J Bangladesh Agril Univ 20(1): 49–56, 2022 https://doi.org/10.5455/JBAU.130804

ISSN 1810-3030 (Print) 2408-8684 (Online)

Journal of Bangladesh Agricultural University

Journal home page: http://baures.bau.edu.bd/jbau

Research Article

Improvement of Bacterial Wilt Tolerance in Eggplants by Endotrophic Mycorrhiza (*Glomus mosseae*)

Sadia Afrin Shupta, Shila Chakraborty, Shimul Akhtar and Md. Atiqur Rahman Khokon✉

Department of Plant Pathology, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh

ARTICLE INFO

Article history
Received: 07 Oct 2021
Accepted: 01 Jan 2022
Published: 31 Mar 2022

Keywords
Bacterial wilt,
Ralstonia solanacearum,
Eggplant,
Glomus mosseae,
Tolerance

Correspondence
Md. Atiqur Rahman Khokon
✉: atiq.ppath@bau.edu.bd

ABSTRACT

The wilt of eggplant caused by *Ralstonia solanacearum* is a seriously damaging, soil-borne, vascular disease having multiple solanaceous hosts. Arbuscular mycorrhizal fungi (AMF), on the other hand, are commonly occurring symbiotic fungi that live with the majority of crop plants. The present experiment was aimed to investigate the efficacy of mycorrhiza (*Glomus mosseae*) to manage wilt disease of brinjal caused by *R. solanacearum*. The experiment was conducted in pots in the net house maintaining artificial inoculated condition. Mycorrhization by *G. mosseae* exhibited significant variation in vegetative parameters *viz.* plant height, shoot length, root length, fresh weight, and dry weight at three important growth stages *viz*. 30, 60, and 90 Days After Transplanting (DAT) compared to non-mycorrhized brinjal plants. Mycorrhization of brinjal plants by *G. mosseae* resulted in significantly taller eggplant plants (29.4, 37.3, and 52.9 cm), root length (16.71, 16.89, and 18.91 cm), root fresh weight (5.68, 6.51, and 7.2 g), and root dry weight (0.64, 0.65 and 0.83 g) than co-inoculation of *R. solanacearum* and *G. mosseae* at 30, 60 and 90 DAT respectively. Moreover, wilt incidence was lower (16.51, 11.93, and 4.68 %) in co-inoculated plants with *R. solanacearum* and *G. mosseae* than the plants (31.42, 43.58, and 80.00 %) inoculated with *R. solanacearum* alone at all growth stages. Spore density of *G. mosseae* (125, 144, 176 /100 g soil), percentage of mycorrhized roots (36.67, 60.00, and 76.70 %) remained higher in *G. mosseae* inoculated soil at three growth stages. A significant reduction of the bacterial population (*R. solanacearum*) in soil was found in co-inoculation with *R. solanacearum* and *G. mosseae* compared to *R. solanacearum* alone. It is revealed that application of *G. mosseae* ensures better vegetative growth of eggplants and effectively reduces bacterial (*R. solanacearum*) colonies in soil and persistently maintains the population of *G. mosseae*.

Introduction

The bacterial wilt of eggplant caused by *Ralstonia solanacearum* is the most important biological impediment during cultivation that causes huge economic loss every year of the farmers in Bangladesh. Bacterial wilt is also the major limitation in the production of Solanaceous crops all over the world (Hayward, 1991). *Ralstonia solanacearum* is a complex species with a large heterogeneous group of related strains. It has been subdivided into five races based on the host range and five biovars based on the biochemical properties (Hayward, 1991). Bacterial wilt symptoms include wilting of the foliage, followed by the collapse of the entire plant. The bacterium can survive in soil or infected plant debris for prolonged periods (Grey et al., 2001). Symptoms are very clear during the morning or immediately after irrigation. Symptoms manifest initially as leaf drooping followed by wilting of the entire plant within a few days. Recently wilted plants look green, a distinct symptom when compared to other vascular wilt diseases which develop yellowing of the leaves. Vascular discoloration (brown) can also be seen in the wilted plant (Ramesh, 2008).

