MANAGEMENT OF EARLY BLIGHT DISEASE OF POTATO THROUGH SELECTED CHEMICAL FUNGICIDES

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JUNE, 2018

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Reg. No.: 12-04847

A Thesis
Submitted to the faculty of Agriculture
Sher-e-bangla Agricultural University
In partial fulfillment of the requirements
For the Degree 0f

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

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CERTIFICATE

This is to certify that the thesis entitled, **"MANAGEMENT OF EARLY BLIGHT DISEASE OF POTATO THROUGH SELECTED CHEMICAL FUNGICIDES''** 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 **MOHAMMAD TAREQ NAZIR** bearing **Registration No.: 12-04847** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma in any other institution elsewhere.

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.

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Dedicated to

My

Beloved Parents

ACKNOWLEDGEMENT

All praises are due to Almighty Allah for best owing mercy upon Author and for imbibing confidence on author to materialize the research work. It is a great gratification to articulate author's gratitude author's respected parents, who entitled much hardship inspiring for prosecuting author's studies, thereby receiving proper education.

The author feel proud to express his cordial gratitude, deep sense of respect and enormous indebtedness to author's research Supervisor ***Prof. Dr. Nazneen Sultana****, Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka, for her educational supervision, incessant encouragement, positive suggestion and unvarying inspiration all through the research work and for taking massive care in preparing this manuscript. Her insight and professional skill have made a distinctive contribution to complete this piece of research.*

The authors express his sincere appreciation, insightful sense, respect and immense indebtedness to the respected Co-supervisor ***Abu Noman Faruq Ahmmed****, Associate Professor, Department of Plant Pathology, SAU, for her constant guidance, unvarying help, timely directions and inspirations throughout the tenure of research work.*

The author is greatly thankful to his respectable teacher ***Prof. Dr. Khadija Akhter****, Chairman, Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka, for her encouragement and co-operation during the entire study period.*

The author expresses his gratitude to all other teacher of department of Plant Pathology for their valuable teachings and lessons during course of the study.

The author would like to expresses cordial thanks to his friends who wished his better life are Md. Kawsar Mian and Liton Chandra Barman helped the author with their valuable suggestions and directions during the preparation of the thesis paper.

The author takes an opportunity to express his cordial thanks and sincere gratitude to the staff of the Department of Plant Pathology, SAU for their valuable suggestions and directions to complete this piece of research. The author expresses his massive thankfulness to all of them who supported and encouraged him to achieve advanced education and regret for his inability for not to mention every one by name.

The Author

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ABSTRACT

Early blight is one of the most common and devastating disease of potato plant which is caused by the fungus, *Alternaria solani*. The efficacy of six commercial chemical fungicides viz. Bicozeb 80 WP (Mancozeb), Rovral 50WP (Iprodione), Sazid 70 WP (Mancozeb + Metalaxyl 7%), Win 77WP (Copper Hydroxide), Pipertax 50WP (Copper Oxychloride) and Tilt 25 EC (Propiconazole) were tested against early blight disease of potato in field condition during 2016-2017 in Sher-e-Bangla Agricultural University, Dhaka. The experiment was conducted following RCBD design with three replications. The finding showed that, all fungicides significantly reduced the early blight disease incidence and severity as well as increased the yield of potato in compared with control under field conditions. The maximum reduction of plant infection 86.95%, leaf infection 86.83% and disease severity 86.70% were observed at 80 days after planting by the application of Bicozeb 80 WP. The maximum yield increased by 121.18% when the field was applied by Bicozeb 80 WP against early blight disease of potato. Rovral 50 WP (Iprodione) also showed better performance in controlling disease. Thus, the present study revealed that, application of fungicides viz. Bicozeb 80 WP (Mancozeb) have shown significant effect and proved to be cost effective for the management of early blight disease of potato in field condition.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

