OCCURRENCE OF PANAMA DISEASE OF BANANA CAUSED BY Fusarium oxysporum f.sp. cumbense IN BANGLADESH AND ITS MANAGEMENT

BY

MD. ABDUR RASHID

DEPARTMENT OF PLANT PATHOLOGY

FACULTY OF AGRICULTURE

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

JUNE, 2016

OCCURRENCE OF PANAMA DISEASE OF BANANA CAUSED BY Fusarium oxysporum f.sp. cumbense IN BANGLADESH AND ITS MANAGEMENT

BY

MD. ABDUR RASHID

Reg. No.: 15-06973

A Thesis
Submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
In partial fulfillment of the requirements
For the degree of

MASTER OF SCIENCE
IN
PLANT PATHOLOGY
SEMESTER: JANUARY - JUNE, 2016

APPROVED BY :

(Dr. Md. Belal Hossain) **Associate professor** **Supervisor**	**(Dr. Md. Mahfuz Alam)** **Senior Scpientific Officer** **Platnt Pathology Division** **Bangladesh Agricultural research institute** **Co- Supervisor**

(Dr. Md. BelalHossain)
Associate professor
Chairman
Examination Committee
Department of Plant Pathology

Department of Plant Pathology
Sher-e-Bangla Agricultural University y
Dhaka -1207, Bangladesh

Fax: +88029112649
Web site: www.sau.edu.bd

CERTIFICATE

This is to certify that the thesis entitled, **"PREVALENCE OF LOTKON (*Baccaureamiflora*) DISEASES INNARSINGDI DISTRICT OF BANGLADESH''** submitted to the Department of Plant Pathology, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M. S.) IN PLANT PATHOLOGY,** embodies the result of a piece of bonafide research work carried out by **MD. ABDUR RASHID** bearing **Registration No.15-06973** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated: June 2016
Place: Dhaka, Bangladesh

(**Dr. Md.Belal Hossain**)
Associate Professor
Department of Plant Pathology
Sher-e-Bangla Agricultural University
Supervisor

CHAPTER I

INTRODUCTION

Banana (*Musa* spp.) is the fourth most important global food commodity after rice, wheat and maize in terms of gross value production. At present, it is grown in more than 120 countries throughout tropical and subtropical regions and it is the staple food for more than 400 million people (Molina and Valmayor, 1999). In Bangladesh it cultivated 52867 ha of land and production is 800840 mt (Anonymous, 2012). Diseases are the major constraints for banana production in all over the world including Bangladesh. The most common and widely damaging diseases of banana in Bangladesh are panama caused by *Fusarium oxysporum* f. sp. *cubense* (FOC), Sigatoka (*Mycosphaerella musicola*), burrowing nematode (*Rodopholus similis*) (Meah and Khan,1987), Mosaic and Streaks virus. Among the diseases panama/*fusarium* wilt disease caused by the fungus *Fusarium oxysporum* f.sp *cubense* (Foc) is the most devastating disease affecting commercial and subsistence production of banana throughout the banana producing areas of the world (Ploetz, 2005). The disease is ranked 6th among the important plant diseases in the world (Ploetz & Pegg, 1997). In terms of crop destruction, it ranks with the few most devastating diseases such as wheat rust and potato blight (Carefoot and Sprott, 1969). The disease almost destroyed the banana export industry, built on the Gros Michel variety, in Central America during the 1950's (Stover, 1962). Presently, Fusarium wilt has been reported in all banana growing regions of the world (Asia, Africa, Australia and the tropical Americas) except some islands in the South Pacific, the Mediterranean, Melanesia, and Somalia (Stover, 1962; Anonymous, 1977; Ploetz and Pegg, 2000). The characteristics symptoms includes, yellowing begins along the leaf margins and advances towards the midribs; finally the

whole dropping leaf turns dark brown. Yellowing and buckling progress from older to younger leaves and the entire plant dies (Su *et al*, 1986).

The panama disease incidence in India ranged from 0.5 to 20% in main crop and the maximum of 85.0% in second crop (Thangavelu, 2004) whereas in Bangladesh, 24.0% disease incidence was recorded from Jessore in Sabri variety. Higher incidence of fusarium wilt ranging from 7.51 to 43.11% was reported by (Alam 1995) in "Sabri" the Silk type of banana and "Sagar" (Gross Michel) who also observed that both the variety be susceptible to FOC except "Grande Naine"- a exotic banana variety was found resistant, but it has less popularity due to greenish color at ripening. Removal and destruction of infected plants and application of lime (1-2 kg) in the pits are also suggested. Application of *Pseudomonas fluorescens* @ 50 g/pit before planting and 3rd, 5th and 7th months after planting can control panama of banana (Ponniah and Subramaniam 1994).

Since the discovery of Fusarium wilt of banana, though various control strategies like soil fumigation (Herbert and Marx, 1990); fungicides (Lakshmanan *et al.*, 1986); crop rotation (Hwang, 1985; Su *et al.*, 1986), flood fallowing (Wardlaw, 1961; Stover, 1962) and organic amendments (Stover, 1962) have been evolved and attempted, yet, the disease could not be controlled effectively except by planting of resistant cultivars (Moore *et al.*, 1999). Planting of resistant varieties also cannot be implemented because of consumer preference (Viljoen, 2002).

Hoque and Hossain (2001) reported that major cultivated varieties in Bangladesh are susceptible to panama. Recently Plant Pathology Section of HRC, BARI completed one research program under Core Research Project of BARC entitled" Integrated Management of Banana Diseases

Incited by Fungi and Nematode" and under this program, they surveyed few locations for panama and nematode diseases and for management only few fungicides were tested. But only chemical fungicides are not always effective for management of plant diseases especially soil borne pathogen like panama disease. On the other hand chemical control is very expensive and also affects the agro-eco system.

Under these circumstances, use of antagonistic microbes which protect and promote plant growth by colonizing and multiplying in both rhizosphere and plant system might be a potential alternative approach for the management of Fusarium wilt of banana. Besides, biological control of *Fusarium* wilt disease has become an increasingly popular disease management approach because of its environmental friendly nature which offers a potential alternative to the use of resistant banana varieties. The discovery of novel mechanisms of plant protection associated with certain microorganisms (Weller *et al.*, 2002; Biological control of soil borne diseases caused especially by *Fusarium oxysporum* is well documented (Marois *et al.*, 1981; Sivan and Chet, 1986; Larkin and Fravel, 1998; Thangavelu *et al.*, 2004). Several reports have previously demonstrated the successful use different species of *Trichoderma*, *Pseudomonas*, *Streptomyces*, nonpathogenic *Fusarium* (np*Fo*) of both rhizospheric and endophytic in nature against *Fusarium* wilt disease under both glass house and field conditions (Lemanceau & Alabouvette, 1991; Alabouvette *et al.*,1993; Larkin & Fravel, 1998; Weller *et al.* 2002; Sivamani and Gnanamanickam, 1988; Thangavelu *et al.* 2001; Rajappan *et al.*, 2002; Getha *et al.*, 2005).