Different kinds of management practices have been tried to restrain the threat of bacterial wilt of eggplant. But, many of the endeavors have not been completely successful. Crop rotation with non-host plants has not been effective, since *R. solanacearum* has its disseminating and survival stages in the soil. The race and strain diversity of the pathogen has made breeding for resistant cultivars ineffective (Wang et al., 1998). Chemical and soil treatments such as modification of soil pH, heat treatment by solarization, application of stable bleaching powder, as well as plant resistance inducers (e.g. Acibenzolar-S-methyl), plant essential oils (*e.g.* Thymol), or phosphorous acid (Norman et al.,

Cite This Article

Shupta, S.A., Chakraborty, S., Akhtar, S. and Khokon, M.A.R., 2022. Improvement of Bacterial Wilt Tolerance in Eggplants by Endotrophic Mycorrhiza (Glomus mosseae). *Journal of Bangladesh Agricultural University*, 20(1): 49–56. https://doi.org/10.5455/JBAU.130804

2006) have been shown to reduce bacterial populations and disease severity on a small scale. Drawbacks of these methods include environmental damage, cost and high labour inputs (Champoiseau et al., 2009). Attempts have also been made by applying organic material for controlling the disease. Application of poultry refuse combined with stable bleaching powder ($NaCO_3$) and carbofuran (Furadan 5G) was reported effective by Faruk et al. (2019). But the management methods are inconsistent in field performance and not sustainable against wilt diseases of eggplant (Hayward, 1992). On the other hand, resistant microorganisms and harmful residual effects of chemical pesticides are now serious health concerns around the globe (Kaur and Arora, 1999).

Thus, there remains a need for developing management methods of bacterial wilt which are more affordable, effective, and provide a high degree of food safety and minimal environmental impact. Arbuscular mycorrhizal fungi (AMF) colonize the roots of most plants; their extraradical mycelium (ERM) extends into the soil and acquires nutrients for the plant. These mutualistic endotrophic mycorrhizal fungi have gained considerable recognition as biological agents for better nutrient accumulation and management of soil-borne pathogenic microorganisms. Among the arbuscular mycorrhizal fungi, *Funneliformis mosseae* (syn. *Glomus mosseae*) plays pivotal roles in plant disease management. Root colonization of onion by *Funneliformis mosseae* significantly alleviated the pink root disease caused by *Pyrenochaeta terrestris* (Safir, 1968). The verticillium wilt was significantly reduced in cotton plants colonized by AMF, *F. mosseae*, *G. versiforme*, and *Sclerocystis sinuosa* (Liu, 1995). Mycorrhizal colonization improved tomato resistance to an array of diseases caused by *Erwinia carotovora* (García-Garrido and Ocampo, 1988), *Fusarium oxysporum* f. sp. *lycopersici* (Akköprü and Demir, 2005), *Phytophthora nicotianae* var. *parasitica* (Cordier et al., 1996), *P. parasitica* (Cordier et al., 1998), and *Pseudomonas syringae* (García-Garrido and Ocampom, 1989). Several mechanisms are involved in controlling and suppression of the pathogen by mycorrhizal fungi roots such as the exclusion of pathogen, changed P nutrition, lignifications of the cell wall, and exudation of low molecular weight compounds (Sharma et al., 2004).

The farmers are completely dependent on chemical pesticides for crop disease management in Bangladesh. While the consumers are more conscious regarding pesticide residues in crops. Control wilt disease using mycorrhizae in eggplant would be an alternative to the conventional management approach. Therefore, the objective of the research was to know the effectiveness of arbuscular mycorrhizae (*G. mosseae*) in increasing tolerance of eggplant plants for the management of bacterial wilt caused by *R. solanacearum*.