CHAPTER I

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most valuable non-cereal food crops, grown in most of the temperate and subtropical countries of the world. It contributes the highest amount of dry matter, protein and other nutrients per unit area and time. Potato is a unique crop which can supplement the food needs of the country in a substantial manner (Shailbala and Pathak, 2008). Potato is the third important food & cash crop in Bangladesh belonging to the family Solanaceae. It's a global crop & globally it is the fourth most important world crop next to rice, wheat and maize (Spooner and Bamberg, 1994). The production of potato was 2.93 million tons from 0.243 million hectare of land in Bangladesh during 1999-2000 (BBS, 2000). But at present Potato is grown in an area of 0.47 million hectares with production 10.216 million tons in Bangladesh (BBS, 2017). The area under this crop is increasing rapidly and the farmers are gradually adopting it as a cash crop. Tuber yield was only 12.06 t/ha in the country which is lower as compared to other potato growing countries of the world like Ukraine (44.0 t/ha) and Netherlands (41.3 t/ha) (Chadha, 1995), but at present it's increases up to 18.5 t/ha (BBS, 2017).

Potato can play an important role in supplying vegetable throughout the year and can solve the nutritional problems to a great extent for the lower income group of people. Potato contains significant levels of phenolic compounds and vitamin C as potent antioxidants (Brown, 2005), which inactivate reactive oxygen species, reduce oxidative damage, lead to improved immune functions and reduce risk of cardiovascular diseases, cancer, cataract, diabetes and aging (Shtienberg *et al*., 1990).

The major constraints in potato production have been the incidence of wide range of pests and diseases, difficulties in the production and distribution of disease free seeds, inadequacies of cold storage facilities resulting in rotting and sprouting and violent price fluctuations. Of them diseases play an important role for such low yield in the country. So far in Bangladesh a total of 54 diseases (both biotic and abiotic) of potato have been recorded (Vander *et al*., 2001). Among them, early blight of potato caused by *Alternaria solani* (Ellis and Martin., 2007) Jones and Grout is of major cause of concern in potato production at present. Early blight is one of the most important diseases which is caused by the fungus *Alternaria solani*, which occurs in most potato growing regions world-wide (Shtienberg *et al*., 1990; Vanderwalls *et al.,* 2001). In recent years, increasing of early blight disease on potato foliage has been reported in various potato growing areas (Vloutoglou and Kalogerakis, 2000). Primary damage by early blight is attributed to premature defoliation of the potato plants, resulting in tuber yield reduction. Yield loss estimates resulting from foliar damage incited by early blight on potato varied by location, cropping season, cultivar, and the stage of potato maturity. Early blight is a major foliar disease of potato and causes 20- 50% yield loses, it produces small, darkened lesions on the plants that spread into growing black spots of dead tissue. Disease symptoms are characteristic dark brown to black lesions with concentric rings, which produce a ‘target spot’ effect (Vander *et al*., 2001). Symptoms are initially observed on older, senescing leaves. *Alternaria solani* overwinters as mycelium or conidia in plant debris, soil, infected tubers or on other host plants of the same family.

The disease is controlled primarily through the use of cultural practices such as resistant cultivars, foliar fungicides, crop rotation, tillage, removal and burning of infected plant debris and eradication of weed hosts helps to reduce the inoculums level for subsequent plantings.

Among the diseases, early blight caused by *Alternaria* species like *Alternaria solani & Alternaria alternata are* serious one. Fungicides like Dithane M 45, Tilt 25 EC, Win 77 WP, Rovral 50 WP, Pipertax 50 WP and Bicozeb 80 WP etc. showed good result against early blight of potato (Mane *et al*., 2014; Ganie *et al.*, 2013, axb). Crop disease control with chemicals is very popular because of its quick action, broad spectrum activity and easy availability to the growers. Different fungicides have been successfully used in controlling Alternaria blights of mustard, cabbage, tomato and cauliflower (Hossain and Mian, 2004; Khuda *et al*., 2003; Rahman, 2000). However, limited information is available about the fungicidal control of potato early blight in Bangladesh (Meah, 1994). The present attempt was, therefore, made to evaluate the effectiveness of six fungicides available against early blight of potato in field condition.

Considering the above facts and points, the present investigation was undertaken to achieve the following objectives-

i. To isolate and identify the causal organism of early blight disease of potato.

ii. To evaluate the efficacy of six selected chemical fungicides against early blight disease of potato in field conditions.