In general, single approach for disease management involved to a single pathogen. This has led to inconsistent performance and poor activity in all soil environments against all pathogens that attack the host plant. To

overcome these problems, applications of integrated of biocontrol agent and organic amendments having multiple modes of actions are advocated particularly under field conditions, where they are highly influenced by abiotic and biotic conditions (Duffy *et al.*, 1996; Raupach and Kloepper, 1998; Guetsky *et al.*, 2001). In the case of banana, integration of multiple control methods was found more effective than single method for controlling banana diseases. Recently, Zhang *et al.*, 2011. evaluated the effects of novel bio-fertilizers, which combined an amino acid fertilizer and mature pig manure compost with the antagonists *Paenibacillus polymyxa* SQR21, *Trichoderma harzianum* T37 and *Bacillus subtilis* N11 (isolated from the healthy banana roots) in a severely *Fusarium* wilt diseased field for the suppression of *Fusarium* wilt of banana as pot experiments. The results showed that the bio-organic fertilizers which contained the bio-agents significantly suppressed the incidence of wilt disease (by 64–82%), compared to the control.

In Bangladesh, *Trichoderma* isolates were found effective in suppressing root knot nematode (Faruk *et al.*, 1999) and antagonistic isolates of *Trichoderma harzianum* suppressed *Rhizoctonia solani* and *Fusarium solani* of tomato seedlings in Bangladesh (Rahman *et al.*, 2001). The other disease control tactics was corm injection with 3ml of 2.0 % Carbendazim on 5^{rd}, 7^{th} and 9^{th} months after planting (Laksmanan *et al.*, 1986). Meristem tissue culture plantlets are primarily less infected by FOC and minimum yield loss recorded. In Bangladesh, research information on panama wilt and sigatoka disease management are scanty. Only little information are generated by PI himself under Core Research Project of BARC during 2011-12 on the incidence of different diseases of banana. Here five districts and their 6 upazillas like Gabtali, Sibganj and Sadar (Bogra); Manahardi (Narsingdi); Kapasia (Gazipur), Trisal

(Mymensingh) and Kaliganj (Jessore) were surveyed on various diseases of banana cultivars. The Sabri and Cocking bananas were found very much susceptible to panama disease especially from the second year of cultivation. In the surveyed gardens, about 30-70% panama infected plants were observed and when the crops were raton for second year. The goal was to control the panama in the field level that should not the cause any residual effect and health hazards. Research information related to panama management of banana in Bangladesh are scanty.

Therefore, it is felt necessary to develop an integrated management of this disease to increase its production to ensure higher income of the banana growers of the country with the following objectives:

Objectives:

- To determine the incidence of panama of banana in the major banana growing areas in Bangladesh.
- To isolate, purify and preservation of the *Fusarium oxysporum* f.sp *cubense* from major banana growing areas in the country.
- To evalute the chemical, organic soil amendments and bio-control agents *Trichoderma* for management of panama disease of banana.

CHAPTER II

REVIEW OF LITERATURE

Banana is considered as a popular and nutritious fruit in Bangladesh. Banana is found to be attacked by different diseases. Fusarium wilt, commonly known as Panama disease, is considered as one of the most destructive diseases of banana. The disease was first discovered in 1876 and by 1950, the *Fusarium* wilt pathogen *Fusarium oxysporum* f. sp. *cubense* (E.F. Sm.) was identified by W.C. Snyder & H.N. Hansen. The disease was disseminated to most banana-growing countries of the world (Stover, 1962). In this chapter an attempt has been made to review the available literature about symptoms of panama diseases of banana, their causal organisms, diseases status and their epidemiology.

Meah and Khan (1987) reported that the most common and widely damaging diseases of banana in Bangladesh are panama caused by *Fusarium oxysporum* f. sp. *cubense* (FOC), Sigatoka (*Mycosphaerella musicola*), burrowing nematode (*Rodopholus similis*), Mosaic and Streaks virus.

Fusarium wilt causes highly destructive diseases in many economically important agricultural crops. *Fusarium* wilt, commonly known as Panama disease, is considered as one of the most destructive diseases of bananas (Ploetz and Pegg, 2000).

Higher incidence of Fusarium wilt ranging from 7.51 to 43.11% was reported in “Sabri” the Silk type of banana and “Sager” (Gross Michel) (Alam,1995).He also observed that both the variety were susceptible to FOC except “Grande Naine”- a exotic banana variety which was resistant, but it has less popularity due to greenish color at ripening. He observed that the panama disease incidence in India was ranged from 0.5 to 20% in main crop and the maximum of 85.0% in second crop.

Alam (1995) reported that in Bangladesh, 24.0% disease incidence was recorded from Jessore in Sabri variety.

Hoque and Hossain (2001) reported that major cultivated varieties in Bangladesh are susceptible to panama. Recently Plant Pathology Section of HRC, BARI completed one research program under Core Research Project of BARC entitled,"Integrated Management of Banana Diseases Incited by Fungi and Nematode" and under this program, they surveyed few locations of Bangladesh for panama and nematode diseases. For for management they used only few fungicides. But only chemical fungicides were not always effective for management of plant diseases especially soil borne pathogen like panama disease. On the other hand chemical control is very expensive and also affects the agro-eco system.

Ploetz (2005) repoted that among the banana diseases panama/*fusarium* wilt disease caused by the fungus *Fusarium oxysporum* f.sp *cubense* (Foc) is the most devastating disease affecting commercial and subsistence banana production throughout the banana producing areas of the world.

Ploetz & Pegg, (1997) stated that this disease is ranked 6 than arrange the important plant diseases in the world. Carefoot and Sprott (1969) mentioned that in terms of crop destruction, it ranks with the few most devastating diseases such as wheat rust and potato blight.

Presently, many researcher found that *Fusarium* wilt has been occured in all banana growing regions of the world (Asia, Africa, Australia and the tropical Americas) except some islands in the South Pacific, the Mediterranean, Melanesia, and Somalia (Stover, 1962; Anonymous, 1977; Ploetz and Pegg, 2000).

Su *et al.* (1986) mentioned the characteristics symptoms panama disease includes yellowing begins along the leaf margins and advances towards

the midribs; finally the whole dropping leaf turns dark brown. Yellowing and buckling progress from older to younger leaves and finally the entire plant dies.