Materials and Methods

Preparation of mycorrhizal inocula

The initial inocula of *Glomus mosseae* (spores mixed in soil and roots of maize) were collected from Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. To produce a bulk amount of inocula, the initial inocula were multiplied in maize seedlings grown in sterilized soils in pots as trap culture (Dhar et al., 2020). After 60 days of inoculation, the potting soil containing maize roots was used as secondary inocula. This secondary inoculum was used @ 10 g inocula/kg soil for further experimentation (Dhar et al., 2020). Moreover, to understand the population dynamics of *R. solanacearum*, a time series *viz*. 10, 30, 50, 70, and 90 DAI was maintained for counting the population number (CFU/g soil) (Tahat et al., 2008).

Isolation and preparation of Ralstonia solanacearum for artificial inoculation

Ralstonia solanacearum was isolated from wilted eggplant by following bacterial streaking method on Triphenyl Tetrazolium Chloride (TTC) medium. The bacteria were purified by successive cultures by single colony streaking method. Bacterial colonies showing dull white colour, fluidal appearances with the pink centre were initially recognized as *R. solanacearum* isolates. For artificial inoculation, 7 days old culture was used and the cell concentration was adjusted to 1×10^8 Colony Forming Unit (CFU)/mL. Crosin solution @ 500 ppm (30 mL/pot) applied 5 times at 20 days intervals after inoculation was considered as a positive control for comparison.

One-month-old eggplant seedlings were transplanted in the pots. Inocula of *G. mosseae* was mixed with soil ten days before transplantation. Root clipping of eggplant seedlings followed by dipping into 50 mL suspension of *R. solanacearum* @ 1×10^8 CFU/mL for 10 minutes in a beaker was done for inoculation during transplantation. Regular and uniform care was maintained as and when necessary (Rashid and Singh, 2000).

Measurement of root colonization and spore abundance in soil

Histochemical staining was done to confirm the root colonization by *G. mosseae*. To assess root colonization, root samples were collected and stained using a modified technique described by Rajesh et al. (2011). The fungal spores in the soil were estimated by the wet sieving and decanting method described by Rajesh et al. (2011). The abundance of spores in soil and root

colonization was counted three times. Data were recorded at 30 days intervals after transplanting.

Data collection and statistical analyses

The following parameters were considered during data collection: root length (cm), shoot length (cm), root fresh weight (g), root dry weight (g), shoot fresh weight (g), shoot dry weight (g), disease incidence, percent root colonization and abundance of spore/100 g soil. The experiment was carried out using a Completely Randomized Design (CRD) with three replicates and means were compared according to Duncan's Multiple Range Test ($p \leq 0.05$). WASP computer programming was used for ANOVA.

Results

Effect of soil application of G. mosseae on different vegetative parameters and biomass production at different growth stages of eggplants

Three vegetative stages *viz*. seedling stage (30 DAT), maximum vegetative stage (60 DAT), and flower initiation to first picking stage (90 DAT) of eggplants were considered to observe the impact of *G. mosseae* inoculation in soil on vegetative parameters (Dhar et al., 2020) (Table 1). Differences were found considering plant height at three time intervals. At every time interval, the highest plant height was recorded in T_1 (29.4, 37.3, and 52.9 cm) where the soil was treated with *G. mosseae* alone followed by T_4 (*R. solanacearum* @ 1×10^8 CFU/mL + CrosinAG10ASP solution @ 500 ppm). The lowest plant height was found in T_2 (23.2, 26.9, and 28.4 cm) where the soil was inoculated with the *R. solanacearum* only. The intensity of wilting caused by *R. solanacearum* was found significantly reduced when *G. mosseae* was co-inoculated with R. *solanacearum* (Table 1). A similar trend was also found in the case of shoot length and root length at 30, 60, and 90 DAT. Both the highest shoot length (15.5, 26.8 and 43.5 cm) and root length (16.7, 16.8 and 18.9 cm) were recorded in T_1 (*G. mosseae* @ 10 g/kg soil) followed by T_4 (*R. solanacearum* @ 1×10^8 CFU/mL + CrosinAG10ASP solution @ 500 ppm). On the contrary, the lowest shoot length (10.4, 14.0, and 21.2 cm) and root length (10.5, 10.2, and 9.1 cm) were recorded in T_2 (*R. solanacearum* @ 1×10^8 CFU/mL). At 90 DAT 62.32, 70.28, and 51.64 % increment in plant height, shoot length, and root length were found in T_1 (*G. mosseae* @ 10 g/kg soil) over *R. solanacearum* inoculated plants. So, a steady increment in vegetative growth parameters with time by applying *G. mosseae* was evident from this study.