CHAPTER II
REVIEW OF LITERATURE

Potato (*Solanum tuberosum* L.) is considered as one of the most important global food crops which is grown in more than 100 countries with different climatic conditions including temperate, subtropical and tropical zones. Its origin is in the Andean region of Peru in South America. It is also a promising source for non-food industry. Potato is the most economic subtropical vegetable in India. It belongs to family Solanaceae. The farmers face yield losses both in quality and quantity of produce due to various diseases, one of the most significant being early blight, caused by the fungus *Alternaria solani*.

2.1 Occurrence of Early Blight Disease

The *Alternaria* spp. causes diseases in considerably large number of crops. It is one of the eight genera of Hyphomycetes. The taxonomy of the genus *Alternaria* has undergone several refinements since it was established by Nees (1817) and Rao (1971) with *A. tenuis* as a type species.

Berkeley (1836) identified the causal fungus on plants belonging to family Brassicaceae as *Macrosporium brassicae* Berk., which was later renamed as *Alternaria brassicae* (Berk.) Sacc.

The early blight disease was first described by Ellis and Martin (1882) from U.S.A. on Potato and the causal organism was identified as *Macrosporium solani*.

Agrios (2005) studied taxonomic characters of the Genera *Alternaria*. According to him in "Sylloge Fungorum" of Saccardo, 41 species of *Alternaria* are described. Further, he reported *Alternaria solani* (E.& M.) J. & G. as a destructive parasite.

The fungi *A. solani* and *A. alternata* are classified under *Eukaroyota* domain, Kingdom *Fungi*, phylum *Deuteromycota* (formerly) or *Ascomycota* (present), class *Hyphomycetes*, order *Hyphomycetales* (Waals *et al*., 2001).

These are classified as fungi imperfecti or Deuteromycetes because their sexual phase has not been discovered yet or if discovered lie in Ascomycotina.

Agrios (2005) reported that *Alternaria solani* belongs to the Fungi Imperfecti (Deuteromycotina) in the class Hyphomycetes and order Hyphomycetales.

Spores of the fungi are one of most important means of dissemination and also used in the identification and classification of the organism. The ability of the pathogen to survive for a long time in the plant parts, soil and on alternative/ collateral hosts in the absence of main host, determine the ability of the pathogen to perpetuate (Moore and Thomas, 1942; Basu, 1971; Rands, 1917 a).

2.2 Symptoms of Early Blight Disease

Sherf and MacNab (1986) described early blight symptoms in detail. They reported that first symptoms of early blight are small, dark, necrotic lesions that usually appear on the older leaves and spread upward as the plant become older. As the lesions enlarge, they commonly have concentric rings with a target-like appearance, and they are often surrounded by a yellowing zone. In severe epidemics, *Alternaria solani* can cause premature defoliation, which weakens the plants and exposes the fruit to injury from sunscald. Large, dark, and sunken lesions may appear on the stems of seedlings at the ground line, causing partial girdling known as collar rot.

Waals *et al.* (2001) studied early blight of potato, resulting in major yield losses. Leaf symptoms are characteristic dark brown to black lesions with concentric rings.

Kemmitt (2002) and Zhang (2004) described that symptoms of early blight have been characterized by dark concentric-ring like lesions. This cycle continues until there is no healthy tissue to infect or the weather prevents further cycles of the disease. Stems may also be infected. Which show dark brown to black sunken and lens shaped lesions with a light center, and have the typical concentric rings.

2.3 Morphology of *Alternaria solani* isolates

King and Alexander (1919) studied nuclear behavior, septation and hyphal growth of *Alternaria solani.*

Neergaard (1945) reported that *Alternaria solani* belongs to the large spored group, characterized by separate conidia borne singly on simple conidiophore, within the genus *Alternaria.*

Further, Ellis and Gibson (1975) noticed that the conidia of *Alternaria solani* are muriform and beaked.

Ellis and Gibson (1975) studied the morphological characters of *Alternaria solani* and reported that the conidia are dark muriform, pale golden or olivaceous brown, smooth and usually 150–300 µm in length and 15–19 µm thick in the broadest part, with 9–11 transverse septa and 1–4 longitudinal or oblique septa; sometimes branched 2.5–5 µm thick tapering gradually.