Management of Panama disease

Sivan and Chet (1986) isolated a new isolate of *Trichoderma harzianum* (T-35) from the rhizosphere of cotton plants from a field infected by *Fusarium*. Under glasshouse conditions, the antagonist they applied to soil growing in a bran/peat mixture (1:1, v/v) or as a conidial suspension or used as a seed coating. When *T. harzianum* was tested against *Fusarium oxysporum* f. sp. *vasinfectum*, *F. oxysporum* f. sp. *melonis* or *F. roseum* 'Culmorum', a significant disease reduction was obtained in cotton, melon and wheat. They determined the long term effect of *T. harzianum* on *Fusarium* wilt of cotton in sucessive plantings. Soil or seed treatments with the antagonist provided a similar disease control of *F. roseum* 'Culmorum' and of *F. oxysporum* f. sp. *melonis*

Rojoa and Torres (2007) evaluated *Trichoderma harzianum* ITEM 3636 and *T. longibrachiatum* ITEM 3635 in greenhouse and field trial in a commercial field with a previous history of the disease. Two seed treatments were evaluated: seeds coated with a conidial suspension using carboxymethylcellulose (CMC) as sticker and seeds coated with the antagonist fungal biomass on Biodac particles. *T. harzianum* in both seed treatments was more effective than *T. longibrachiatum* in decreasing the mean disease severity index (MSI), increasing the number of healthy plants, and boosting yield. They observed the potential of using this strain to control the disease and the plant growth promoter effect was confirmed in three experiments carried out in fields artificially and naturally infected with the pathogen.

John *et al.*, (2010) determined *Fusarium oxysporum* f. sp. *adzuki* and *Pythium arrhenomanes*, the pathogens significantly influence the germination and P. *arrhenomanes* had a severe effect (only 5% germination). The root system of the soybean plant was poorly developed due to the infection and it exerted a negative influence on the nodulation and further growth phases of the plant. During pot assay along with biocontrol activity, *Trichoderma viride* showed growth promoting action on soybean plant. *Pythium* and *Fusarium* infected soybean plants treated with *Trichoderma* had 194% and 141% more height than pathogens alone. The fruit yield treated with *Trichoderma* was 66 plant^{-1} where as the yield was only 41 in control plant. The plants infected with *Pythium* and *Fusarium* and treated with *Trichoderma* had fruit yields of 43 and 53, respectively and those were 5 and 1.6 times higher than plants infected with pathogens.

Dubey *et al.*, (2007) evaluated *Trichoderma viride*, *Trichoderma harzianum*, and *Trichoderma virens* against four isolates of *Fusarium oxysporum* f.sp. *ciceris* (Padwick) Matuo and K. Sato) representing four different races commonly prevalent in India. Dharwad (race 1), Kanpur (race 2), Ludhiana (race 3), and Delhi (race 4) isolates of *F. oxysporum* f. sp. *ciceris* were included in the study. The isolates of *Trichoderma* species were evaluated against the pathogen in dual culture and through production of volatile and non-volatile inhibitors. *T. viride* isolated from Ranchi followed by *T. harzianum* (Ranchi) and *T. viride* isolated from Delhi inhibited maximum mycelial growth of the pathogen. They also enhanced seed germination, root and shoot length, and decreased wilt incidence under green house condition. The efficacy of Trichoderma species was enhanced in combination with carboxin. They mentioned integration of *T. harzianum* (106 spores/ml/10 g seed) and carboxin (2 g kg−1 seed) for seed treatment was the best which enhanced seed

germination by 12.0–14.0% and grain yields by 42.6–72.9% and reduced wilt incidence (44.1–60.3%) .

Chaur-Tsuen and Chien-Yih (2002) isolated several strains of *Trichoderma* spp. from rhizosphere soils and rhizoplane of agricultural crops in Taiwan and evaluated the root growth of bitter gourd, loofah, and cucumber. In greenhouse stests they found that the strains of the *Trichoderma* species significantly increased 26 to 61% seedling height, 85-209% root exploration, 27 to 38% leaf area, and 38 to 62% root dry weight in 15 days after sowing seeds of bitter gourd. Similarly, These *Trichoderma* strains also increased seedling growth of loofah and cucumber. The concentration of chlorophyll (mg/cm^2 of leaves) was significantly increased in the plants treated with *Trichoderma* and enhanced plant growth.

Harman (2006) mentioned *Trichoderma* act as biocontrol agents against plant pathogens, the principal mechanisms for control have been assumed to be those primarily acting upon the pathogens through mycoparasitism, antibiosis, and competition for resources and space. The effects of *Trichoderma* induced systemic or localized resistance in plant. These fungi colonize the root epidermis and outer cortical layers and release bioactive molecules that cause walling off of the *Trichoderma thallus*. At the same time, the transcriptome and the proteome of plants are substantially altered. As a consequence, in addition to induction of pathways for resistance in plants, increased plant growth and nutrient uptake.

CHAPTER III

MATERIALS AND METHODS

Three experiments were carried out throughout the study period in order to study the panama of banana. The experiment were as follows:

- survey on the panama disease of banana in some selected banana growing areas of Bangladesh,
- identification of causal organisms of the panama disease of banana and
- development of environment friendly disease management practices for the nursery diseases of banana.

3 1.1 Survey and determination of the incidence and severity of panama disease in Bangladesh

A comprehensive survey was made in order to find out the causal agent and extent of damage caused banana disease in the selected major banana growing areas of Bangladesh. For the prevalence of panama disease two years old sabri, kobri, chinichampa and others local variety were selected because older on garden and local varieties are more prone to this disease. Farmer's interview was taken to know the detail information about the disease and production of banana using prescribed questionnaire.

3.1.2 Determination of disease incidence and disease severity

For calculation of disease incidence every plant was counted in the field and also counted the infected plants and then expressed in percentage. The disease incidence of banana plants was determined by the following formula:

$$\text{Percent plant infection} = \frac{\text{Number of diseased plants}}{\text{Number of total plants observed}} \times 100$$

Percent disease incidence (PDI) Percent Disease Index of foliar diseases was determined by the following formula (Rai and Mamatha, 2005):

$$\text{Percent disease incidence} = \frac{\text{Number of diseased leaves on each plant}}{\text{Number of total leaves on each plant}} \times 100$$

For confirmation of panama, the collected soils and roots was investigated in the laboratory following standard methods.

