., 2019). In the present study the used chemical inducers, salicylic acid and potassium, calcium, sodium silicate had high activity against root rot incidence and yield increase as well as when applied as a seed dressing and/or foliar spray. Recently, the application of several chemical inducers received a large amount of attention due to various investigations into the control of plant diseases. Glutathione (GSH) as an antioxidant has a role in regulating plant tolerance to biotic stresses by repressing localized necrotic symptoms following viral infections. Utilizing the pharmacological and transgenic approaches confirmed the role of GSH for reducing disease symptoms in plants which were induced by pathogen infections. Furthermore, recent studies have shown that GSH also has a key role in restricting pathogen levels. In fact, it seems that GSH is a vital agent responsible for the elicitors involved in different types of plant disease resistance (Gullner et al., 2017). Furthermore, glutathione (GSH) was reported to be involved in the activation and regulation of the biosynthetic processes involved in plant defense (Bolter et al., 1993). Moreover, glutathione functions include several roles in biosynthetic pathways, detoxification, antioxidant biochemistry, and redox homeostasis (Noctor et al., 2012). In contrast, applications of silicon salts proved their activity against pathogenic fungal growth *in vitro* as well as plant disease incidence. Silicates were reported to have efficacy for reducing plant diseases in rice (Datnoff et al., 1997), strawberry (Kanto et al., 2006), wheat (Belanger et al., 2003), and cucumber (Menzies et al., 1992). Biggs et al. (1997) stated that PDA medium supplemented with calcium silicate inhibited 65% of the growth of *Monilinia fructicola* (G.Winter) Honey the causal agent of peach brown rot. Furthermore, it also inhibited mycelial growth for several phytopathogenic fungi grown on potassium silicate amended media in vitro (Bekker et al., 2006, 2009). Li et al. (2009) also reported an inhibitor effect for sodium silicate against the growth of *Fusarium sulphureum* Schltdi. *in vitro*. Moreover, an in vivo foliar spray of potato plants with 100 and 200 mM sodium silicate was found to control tuber dry rot disease effectively. They concluded that sodium silicate has direct fungitoxic effects against the fungal pathogen. Furthermore, it was reported that soluble potassium silicate applied as a root and foliar spray caused reductions in disease incidence as well as an increase in growth and fruit quality for capsicum plants (Jayawardana et al., 2014). Ultimately, Shen et al. (2010) stated that it is probable that a reduction in disease incidence in plants treated with silicon sources under field conditions is not likely to be attributed to the fungistatic effects of silicon, but could act as a physical block which directly prevents pathogen penetration to plant tissues or indirectly by enhancing plant defense responses. It is suggested that silicon may act as the first protecting block in treated plants and could inhibit pathogen colonization and subsequent infection. Therefore, potassium silicate could be used as a fungicide since it has direct inhibitor effects on fungal growth and its ability to increase plant self-defense systems (Menzies et al., 1992) and strengthen plant cell walls, inhibiting disease infection (Epstein, 1999). The current investigation showed the lesser effects of contact and systemic fungicides for controlling bean root rot incidence when compared with chemical inducers, despite their superior activity over control treatments against disease occurrence. The fungicide Rizolex (Tolclofos - methyl) is an organophosphate ester chemical compound which has protective, curative and slightly systemic action and has high fungitoxicity to *Rhizoctonia solani* and *Sclerotium rolfsii* (Ohtsuki and Fujinami, 1982). Rizolex was reported to actively reduce the incidence of southern stem rot caused by *R. solani* and *S. rolfsii* and increase peanut yield (Csinos, 1985). Rizolex T50 is a seed treatment fungicide that delivers protection against a broad spectrum of soil borne and seed/seedling diseases, including *Rhizoctonia* damping-off and *Fusarium* (Hopkins 2013). Hamed (2008) reported that Rizolex completely inhibited the growth of *Rhzictonia solani* (100 %) at all concentrations (0.025, 0.05, 0.25, and 0.5 ppm) *in vitro*. Recently, El-Mohamady et al. (2017) concluded that using chemical inducers in comparison with the fungicide Rizolex had superior effects to RIS alone against bean damping-off, root rot diseases, and increasing the produced yields, and therefore may be considered as an eco-friendly applied method for the control of soil-borne plant pathogens. Topsin M70 (thiophanate-methyl) is a fungicidal substance which belongs to the agent group of benzimidazoles. It is a wide range systemic fungicide controlling a wide variety of plant pathogens (Hirschfeld et al. 2010). The primary effect of thiophanate-methyl is caused by the transformation product methyl-benzimidazole-2yl-carbamate, which binds to the fungal tubulin and disturbs the formation of the spindle apparatus during mitosis so that homologous chromosomes cannot divide, and cell growth will be inhibited. It is absorbed by the treated plant roots, leaves, and has a protective and curative action (Saber, et. al, 2011). A combine use of the fungicides Topsin-M and Dimecron showed significant increase in phenolic content (Siddiqui et. al., 1999). Increase in phenolic and phenolic content produced as a result of stress may act as a protective compound against pathogenic fungi and insects (Friend, 1979). *In vitro* tests with Rizolex-T and Topsin-M at 200 ppm have completely inhibited the growth of *R. solani* and *F. oxysporum* Schlecht. emend. Snyder & Hansen the causal pathogens of root rot and wilt complex disease, which used soil culture medium in some surveyed nurseries (Abdel-Kader et. al., 2004). Moreover, the use of Topsin M70 as a foliar spray was effective against various plant diseases, such as citrus mold caused by *Penicillium italicum* Wehmer (Kanan and Al-Najar, 2009), *Fusarium mangiferae* Kanan and Al-Najar, 2009), *Fusarium mangiferae* Britz, Wingfield & Marasas on mango (Iqbal et al., 2010), *Phytophthora infestans* (Mont.) de Bary the causal agent of tomato late blight (Meya et al., 2014), faba bean chocolate spot caused by *Botrytis fabae* Sardina (Moustafa et al., 2015), *Lasiodiplodia theobromae* (Pat.) Griffon & Maubl. the causal of die-back of grapevine (El-Habbaa et al., 2016) and *Fusarium oxysporum* f. sp. *capsici* the causal agent of wilt disease on chili pepper (Bashir et. al., 2018).

The present investigation demonstrates that the applied chemical inducers and fungicides were efficient at controlling green bean root rot disease incidence and increased the accumulated yield. Treatments of seed dressing followed by foliar spray showed higher effectivity on disease incidence and produced greater yields than with the seed dressing or foliar spray individually.

5 CONCLUSIONS

The results of the current study suggest that the combined application method of chemical inducers such as seed and/or foliar sprays was superior to single treatments for reducing root rot incidence on green bean plants and increasing accumulated pod yields. The commercial fungicides Rizolex T50 WP and Topsin M70 WSB showed similar trends for controlling disease incidence. Such treatments may be used commercially and could be said to have characteristics such as being eco-friendly, safe, cheap, and an easily applied alternative fungicide methods for use in natural field conditions.

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