Neergaard (1945) gave a comprehensive account of distinguishing characters of the Indian species of *Alternaria*.

Ellis and Martin (1986) reported that solitary, golden brown and beaked conidia of *Alternaria solani* have nine to eleven transverse and a few or no longitudinal septa. The dimensions of the spores range from 15-19 micrometers by 150-300 micrometers while *Alternaria alternata* grows in long chains, with dark brown conidiophores and conidia having short beak (compared to *A. solani*) and may be smooth or finely warty with both transverse and longitudinal septa. Conidia range from 20-60 by 9-18 micrometers in dimension.

Bose and Som (1986) observed that mycelium of *Alternaria solani* isolated from tomato consisted of septate, branched, light brown hyphae which turn brown with age. The conidiophores were short, 50 to 90 µm and dark coloured. Conidia were 120-296 x 12-20 µm in 15 size, beaked, muriform dark coloured and borne singly.

Rotem (1994) observed that the other members of the genus *Alternaria*, *Alternaria solani* has transverse and longitudinal septate conidia, multinucleate cells and dark-colored (melanized) cells.

Perez and Martinez (1995) reported that variability in four isolates of *Alternaria solani* with respect to morphological characters like colony growth, colony diameter, mycelial color, colony texture, pigmentation and conidia size on the medium, differed between isolates and it was concluded that *Alternaria solani* exhibited variability.

Roberts *et al.,* (2000) worked on morphological segregation of *Alternaria*. They have segregated two hundred and sixty isolates of small-spored *Alternaria*, primarily from fruit substrates into morphological groups.

Vloutoglou and Stamelon (2001) conducted *in vitro* and *in vivo* experiments on *Alternaria solani* isolates from potato and tomato and showed morphological variability of the isolates. According to them potato isolates were characterized by light grey colonies, aerial mycelium and the absence of conidia, whereas isolates from tomato were characterized by black colonies, no aerial mycelium and the production of great amounts of conidia.

Deokar and Raghuwanshi (2002) studied morphological characters in six isolates of *Alternaria carthami* infecting safflower and reported variability with regards to conidial size, number of septa, beak size and colour. They observed that isolates from South Solapur and Barshi were similar in beak size but varied in size (length × width), septation and beak colour. The length of conidia varied between 33 to 79 µm whereas number of septa varied from 0 to 7 µm.

2.4 Disease Incidence of Early Blight Disease

Vander waals *et al.* (2001) conducted a survey of control practices and growers perceptions of early blight in South Africa. The predominant control method for early blight was the use of fungicides with mancozeb or, chlorothalonil as active ingredient. Most respondent commencing spraying at flowering and spray at 7–10 day intervals.

Hossain *et al.* (2010) has conducted a survey during 2006 to 2008. The average higher leaf infection in early blight of potato and tuber infection in soft rot of potato were recorded 37% and 39%, respectively.

Ganie *et al*. (2013 b) reported that the *Alternaria* leaf blight is one of the most important diseases of potato (*Solanum tuberosum* L.) worldwide. The disease was prevalent in all the potato growing areas of Kashmir valley surveyed during 2009 and 2010. The overall mean disease incidence and intensity ranged from 24.54 to 28.23% and 13.84 to 15.98%, respectively. Up to fourth week of June concentric rings form as a result of irregular growth patterns by the fungus in the leaf tissue giving the lesion a characteristic "target spot" or "bulls eye" appearance. The maximum lesion size 7.4 mm was recorded in the second week of August.

Rani *et al*. (2015) conducted field surveys during 2011 and 2012 to diagnose the symptoms of early blight of tomato (*Lycopersicum esculentum* L.) in Jammu, Division of Jammu and Kashmir. The disease intensity and incidence varied from 21.66 to 34.13% and 10.48 to 18.56%, respectively. Weather factors (temperature, humidity and rainfall) were found to play a significant role in its development.

2.5 Management of Early Blight of Potato

Several research workers from various studies reported that the timely application of fungicides is the best method to control early blight. (Mathur *et al*., 1971; Singh, 1971; Dahmen and Staub, 1992; Singh, 1998).