The month wise activities from January 2016 – December 2016 are shown below:

Objectives	**Activity**	**Month wise implementation plan**
		Ja | Fe | Ma | Ap | Ma | Ju | Jy | Au | Se | Oc | No | De
To determine the incidence of panama disease of banana in the selected major banana growing areas in Bangladesh.	Survey and identify the incidence of panama, disease of banana in the selected major banana growing areas in Bangladesh.	From January 2016 to October, 2016 →
To isolate, purify and preserve the fungal pathogens from major banana growing areas in the country.	Isolation, purification and preservation of the fungal pathogens from major banana growing areas in the country	From January 2016 to October, 2016 →
	Analysis of results and preparation of first year reports.	From Nov. to Dec. 16 →

3.1.3 Screening of chemicals and non-chemicals agents for the management of banana diseases.

Two experiments were conducted at the Plant Pathology research field of BARI, Gazipur to screen the chemical fungicides for the management of panama disease of banana, and also to screen the organic soil amendments and bio-control agents especially *Trichoderma* for management of panama disease of banana.

The month wise activities of the project for the 2nd year (January 2016 – December 2016) are shown below:

Objectives	**Activity**	**Month wise implementation plan**											
		Ja	Fe	Ma	Ap	Ma	Ju	Jy	Au	Se	Oc	No	De
To screen the chemicals fungicides for management of panama disease of banana		From January 2016 to October,2016 →											
To screen the organic soil amendments and bio-control agents especially *Trichoderma* for management of panama disease of banana		From January 2016 to October,2016 →											
	Analysis of results and preparation of second year reports.											From Nov. to Dec. 16 →	

Panama susceptible variety named Shabri was planted for the integrated management of panama disease of banana. In this field experiment, 7 treatments have been used with 5 replications in Gazipur. Each plant considered as one replication. On the other hand, 7 treatments have been

used with 3 replications in Ishurdi, Pabna. Each replication represents four plants. The design followed was Randomized Complete Block Design (RCBD). The seven treatments were:

T_1 = Application of poultry refuse @ 5 t ha^{-1}

T_2 = Application of neem oil cake @ 300 kg ha^{-1}

T_3 = Application of mustard oil cake @ 600 kg ha^{-1}

T_4 = Application of sesame oil cake @ 600 kg ha^{-1}

T_5 = Application of *Trichoderma harzianum* mass cultured in wheat grain then used @ 3 t ha^{-1}

T_6 = Sucker treatment with Bavistin 0.2%

T_7 = Control

3.1.4 Satistical analysis

Data on different parameters were analyzed in two factor randomized block design (RCBD) through computer software MSTAT-C (Anonymous, 1989). Duncan's Multiple Range Test (DMRT) and Least Significant difference (LSD) test were performed to determine the level of significant differences and to separate the means within the parameters.

CHAPTER IV

RESULTS

4.1. Survey on panama disease of banana

Banana growing aera was surveyed to record the incidence and severity of panama disease of banana in Bangladesh. The survey areas were Narsingdi, Tangail, Gaibandha, Rangpur, Bogra and Jessore.

4.2. Symptom of the panama diseases and identification of the pathogen

4.2.1. Panama disease of banana

The first external symptoms of Panama disease are a yellowing of the oldest leaves or a longitudinal splitting of the lower portion of the outer leaf sheaths on the pseudostem. This is followed by a wilt and buckling of leaves at the petiole base. In some cases, these leaves remain green. As the disease progresses, younger leaves collapse until the entire canopy consists of dead or dying leaves.

The pathogen isolated from the diseased symptom was identified as *Fusarium oxysporum* f. sp. *cubense* (FOC) . Panama disease is caused by the soilborne hyphomycete, *Fusarium oxysporum* Schlect. f. sp. *cubense*. It is one of more than 100 formae speciales (special forms) of *F. oxysporum* that cause vascular wilts of flowering plants. It contains pathogenic and saprophytic strains that cannot be distinguished morphologically. Colonies grow 4 - 7 mm/day on PDA at 24°C, with slight to significant aerial mycelium, and white to purple pigmentation. Sporodochia are tan to orange, and sclerotia are blue and submerged.

Micro- and macroconidia are produced on branched and unbranched monophialides. Microconidia are 5 - 16 x 2.4 - 3.5 µm, one- or two-celled, oval- to kidney-shaped, and are borne in false heads. Macroconidia are 27 - 55 x 3.3 - 5.5 µm, four- to eight-celled and sickle-shaped with foot-shaped basal cells.

Plate:1 Leaves are yellow due to panama infection.

Plate: 2 Infected Pseudostem of banana plant

Plate:3 Pseudostem were cut in pieces and placed on blotting paper

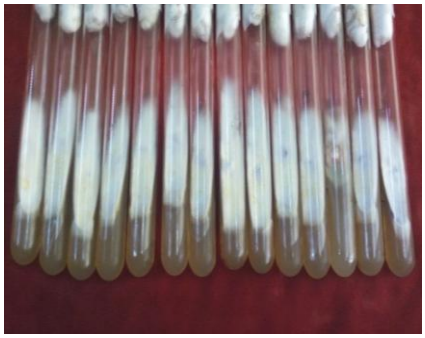

Plate:4 Isolate of *Fusarium oxysporum* f. sp. *cubense*

Plate: 5 Pure culture of *Fusarium oxysporum* f. sp. *cubense*

Plate:6 Conidia of *Fusarium oxysporum* f. sp. *cubense*

4.3. Disease incidence and severity

4.3.1. Incidence and severity of panama of banana at different locations of Bangladesh

In each location 5 banana gardens were surveyed and 20 plants selected for the observation. A group of farmer(s) were interviewed to know the detail scenario about the diseases and production of banana. The pathogen isolation and identification were done from collected samples of surveyed areas and preserved in the laboratory for further study.

Every visited garden was found infected with panama disease, and the rate of infection ranged from (10.67-63.67%) (Table 1-7). Most of the farmers considered panama disease as cancer of banana plant.

Table 1. Incidence and severity of Panama disease of banana at different Upazilla of Narsingdi, Bangladesh during 2016

Name of Upazilla of Norsinghdi	Panama disease	
	Incidence (%)	Severity (%)
Sadar	10.67 b	28.00 b
Polash	14.50 a	32.33 a
Monohordi	15.50 a	26.17 b
CV (%)	4.92	3.61

In Narsingdi, the incidence of the disease was found highest (15.50%) at Monohordi and the severity of the diseases was found highest (32.33%) at Polash. Incidence (10.67-15.5%) and severity (26.17-32.33%) of the diseases were found the lowest at Sadar (Table 1).

Table 2. Incidence and severity of Panama disease of banana at different Upazilla of Tangail, Bangladesh during 2016

Name of Upazilla of Tangail	Panama disease	
	Incidence (%)	Severity (%)
Modhupur	32.67 a	56.67 a
Sadar	19.83 c	43.33 b
Sagordhighi	25.33 b	46.60 b
CV (%)	4.76	7.52

Prevalence (incidence and severity) of the panama disease was found highest at Modhupur and lowest at Sadar in Tangail (Table 2).