Table 1. Effect of soil inoculation of *G. mosseae* on vegetative parameters at different growth stages of eggplant plants

Treatment	Plant height (cm)			Shoot length (cm)			Root length (cm)		
	30DAT	60DAT	90DAT	30DAT	60DAT	90DAT	30DAT	60DAT	90DAT
T_0	29.1 a	33.7 a	37.5 b	14.6 a	23.8 a	29.1 c	12.5 bc	12.3 bc	11.7 bc
T_1	29.4 a	37.3 a	52.9 a	15.5 a	26.8 a	43.5 a	16.7 a	16.8 a	18.9 a
T_2	23.2 b	26.9 b	28.4 c	10.4 b	14.0 b	21.2 d	10.5 c	10.2 c	9.1 c
T_3	26.3 ab	32.5 a	46.1 ab	14.4 a	24.0 a	36.1 b	12.4 bc	14.7 ab	13.8 bc
T_4	30.7 a	36.3 a	49.6 a	16.1 a	26.0 a	41.1 ab	14.9 ab	16.4 a	14.8 ab
CD (0.05)	4.74	5.02	9.0	2.9	3.1	6.8	3.0	2.7	4.7
CV	9.3	8.3	11.5	11.2	7.5	11.0	12.5	10.8	19.2

T_0 = Control, T_1 =*G. mosseae* inocula @ 10g/kg soil, T_2 = *R. solanacearum* suspension @ 1×10^8 CFU/mL, T_3 =*G. mosseae* inocula @ 10g/kg soil + *R. solanacearum* suspension @ 1×10^8 CFU/mL, T_4= *R. solanacearum* suspension @ 1×10^8 CFU/mL + 500 ppm crosin AG_{10ASP} solution @ 30 mL/pot, DAT=Days after transplanting, CD=Critical difference, CV=Co-efficient of variations

Eggplant shoot weight was significantly influenced by different treatments at different time intervals (Table 2). Both fresh weight and dry weight of shoot significantly varied at 60 and 90 DAT. The highest fresh weight (31.4 g and 43.4 g) and dry weight (7.58 g and 9.0 g) of the shoot were recorded in T_1 (*G. mosseae* @ 10 g/kg soil) at 60 and 90 DAT respectively. The lowest fresh weight (16.8 g and 22.1 g) and dry weight (3.55 g and 2.37 g) of the shoot were recorded in T_2 (*R. solanacearum* @ 1×10^8 CFU/mL). Co-inoculation of *G. mosseae* and *R. solanacearum* recovered fresh and dry weight of shoot. Similarly, the fresh weight of the root showed significant differences among the treatments at different time intervals. The highest fresh weight of root (6.5 g and 7.0 g) was found in T_1 (*G. mosseae* @ 10 g/kg soil) at 60 and 90 DAT respectively. The lowest fresh root weight (1.9 g and 2.5 g) was found in T_2 (*R. solanacearum* @ 1×10^8 CFU/mL). Root dry weight varied significantly at 60 DAT, but the variation was not significant at 90 DAT. Fresh root weight was recovered when brinjal plants were co-inoculated by *G. mosseae* and *R. solanacearum* compared to sole inoculation with *R. solanacearum* (Table 2).