Kalra and Sohi (1984) studied efficacy of different fungicides against *A. alternata* that causes early blight of potato under *in vitro* conditions and reported that Thiram (0.05-0.2per cent), Dithane M-45 (0.1 – 0.2 per cent) and Difolaton (0.2 per cent) completely inhibited the growth and sporulation of *Alternaria alternata.*

Choulwar and Datar (1989) assessed the efficacy of eight fungicides (Copper oxychloride, Zineb, Mancozeb, Carbendazim, Dithianon, Iprodione, Thiophanate methyl and Captafol) to reduce the mycelial growth of *Alternaria solani* under *in vitro* conditions and reported that Mancozeb (1000 ppm) was the most effective fungicide with 77% growth inhibition followed by Captafol. They also observed that Carbendazim and Thiophanate methyl were not effective in inhibiting mycelial growth of *A. solani.*

Christ and Maczuga (1989) evaluated spray schedule of fungicide for their effect on controlling potato early blight under Pennsylvania growing condition. Disease severity and lesion number were lowest when fungicide sprays were initiated before flowering of the potato plant.

Sinha and Prasad (1991) tested seven fungicides in the field against *Alternaria solani* infecting tomato over three seasons and reported that Mancozeb @ 0.2% was the best and cost effective treatment with the highest yield.

According to Dahmen and Staub (1992) Difenoconazole (Score 250) was found to be very effective against early blight of potato because of its protectant, curative and eradicant mode of action and especially its long lasting protective activity up to 3 weeks.

Bartlett *et al.* (2001) in their scientific paper stated that Azoxystrobin gives control of fungi from all four classes of plant pathogens, namely the Ascomycetes, Basidiomycetes, Deuteromycetes and Oomycetes.

Ben-Noon *et al.* (2001) tested the efficacy of different fungicides namely, Difenconazole, Tebuconazole, Chlorothalonil, Mancozeb, Propineb, Flutrifol, Copper hydroxide and Iprodione in two field experiments for the management of *Alternaria* leaf blight of Carrot. They observed that all fungicides reduced disease severity, but there were significant differences in efficacy amongst them. The most effective were Difenoconazole and Chlorothalonil; less effective were Copper hydroxide, Tebuconazole, and Mancozeb; the least effective in our experiments were Flutrifol, Propineb and Iprodione.

Vloutoglou *et al.* (2000) tested the efficacy of Mancozeb (0.14% a. i.), Iprodione (0.075% a.i.), Prochloraz (0.025% a.i.), Chlorothalonil (0.15% a. i.) and Azoxystrobin (0.025%a. i.) on spray inoculated tomato plants with spore suspension of *Alternaria solani* as a protective and curative application in Greece. They found that when the fungicides were applied one day prior to inoculation disease severity was reduced by 91-100% and defoliation by 100% as compared to untreated control. Prochloraz, Azoxystrobin and Iprodione showed the greatest curative activity, especially when they were applied to one day prior to inoculation (reduction in disease severity by 71-98%, in defoliation by 75-100%).

Bartlett *et al.* (2002) evaluated effect of strobilurin fungicides such as Azoxystrobin, Kresoxim methyl, Trifloxystrobin and Pyraclostrobin in influencing yield and quality of wheat, barley, tomato, potato, mangoes etc and reported that strobilurin based spray programme delivered consistently greater yield benefits as compared to triazole based programmes. This phenomenon of strobilurins to provide yield and quality benefits is termed as strobilurin greening effect because it is closely associated with their ability to maintain the green leaf area of the crop until late in the season, thereby maximizing grain filling/fruit setting period with resultant yield benefits. Further, they presented two hypotheses to explain this phenomenon, firstly variety of physiological processes such as carbon dioxide compensation point, leaf senescence, ethylene biosynthesis, chlorophyll content, photosynthetic activity, water consumption, plant antioxidant enzyme activity, levels of plant hormones and nitrate reductase activity are directly influenced by strobilurins and secondly they prevent spores of pathogenic, nonpathogenic and saprophytic fungi from germinating and thereby avoid the wastage of energy in host-defense mechanism and this results in improving the yield and quality of produce. They also reported that Azoxystrobin, Kresoxim methyl, Pyraclostrobin and Trifloxystrobin have good efficacy against tomato early blight.