Table 3. Incidence and severity of Panama disease of banana at different Upazilla of Bogra, Bangladesh during 2016

Name of Upazilla of Bogra	Panama disease	
	Incidence (%)	Severity (%)
Sadar	13.17 c	32.67 c
Gabtoli	23.00 b	53.33 b
Shibgonj	28.30 a	63.67 a
CV (%)	3.66	5.35

Incidence and severity for Panama disease was the highest (28.30 & 63.67%) at Shibgonj, Bogra and the lowest incidence and severity of Panama **disease** was range (13.17 & 32.67%) at Sadar, Bogra (Table 3).

Table 4. Incidence and severity of Panama disease of banana at different Upazilla of Gaibandha, Bangladesh during 2016

Name of Upazilla of Gaibandha	Panama disease	
	Incidence (%)	Severity (%)
Gabindhogonj	20.83 b	43.93 b
Polashbari	19.83 b	35.97 c
Shadullapur	25.17 a	52.33 a
CV (%)	5.15	4.11

Prevalence (incidence and severity) of the disease was found highest at Shadullapur and lowest at Polashbari in Gaibandha (Table 4).

Table 5. Incidence and severity of Panama disease **of banana at different Upazilla of Rangpur, Bangladesh during 2016**

Name of Upazilla of Rangpur	**Panama** disease	
	Incidence	Severity
Mithapukur	13.67 b	32.67 b
Sadar	16.17 a	41.33 a
Taragong	10.33 c	28.83 b
CV (%)	7.26	6.03

Incidence and severity of Panama disease was highest (16.17& 41.43%) at Sadar, Rangpur and lowest (10.33 & 28.27%) at Taragonj, Rangpur (Table 5).

Table 6. Incidence and severity of Panama disease of banana at different Upazilla of Jessore, Bangladesh

Name of Upazilla of Jessore	**Panama disease**	
	Incidence (%)	**Severity (%)**
Jhikorgacha	11.33 c	26.00 c
Kaligonj	21.60 a	40.33 a
Sadar	16.50 b	33.00 b
CV (%)	10.61	8.33

Prevalence (incidence and severity) of the disease was found highest at Kaligonj, Jessore and lowest at Jhikorgacha, Jessore (Table 6).

Table 7. Comparison of incidence and severity of Panama disease of banana at different Upazillas of six districts in Bangladesh during 2016

Districts	Upazillas	Panama disease	
		Incidence (%)	Severity (%)
Narsingdi	Sadar	10.67 gh	28.00 h
	Polash	14.50 ef	32.33 fg
	Monohordi	15.50 e	26.17 h
Tangail	Modupur	32.67 a	56.67 b
	Sadar	19.83 d	43.33 de
	Sagordhighi	25.33 bc	46.60 d
Bogra	Sadar	13.17 efgh	32.67 fg
	Gabtoli	23.00 cd	53.33 bc
	Shibgonj	28.30 b	63.67 a
Gaibandha	Gobidagonj	20.83 d	43.93 de
	Polashbari	19.83 d	35.97 f
	Shadullapur	25.17 bc	52.33 c
Rangpur	Mithapukur	13.67 efg	32.67 fg
	Sadar	16.17 e	41.33 e
	Taragong	10.33 h	28.83 gh
Jessore	Jhikorgacha	11.33 fgh	26.00 h
	Kaligonj	21.60 d	33.00 fg
	Sadar	16.50 e	40.33 e
	CV (%)	9.57	6.15

Incidence of panama disease ranged from (10.33-32.67%). The highest rate was found at Modhupur, Tangail and the lowest at Taragonj, Rangpur. The highest severity of panama was found at Shibgonj, Bogra and lowest at Jhikorgacha, Jessore that ranged from (26.00-63.67%) (Table 7).

Finally, in the field observation it was found that local varieties like, Shobri, Kobri, Chinichampa, Kachkola were found susceptible to Panama disease. So, it was observed that the local varieties are greatly affected by panama.

4.4.1. Effect of management practices on panama disease of banana

Poultry refuse, neem oil cake, mustard oil cake and sesame oil cake were applied three weeks before the planting to incorporate with the soil properly for well decomposition. *Trichoderma* was applied one week before planting into the soil. Sucker treatment with Bavistin(@ 0.2%) had been done just before the planting. Irrigation and other cultural management have been done properly as and when necessary. Data on disease incidence were recorded four times after appearance of the disease. Application of *Trichoderma* in soil performed better than other treatments for controlling panama disease of banana (Table 8 and Table 9). The highest yield (30.9 t ha^{-1}) was also obtained from *Trichoderma* treated plots whereas the lowest (15.5 t ha^{-1}) from untreated control treatment (Table 9). In this trial there was significant increase in plant growth and yield due to *T. harzianum* bio-fungicides which was supported by the findings of many investigators (Prasad and Anes, 2008; Mishra and Sinha, 2000; Chaur-Tsuen and Chien-Yih, 2002). Harman, (2006) and Manju & Mall, (2008) also reported positive role of

Trichoderma species in increasing plant growth and productivity. The study confirmed the reports of other researchers regarding the role of *T. harzianum* to enhance root and shoot growth of seedlings as reported by (Dubey *et al*., 2007) and thereby increasing the frequency of healthy plants as described by Rojoa *et al*., 2007.

Table- 8. Incidence of panama disease of banana in Gazipur at different dates

Name of Treatment	Disease incidence (%)			
	July, 16	**August, 16**	**September,16**	**October, 16**
Poultry refuse	20	40	40	40
MOC	20	20	40	40
SOC	20	40	60	60
NOC	00	20	20	40
***Trichoderma**	**00**	**00**	**20**	**20**
Bavistin	20	20	20	40
Control	60	80	80	80

***** ***Trichoderma harzianum*** mass cultured in wheat grain then used @ 3 t ha^{-1}.

Table-9. Average yield and yield attributes of banana in panama-controlled plants at Gazipur

Treatments	Wt. of bunch (kg)	No. of hands/ bunch	No. of fingers/ bunch	Length of finger (cm)	Yield * (t/ha)
Poultry refuse	7.3	6.0	51.4	13.3	22.1
MOC	7.5	5.5	51.3	13.4	24.4
SOC	6.0	5.8	47.7	12.2	20.8
NOC	6.8	5.9	52.9	12.8	24.6
Trichoderma	**8.9**	**6.8**	**65.8**	**14.8**	**30.9**
Bavistin	7.6	6.3	57.8	14.4	26.0
Control	5.4	4.2	34.4	11.2	15.5

***** ***Trichoderma harzianum*** mass cultured in wheat grain then used @ 3 t ha^{-1}

Fig 1. Field view of the panama disease management at Gazipur and Ishurdi, Pabna

Fig 2. Healthy plants in *Trichoderma* treated plots

Fig 3. Severe panama attacked plants in control plots

CHAPTER V

DISCUSSION

In the investigation, *Fusarium oxysporum* f. sp. *cubense* (FOC) were isolated from panama diseased plant. Panama in banana caused by *Fusarium oxysporum* f. sp. *cubense* (FOC) were reported by researcher from many parts of the world (Stover, 1962; Anonymous, 1977; Ploetz & Pegg, 1997).The observed symptoms of the present study corroborates with the description of Su *et al.*, 1986. The prevalence of the recorded the disease on banana varied in respect of location. Similar variation in prevalence of seedling diseases in respect of nursery location and time was recorded by Alam (1995) in different banana growing regions.