Table 2. Effect of soil inoculation of G. mosseae on biomass production at different growth stages of eggplant plants

Treatment	Shoot weight (g)						Root weight (g)					
	30 DAT		60 DAT		90 DAT		30 DAT		60 DAT		90 DAT	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
T_0	17.8	3.62	21.7 cd	5.62 ab	30.9 bc	6.58 b	4.5	0.48 ab	3.6 b	0.33 bc	3.7 c	0.42
T_1	19.8	4.15	31.4 a	7.58 a	43.4 a	9.0 a	5.6	0.64 a	6.5 a	0.65 a	7.2 a	0.83
T_2	13.7	2.48	16.8 d	3.55 b	22.1 c	2.37 c	3.3	0.32 b	1.9 b	0.18 c	2.5 c	0.24
T_3	17.5	3.27	24.8 bc	6.48 a	38.3 ab	7.56 ab	3.8	0.33b	5.6 a	0.48 ab	5.8 ab	0.64
T_4	21.2	4.97	29.1ab	7.25 a	41.5 a	8.13 a	4.6	0.51 ab	6.3 a	0.60 a	6.9 a	0.74
CD (0.05)	NS	NS	6.4	2.556	9.1	1.829	NS	0.228	1.7	0.227	2.9	NS
CV	16.6	24.22	14.197	23.056	14.3	14.888	26.4	26.54	20.3	27.813	30.3	38.012

T_0 = Control, T_1 =*G. mosseae* inocula @10g/kg soil, T_2 = *R. solanacearum* suspension@ 1×10^8CFU/mL, T_3 =*G. mosseae* inocula @ 10g/kg soil + *R. solanacearum* suspension@ 1×10^8 CFU/mL, T_4= *R. solanacearum* suspension @ 1×10^8CFU/mL + 500 ppm crosin AG_{10ASP} solution @ 30 mL/pot, DAT=Days after transplanting, CD=Critical difference, CV=Co-efficient of variations

Effect of G. mosseae inoculation on the incidence of wilt of eggplant caused by R. solanacearum

Experiments were conducted in pots under the artificial inoculated condition to investigate the effect of soil inoculation of *G. mosseae* in wilt disease incidence of eggplant plants (Figure 1). Disease incidence was recorded at 10 days intervals starting from 20 DAT and continuing up to 90 DAT. Incidence of wilting was first noticed at 10 DAT and continued up to 90 DAT. Reduction of wilt incidence at 10 and 20 DAT was not statistically significant meaning that the effect of *G. mosseae* required some time to be effective in the plant system. At 30 DAT both the treatment showed a significant effect in reducing wilt incidence. The highest disease incidence (31.42%) was recorded when *R. solanacearum* was inoculated alone, whereas the lowest disease incidence (16.51%) was found when *G. mosseae* was co-inoculated with *R. solanacearum* at 30 DAT. With the progress of time, the reduction in wilt incidence was higher for *G. mosseae* and Crosin AG10ASP. The highest reduction in wilt incidence (1.75%) was found in Crosin AG10ASP treatment at 90 DAT which was statistically similar with *G. mosseae*. On the other hand, the highest incidence (80.00%) was recorded at 90 DAT where the plants were inoculated with *R. solanacearum* alone.

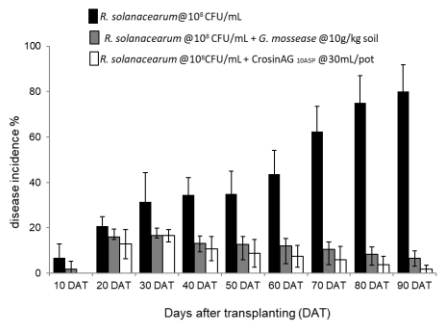

Figure 1. Disease incidence (%) of wilt of eggplant caused by *Ralstonia solanacearum* at different days after transplanting (DAT)