The highest rate of incidence of panama disease was found at Modhupur (32.67%),Tangail and the lowest at Taragonj, Rangpur which ranged from (10.33-32.67%). The highest severity of panama disease was found at Shibgonj(63.67%), Bogra and lowest at Jhikorgacha, Jessore that ranged from (26.00-63.67%) (Table 7). In the field observation it was found that local varieties like, Shobri, Kobri, Chinichampa, Kachkola were found susceptible to Panama disease and were greatly affected by panama.

Comparative effectiveness of Biofungicide viz. Bavistin and three oil cake were evaluated in banana field to the disease. Significant effect of different management practices on the incidence, severity and yield were observed. Application of control measures resulted in gradual decrease of the incidence and severity of diseases over untreated control.

Application of *Trichoderma* in soil performed better than other treatments for controlling panama disease of banana in all locations. The highest yield (30.9 t/ha) was obtained also from Trichoderma treated plots whereas the lowest (15.5 t ha^{-1}) from untreated control treatment Tjamos

et al. 1992 reported that *T. harzianum* controls *F. oxysporum* by competing for both rhizosphere colonization and nutrients. Disease incidence of brinjal, water melon and cotton was reported to be reduced considerably by the application of *T harzianum* Sivan and Chet, 1986. (Shoresh *et al.* 2005) stated that *Trichoderma* spp. were effective bio-control agents for a number of soil borne plant pathogens.

Application of *Trichoderma* in soil performed better than other treatments for controlling panama disease of banana. Different management practices resulted significant effect on the yield contributing character of Banana. Conventional disease management with fungicide is less effective to control the soil borne *F. oxysporum*. On the other hand, application of chemical fungicides is expensive and also hazardous to health and environment (Brown and Hendrix 1980, Punja *et. al*. 1982). The beneficial microbes such as *Trichoderma harzianum* has been reported as a bio-control agent that effectively controlled the soil borne pathogens (Elad *et al*., 1983; Roy, 1989). Enhancement of growth by using *Trichoderma harzianum* or *Trichderma* based formulations have been studied and reported by many workers around the world (Chowdhry, 2009 and Hossain, 2011). *Trichoderma harzianum* has been tested against disease of many crops like wheat, rice, maize, pulses and legumes and found to be effective Hossain, (2007); Mostofa, (2009); Shultana *et al.*, (2009) and Chowdhury, (2009). This new eco-friendly means of disease control may be used in the management of panama disease in Bangladesh.

In the present study on the extent of incidence of panama disease was depend on the location. Other parameters of epidemiology viz, leaf wetness period, vapor presure deficit, sunshine hour, microclimatic parameters including canopy temperature, relative humidity etc, should be critically evaluated to determine thier effects on over wintering

formation, germination and development of inoculum in different pathosystems. These should be critically studied for each host-pathogen system to find out the most appropriate time to combat the disease at minimum effort. Use of biofungicide should be incorporated in the nursery disease management system. It might be most important alternative to avoid hazardous chemical fungicides.

CHAPTER VI

SUMMARY AND CONCLUSION

Though banana (*Musa* spp.) is considered as the popular fruits of Bangladesh, it suffers from various diseases but least concrete information regarding their distribution, prevalence and epidemiology are available in country. Among the diseases panama/*fusarium* wilt disease caused by the fungus *Fusarium oxysporum* f.sp *cubense* (FOC) is the most devastating disease which affecting commercial and subsistence banana production throughout the banana producing areas of the world. Therefore, the present study has been designed to study the occurrence and prevalence of panama disease of banana in six selected districts of Bangladesh namely, Narsingdi, Tangail, Gaibandha, Rangpur, Bogra and Jessore.

Three experiments were carried out throughout the study period from January, 2016 to April, 2017. The disease was identified based on matching the observed symptoms in the infected plants with the symptoms. The disease also identified by observing the symptoms on the plants and determination of presence of fungi was made either directly by preparation of slides and examining them under compound microscope or indirectly by isolation to agar culture following keys outlined by Singh, 1978; Pathak, 1980; Peterson, 1986;Singh,1998 and Ploetz *et al*., 1998.

Incidence of panama disease ranged from 10.33-32.67%. The highest rate found at Modhupur, Tangail and the lowest at Taragonj, Rangpur. The highest severity of panama was found at Shibgonj(63.67%), Bogra and lowest at Jhikorgacha, Jessore that range from (26.00-63.67%).

Finally, in the field observation it was found that local varieties like, Shobri, Kobri, Chinichampa, Kachkola were found susceptible to Panama disease and were greatly affected by panama.

The highest incidence found at Modhupur, Tangail and the lowest at Taragonj, Rangpur. The highest severity of panama was found at Shibgonj, Bogra and lowest at Jhikorgacha, Jessore that range from (26.00-63.67%). Therefore, the findings on the incidence of panama disease of banana in different locations reveales that the disease studied is related to the environment. Other parameters of epidemiology viz, leaf wetness period, vapor presure deficit, sunshine hour and microclimatic parameters should be critically observed for each host-pathogen system to find out the most appropriate time to combat the diseases at minimum effort.

Application of *Trichoderma* in soil performed better than other treatments for controlling panama disease of banana. The highest yield (30.9 t ha^{-1}) was obtained also from *Trichoderma* treated plots whereas the lowest (15.5 t ha^{-1}) from untreated control plot. *Trichoderma spp*. is used in reasonably large quantities in plant agriculture, both for disease control and yield increase. The genes encoding the enzymes appear useful for producing transgenic plants resistant to diseases and the enzymes themselves are beneficial for biological control. Use of biofungicide should be included in the disease management system which is the most important alternative to avoid hazardous chemical fungicides.

REFERENCES

Alabouvette, C., Lemanceau, P., Steinberg, C. (1993). Recent advances in the biological control of *Fusarium* wilts. *Pesticides Science* **37**, 365-373.

Alam. M.S. (1995). Studies on banana diseases. PhD thesis, Department of Botany, Rajshahi University, Rajshahi, Bangladesh.

Anonymous. (2012). Year book of Agricultural Statistic of Bangladesh, Dhaka 49p.

Anonymous,(1977). *Fusarium oxysporum* f. sp. *cubense*, Distribution maps of plant diseases. Map No. 31, 4th ed. Commonwealth Mycological Institute, Kew, England.

Brown, E. A., Hendrix, F. F. (1980). Distribution and control of *S. rolfsii* on apple. *Plant Dis*. **64**, 205-206.

Carefoot, G. L. and Sprott, E. R. (1969). Famine on the wind. Angus and Robertson, London, UK, 222pp.

Chaur-Tsuen, L.and Chien-Yih, L. (2002). Screening strains of *Trichoderma* spp. for plant growth enhancement in Taiwan. *Plant Pathology Bulletin,* **11**, 215-220

Chowdhury, M. S. M. (2009). Seed and seedling diseases of some selected fruits of Bangladesh. Ph.d. Thesis. Department of Plant Pathology, Bangladesh Agricultural University Mymensingh., pp. 97-124.

Dubey, S. C., Suresha, M. and Singha, B. (2007). Evaluation of *Trichoderma* species against *Fusarium oxysporum* f. sp. *ciceris* for integrated management of chickpea wilt. *Biological Control,* **40**, 118-127.

Duffy, B.K., Simon, A., Weller, D.M. (1996). Combination of *Trichoderma koningii* with fluorescent pseudomonads for control of take-all on wheat. *Phytopathology ,86*: 188–194.

Elad, Y., Chet, I., Katan, J. (1983). *Trichoderma harzianum*: A biocontrol agent effective against *Sclerotium rolfsii* and *Rhizoctonia solani*. *Phytopathology,* **70**, 119-121

Faruk, M.I. Bari, M.A. Rahman, M.A Nahar, MS and Khanam. NN (1999).Suppression of root-knot (*Meloidogyne*) of tomato using an antagonistic solates of *Trichoderma* species. *Bangladesh J. Plant Pathology,***15** (1&2): 39-42.

Getha K., Vikineswary, S., Wong, W., Seki.T., Ward, A., Goodfellow, M.,(2005). Evaluation of *Streptomyces* sp. strain G10 for suppression of *Fusarium* wilt and rhizosphere colonization in pot grown banana plantlets. *Journal of Industrial Microbiology and Biotechnology,***32**, 24-32.

Guetsky, R., Shtienberg, D., Elad, Y., Dinoor, A., (2001). Combining biocontrol agents to reduce the variability of biological control. Phytopathology 91, 621–627.

Harman, G. E. (2006). Overview of mechanisms and uses of *Trichoderma* spp. *Phytopathology***, 96,** 190-194.

Herbert, J.A. and Marx, D. (1990), Short-term control of Panama disease on South Africa. *Phytophylactica* **22,** 339-340.

Houqe, M. A. and Hossain. M. M. (2001). Modern production technology of banana. HRC, BARI, Gazipur, pp22.

Hossain, I. (2011). Nursery diseases of some selected fruit species in Bangladesh. Eco-friendly Plant Disease Management Laboratory, Department of Plant Pathology, Bangladesh Agricultural University, Mymensingh, Bangladesh. pp. 13-16.

Hossain, I. (2007). Research on crop disease management carried out at Bangladesh Agricultural University. Paper presented at the National Workshop 2000 held on 11-12 February, 2007 at

Bangladesh Agricultural Research Institute (BARI), Joydevpur, Gazipur.

Hwang, S.C., (1985). Ecology and control of *Fusarium* wilt of banana. *Plant Protection Bulletin* (Taiwan) **27**, 233-245.

John, R. P., Tyagi, R. D., Prévost, D., Brar, S. K., Pouleur, S. and Surampalli, R. Y. (2010). Mycoparasitic *Trichoderma viride* as a biocontrol agent against *Fusarium oxysporum* f. sp. *adzuki* and *Pythium arrhenomanes* and as a growth promoter of soybean. *Crop Protection*, **29**(12), 1452-1459.

Laksmanan P. Selvaraj, P. and Mohan, S. (1986). Efficacy of different methods for the control of Panama disease. *Tropical Pest Management*. **33**: 373-376.

Larkin, R. and Fravel, D. 1998. Efficacy of various fungal and bacterial biocontrol organisms for the control of *Fusarium* wilt of tomato. *Plant Disease* **82**, 1022-1028.

Lemanceau, P. and Alabouvette, C. (1991). Biological control of *Fusarium* diseases by fluorescent *Pseudomonas* and non-pathogenic *Fusarium*. *Crop Protection*,**10**, 279-286.

Manju, S. andMall, T. P. (2008). Efficacy of *Trichoderma* species on *Phytopthora dresceleri* f.sp. *cajani* of Pigeon pea. *Ann. Plant Prot. Sci.*, **16**, 162-164.

Marois, J.J., Mitchem, D.J. and Somada, R.M. (1981). Boological control of *Fusarium* Crown and root rot of tomato under field condition. *Pytopathology*,**12**, 1257-1260.

Meah, M. B. and Khan, A. A. (1987). Checklist of fruit and vegetable diseases in Bangladesh. Dept. of Plant Pathology, BAU, Mymensingh, 23p.

Mishra, D. S. and Sinha, A. P. (2000). Plant growth promoting activity of some fungal and bacteria agents on rice seed germination and seedling growth. *Tropical Agric*., **77**, 188-191.

Molina, A.B. and Valmyor, R V., (1999). Banana Production systems in South East Asia. Bananas and Food security, Pica C., Foure, E., Frison, E.A., (eds.), INIBAP, Montpellier, France, 423-436.

Moore, N.Y., Pegg, K.G., Bentley, S. and Smith, L.J. (1999). *Fusarium* wilt of banana: global problems and perspectives. In: Molina, A.B., Masdek, N.H.N. Liew, K.W, (eds). Banana Fusarium Wilt Management: Towards Sustainable Cultivation. Proceedings of the International Workshop on Banana Fusarium Wilt Disease. Kuala Lumpur, Malaysia: INIBAP, 11–30.

Mostofa, G. M. (2009). Efficacy of BAU-Biofungicide and fungicides in controlling diseases of soyabean. M.S. Theis, Dept. of Plant Pathol. BAU, Mymensingh, Bangladesh.