Effect of co-inoculation of G. mosseae and R. solanacearum on eggplant root mycorrhization and mycorrhizal spore production in soil

The investigation was carried out on the interaction effect of *G. mosseae* and *R. solanacearum* on spore density and root colonization capacity in eggplant plants at different growth stages (Table 3). An increasing tendency of mycorrhizal spore production and root mycorrhization by *G. mosseae* was recorded at every stage of plant growth. A significantly higher number of spores (176.0) and mycorrhized roots (76.70%) were developed at 90 DAI when *G. mosseae* was inoculated alone. On the contrary, the spore number (157.0) and mycorrhized roots (61.67%) were decreased when *G. mosseae* was co-inoculated with *R. solanacearum*. The number of spores of *G. mosseae* in soil and mycorrhized roots reduced in co-inoculated conditions. But the spores of *G. mosseae* and mycorrhized roots are still available in considerable numbers in co-inoculated application of *G. mosseae* and *R. solanacearum*. It indicates that mycorrhizae can grow and multiply in the presence of plant pathogens and can enhance tolerance against bacterial wilt of eggplant.

Effect of G. mosseae inoculation on population dynamics of R. solanacearum in the soil at different time intervals

Ralstonia solanacearum is a soil inhabitant that may cause infection in its host plants. Population dynamics of *R. solanacearum* were observed in rhizospheric soil of eggplants treated by *G. mosseae* and compared with untreated control and positive control (Crosin AG10ASP). To understand the population dynamics of *R. solanacearum*, a time series *viz*. 10, 30, 50, 70, and 90 DAI was maintained for counting the population number (CFU/g soil). A time-dependent gradual increase of the *R. solanacearum* population was observed in all treatments (Table 4). The highest CFU

(420 X 10^{16} CFU/g soil) was recorded in T_2 (*R. solanacearum* @ 1×10^8 CFU/mL) at 90 DAI followed by T_3 (150 X 10^{16} CFU/g soil) (*R. solanacearum* @ 1×10^8 CFU/mL and *G. mosseae* inocula @ 10 g/ kg soil). The lowest *R. solanacearum* population (25 X 10^{16} CFU/g soil) was counted in T_4 (500 ppm Crosin AG10sp and *R. solanacearum* suspension @ 1×10^8 CFU/mL). It is evident that the reduction in the population of *R. solanacearum* was significantly highest in the chemical bactericide Crosin AG10sp. But, a significant reduction in *R. solanacearum* population was also observed by co-inoculation of *G. mosseae* and *R. solanacearum* (Table 4).

Table 3. Effect of co-inoculation of *G. mosseae* and *R. solanacearum* on eggplant root mycorrhization and mycorrhizal spore production in soil

Treatment	Spores' number/100 g soil			Percent root colonization		
	30 DAI	60 DAI	90 DAI	30 DAI	60 DAI	90 DAI
G. mosseae inocula @ 10 g/kg soil	125 a	144 a	176 a	36.67 a	60 a	76.7 a
R. solanacearum suspension @ 1×10^8 and *G. mosseae* inocula @ 10 g/kg soil	112 b	130 b	157 b	23.33 b	43.33b	61.67 b
CD (0.05)	8.372	9.709	16.44	13.081	12.240	10.345
CV	3.120	3.123	4.353	19.240	10.458	6.59

DAI=Days after inoculation, CFU= Colony-forming unit, Average mean with different letters are statistically different, CD= Critical Difference, CV= Co-efficient of variations

Table 4. Effect of *G. mosseae* inoculation on population dynamics of *R. solanacearum* in rhizospheric soil of eggplant

Treatment	Days after inoculation (10^{16} CFU/g soil)				
	10 DAI	30 DAI	50 DAI	70 DAI	90 DAI
R. solanacearum @ 1×10^8 CFU/mL	215 a	250 a	300 a	375 a	420 a
*R. solanacearum*1×10^8 CFU/mL and *G. mosseae* @ 10 g/kg soil	70 b	95 b	100 b	115 b	150 b
Crosin AG_{10ASP} solution @ 500 ppm and *R. solanacearum* @ 1×10^8 CFU/mL	11 c	12 c	15 c	17 c	25 c
CD (0.05)	8.267	13.105	8.753	13.105	17.309
CV	4.191	5.514	3.163	3.881	4.365