Pathak, V. N. (1980). Diseases of fruit crops. Oxford & IBM Publishing Co.New Delhi. pp. 12-22.

Peterson, R. A. (1986). Mango Diseases. Proceeding of CSIRO 1st Australian mango Research Workshop, CSRI, Cairns. pp. 233-247.

Ploetz, R. C., Zentmyer, G. A., Nishijima, W. T., Rohrbach, K. G. and Ohr, H. D. (1998). Compendium of Tropical Fruit Diseases. APS Press. *The American Phytopathological Society*. pp. 34-44.

Ploetz, R. C. (2005). Panama disease, an old enemy rears its ugly head: Parts 1 and 2. In: Plant Health Progress, APSnet: Online doi:10.1094/PHP-2005- 1221-01- RV.

Ploetz, R. C. and Pegg, K. G. (1997). *Fusarium* wilt of banana and Wallace's line: Was the disease originally restricted to his Indo-Malayan region? *Australasian Plant Pathology*, **26**, 239-249.

Ploetz, R. C. and Pegg, K. G., (2000). *Fusarium* wilt. Pages 143-159 In: Diseases of Banana, Abacá and Enset. D. R. Jones, ed. CABI Publishing, Wallingford, UK

Ponniah, S. and Subrahmanium, K. S. (1994). Biocontrol of Banana Wilt. .*Kisan World. Jan*,**42**, 55-56.

Punja, Z. K., Grogan, R. G. and Unruh, T. (1982). Comparative control of *S.rolfsii* on golf grass in Northern Calfornia with fungicides, inorganic salt and *Trichoderma* spp. *Plant Dis*, **66,** 1125-1128.

Rahman, M. A. Sultana, N. Morshed, M.M. Shahnoor, S. M. and Rahman, M. M. (2005). Efficacy of some fungicides in controlling sigatoka disease of Banana. *Bangladesh J. Aril. Res*. **30**(3):489-495.

Rahman, M. R. Faruk, M. I. . Rahman, M. L Begum, F. and Bari, M. A. (2001). Suppression of of tomato seedling disease by *Trichoderma harzianum* isolates. *Bangladesh J. Plant Pathology*, **17** ,(12)1-4.

Rajappan, K., Vidhyasekaran, P., Sethuraman, K., and Baskaran,T. L. (2002). Development of powder and capsule formulations of *Pseudomonas fluorescens* strain Pf-1 for the control of banana wilt. *Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz*, **109**, 80–87.

Raupach, G.S.and Kloepper, J.W.(1998). Mixtures of plant growth-promoting rhizobacteria enhance biological control of multiple cucumber pathogens. *Phytopathology* ,**88**, 1158–1164.

Rojoa, F. G., Reynosoa, M. M., Fereza, M., Chulze, S. N., and Torres, A. M. (2007). Biological control by *Trichoderma* species of *Fusarium solani* causing peanut brown root rot under field conditions. *Crop Prot*., **26,** 549-555.

Roy, S. J., Das, B. S., and Bora, L. C. (1989). Non pestcidal management of damping-off of cabbage caused by *Rhizoctonia solani* kuehn. *J. Agril. Sci. Society of North East India*., **11**(2), 127-130.

Shoresh, M., Yedidia, I., and Chet, I. (2005). Involvement of Jasmonic Acid/Ethylene Signaling Pathway in the Systemic Resistance Induced in Cucumber by *Trichoderma asperellum* $T_{203.}$ *Phytopathology* , **95**(1), 76-84.

Shultana, R., Hossain, I., Ahmed, S. and Mamun, M. A. A. (2009). Efficacy of BAU-Biofungicide in controlling leaf spot of wheat (*Triticum aestivum*). *Eco-friendly Agril. J*. **2**(2): 392-395.

Singh, R. N. (1978). Mango. Indian Council of Agricultural Research, New Delhi. pp. 60-64.

Singh, R. S. (1998). Plant Disease. 7th edition. Oxford and IBH Publishing Co. New Delhi. pp. 97-98.

Sivan, A., and Chet, I. (1986). Biological control of *Fusarium spp*. in cotton, wheat and muskmelon by *Trichoderma harzianum*. *J.Phytopathol.* **116**, 39–47.

Sivamani, E., and Gnanamanickam, S. S. (1988). Biological control of *Fusarium oxysporum* f.sp. *cubense* in banana by inoculation with *Pseudomonas fluorescens*. *Plant Soil* ,**107**, 3- 9.

Stover, R. H. (1962). Fusarial wilt (panama) disease of bananas other Musa species, Phytopathology, Kew, Surrey, England: Commonwealth Mycological Institute, 177p.

Su, H. J., Hwang, S. C. and Ko, W. H. (1986).Fusarial wilt of Cavendish banana in Taiwan. *Plant Disease,* **70**:814-818.

Thangavelu, R., Palaniswami, A., Ramakrishnan, G., Sabitha, D., Muthukrishnan, S., and Velazhahan, R., (2001). Involvement of Fusaric acid detoxification by *Pseudomonas fluorescens* strain Pf10 in the biological control of *Fusarium* wilt of banana caused by *Fusarium oxysporum* f.sp. *cubense*. *Journal of Plant Disease and Protection,* **108,** 433-445.

Tjamos, E. C., Papavizas, G. C., Cook, R. J. (eds), (1992). Biological control of plant diseases. Progress and challenges for the future. Plenum Press, New York.

Viljoen, A. (2002). The status of Fusarium wilt (Panama disease) of banana in South Africa. *South African Journal of Science,* **98**, 341–344.

Wardlaw, C.W. (1961). Banana diseases, including Plantains and Abaca. Longmans, Green and Co. Ltd. Lond, 648.

Weller, D.M., Raaijmakers, J.M., McSpadden Gardener,B.B., and Thomashow, L.S. (2002). Microbial populations responsible for specific soil suppressiveness to plant pathogens. *Annual Review of Phytopathology,* **40,** 309–48.

Zhang, N., Wu, K., He, X., Li, S., Zhang, Z., Shen, B., Yang, X., Zhang, R.,Huang, Q., and Shen, Q. (2011). A new bioorganic fertilizer can effectively control banana wilt by strong colonization with *Bacillus subtilis* N11. *Plant Soil*. **344**, 87–97

LIST OF ABBRIVIATIONS

BARI	=	Bangladesh Agricultural Research Institute
et. al	=	and others
Kg ha^{-1}	=	Kilogram/hectare
LER	=	Land Equivalent Ratio
LSD	=	Least Significant Difference
MP	=	Murate of potash
P^H	=	Hydrogen ion conc.
RCBD	=	Randomized Complete Block Design
R^H	=	Relative Humidity
t ha^{-1}	=	ton/hectare