DAI=Days after inoculation, CFU= Colony-forming unit, CD=Critical difference, CV=Co-efficient of variations, values in the table having similar letter (s) are statistically identical

Discussions

Ralstonia solanacearum is a persistent inhabitant in soil which makes it difficult to manage by conventional chemical pesticides. Although using a resistant cultivar is one of the best options in some cases, however, the possibility of emerging new races could breach the resistance of the host. The above-mentioned facts led us to explore the efficacy of AM Fungi (*G. mosseae*) to enhance host tolerance, which has recently received much attention because of their influence in plant growth promotion, yield increment, and disease control (Abbasi et al., 2015). Significant differences in vegetative parameters can be explained by the ability of mycorrhizal fungi to uptake more essential nutrients from the soil. Again, in an experiment, Dehne (1982) reported that the growth of the plant inoculated with the AMF, and the pathogens were more resistant to the pathogen due to the more nutrients absorbed from the soil. One of the most acceptable mechanisms proposed to explain the biocontrol by AMF is the enhancement of the crop nutrient uptake (Smith and Gianinzzi-Pearson, 1988; Clark and Zeto, 2000; Karaginnidis et al., 2002; Harrier and Waston, 2004).

In this experiment, the eggplant seedlings were mycorrhized with *G. mosseae* first and then inoculated with *R. solanacearum* meaning that *G. mosseae* can get more chances to establish a physiological relationship and up-taking more nutrition by eggplants which might help defend the attack of *R. solanacearum*. It is evident from the present experiment that *G. mosseae* inoculation can influence all the vegetative parameters and biomass production. Similar kinds of research documented by Tahat et al. (2012) where they described that the tomato plant responded positively to AMF *G. mosseae* inoculation but before six weeks of inoculation the plant height was not increased by the *G. mosseae* treated plant. Hwang et al. (1992) also stated that mycorrhizal inoculation before pathogen attack has been reported to plant biological protection. The present research findings are also in the same line where an increase in shoot fresh and dry weight of

tomato and eggplant was observed by the application of *G. mosseae* that was reduced significantly by combined application of AMF and pathogenic fungi (Karaginnidis et al., 2002).

In this study, the incidence of wilt disease was observed lowest when eggplants were co-inoculated with *G. mosseae* and *R. solanacearum* indicating that the mycorrhizal fungi may colonize in the root system of the host plant that enhances the defense ability against *R. solanacearum*. The potential of *G. mosseae* to reduce the bacterial wilt of eggplant is supported by the findings of Meyer and Linderman (1986) where they applied extracts of rhizosphere soil of AM plants to control the number of sporangia and zoospores formed by cultures of *Phytophthora cinnamomi*. Khaosaad et al. (2007) also reported the suppression of soil-borne fungal pathogens by pre-colonization with mycorrhizae where they mentioned that the releases of volatile substances are the factors of fungal suppression.

The abundance of *G. mosseae* spores in soil and percent mycorrhized root were gradually increased in the present study. The highest number of spores and mycorrhized roots were found by the sole application of *G. mosseae* compared to untreated control treatment. On the other hand, *G. mosseae* spores in soil and mycorrhized roots were reduced substantially in the case of co-inoculation of *G. mosseae* and *R. solanacearum*. Similar kinds of findings were also reported by Jothi and Sundarababu (2001) who documented that arbuscular mycorrhizal colonization such as *G. mosseae* colonization and spore number was higher in *G. mosseae* inoculated alone plants compared to *G. mosseae* and pathogen inoculated treatment. It can be further hypothesized that in the case of co-inoculation the bacterium might produce antibiotics that can inhibit the production of spores of *G. mosseae*. Although the number of spores of *G. mosseae* and colonized roots reduced compared to *G. mosseae* alone, there are ample spores and colonized roots available in the combined application of *G. mosseae* and *R. solanacearum* meaning that *G. mosseae* can tolerate the presence of *R. solanacearum* and can enhance the growth and development of the plant.

From this present study, it can be speculated that the application of *G. mosseae* in soil or co-inoculated condition with *R. solanacearum* significantly reduces the population of *R. solanacearum* in soil with time. Sharma and Kumar (2009) also documented that AM fungus such as *G. mosseae* has a significant effect on the bacterial population in the soil. Mycorrhizae often release certain components in soil and roots which in turn may antagonize root pathogens. It is reported that the total population of soil microorganisms and the specific functional groups in the rhizosphere soil can be changed (Meyer and Linderman, 1986).

In conclusion, the findings of the present study revealed that the bacterial wilt of eggplant can be slowed down by the application of *G. mosseae*. Application of *G. mosseae* colonizes the root system and improves the vegetative growth of brinjal plants. A substantial amount of spores of *G. mosseae* also remain in the soil even in the presence of wilt-causing bacteria (*R. solanacearum*) (Fig. 2). However, a comprehensive study in field conditions in different agro-ecological zones of Bangladesh under natural epiphytotic conditions is imperative. Assessing the compatibility of *G. mosseae* with other plant growth promoting rhizobacteria (PGPR) and chemical pesticides is an important area to be studied before fitting it in the existing integrated pest management system of Bangladesh for effective management of wilt disease in eggplant and other solanaceous crops.

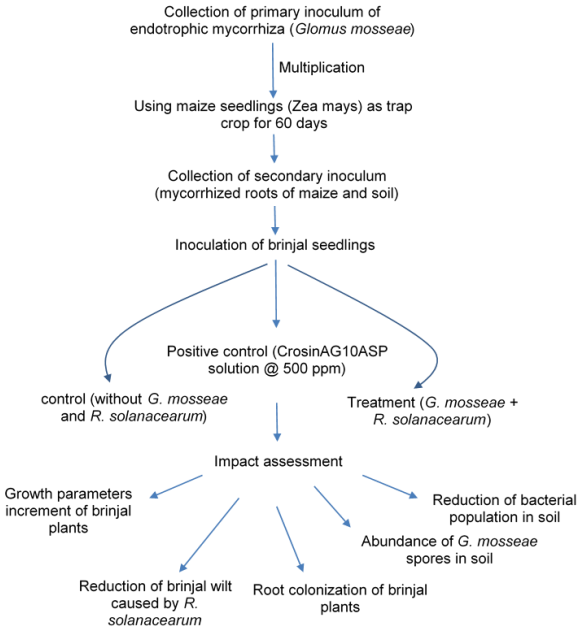

Figure 2: A schematic diagram showing evaluation procedure of *Glomus mosseae* for management of wilt of brinjal caused by *Ralstonia solanacearum*

Abbreviations

AMF: Arbuscular Mycorrhizal Fungi; ERM: Extra-Radical Mycelium; BARI: Bangladesh Agriculture Research Institute; DAT: Days After Transplanting; DAI: Days after inoculation; TTC: Triphenyl Tetrazolium Chloride; CFU: Colony Forming Unit; WASP: Web Agri Stat Package; ANOVA: Analysis of Variance; CRD: Completely Randomized Design; PGPR: Plant Growth Promoting Rhizobacteria; CD: Critical Differences; CV: Coefficient of Variations.

Acknowledgment

The study was jointly funded by the Ministry of Science and Technology, The peoples' Republic of Bangladesh for awarding National Science and Technology (NST) fellowship for the first author and Bangladesh Agricultural University Research System (BAURES - Project no. 2017/249/BAU), Bangladesh Agricultural University, Mymensingh, Bangladesh.

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