Singh *et al*. (2002) reported effectiveness of Contaf (Hexaconazole), Dithane M-45, Kavach, Foltaf, Bayleton and Baycor in controlling *A. brassicicola* and improving yield of cabbage.

Tofoli *et al.* (2003) evaluated the effectiveness of various groups of fungicides for controlling early blight (*Alternaria solani*) as well as their effect on tomato fruit yield, following early blight severity in leaf lets and stems; percentage of leaf drop; incidence of healthy, infected and sun damaged fruits; yield and the percentage of large, medium and small sized fruits were evaluated. The highest level of disease control, quality and increase in fruit yields were obtained with pyraclostrobin + metiram, fenamidone + chlorothalonil, famoxadone + cymoxanil + mancozeb, Kresoxim methyl, azoxystrobin, difenoconazole, tebuconazole, pyrimethanil, cyprodinil, famoxadone +. Mancozeb followed by prochloraz, fluazinzm, procymidone, mancozeb and chlorothalonil.

Prasad and Naik (2003) tested the efficacy of non-systemic fungicides (Iprodione, mancozeb, copper oxychloride and SAAF), systemic fungicides (thiphante methyl, triademefon, benomyl and carbendazim) in controlling early blight of tomato. Mancozeb gave the highest cost benefit ratio of 1: 1.14 in addition to reducing the disease incidence.

Kapsa and Osowski (2003) conducted study during 1997-2001 to estimate the efficacy of Mancozeb, Chlorothalonil and a mixture of plant protection product with a contact mode of action Zoxamide + Mancozeb against early blight on potato. Spraying with fungicides limited the development of the disease and increased tuber yield ranging from 21.9 to 60.9% for bonin and from 13.0 to 101.9% for stare olesno surveys. The mixture of Zoxamide + Mancozeb showed the greatest efficacy.

Abhinandan *et al.,* (2004) tested the efficacy of commercial fungicides (Dithane M-45) (Mancozeb) at 0.25%, Kavach @ 0.25%, Rovral (Iprodione) @ 0.20%, Copper oxychloride (Blitox) @ 0.25%, Antracol (Propineb) @ 0.15%, Propiconazole @ 0.05%, Penconazole @ 0.05% in controlling the early blight disease of potato where Mancozeb and Kavach (Chlorothalonil) were found to be very effective in controlling the disease with more than 50% disease control as compared to the untreated check.

Pasche *et al.,* (2005) studied effectiveness of Azoxystrobin in management of early blight of tomato and reported that *Alternaria solani* was considered to be difficult to control until the registration of the first strobilurin fungicide, azoxystrobin in 1999.

Miles *et al.* (2005) tested efficacy of strobilurins azoxystrobin, trifloxystrobin, pyraclostrobin and copper hydroxide, mancozeb, captan, iprodione and chlorothalonil in the field for control of brown spot caused by *Alternaria alternata* on Citrus. They observed in all experiments, that strobilurins incorporated with copper and mancozeb were better than the stand alone application.

Ganeshan and Chethana (2009) evaluated broad spectrum strobilurin fungicide, Pytaclostrobin 25% EC @ 50, 75 and 100 g a. i./ha in comparison with Mancozeb 75% WP @ 3.0 g/l and Captan 50% WP @

2.5 g/l and observed that all the doses of Pyraclostrobin 25% EC were significantly superior to Mancozeb and Captan for minimizing intensity of early blight of tomato.

Horsfield *et al.* (2010) conducted series of experiments to evaluate fungicide use strategies for the control of early blight (*Alternaria solani*), the most significant foliar disease of potatoes in Australia. The protective and curative activity of fungicides was evaluated in glasshouse and field studies. Boscalid, Azoxystrobin and Difenoconazole were highly effective in the control of early blight when applied up to three days before or three days after inoculation.

Gohel and Solanky (2011) had done an in vitro screening of eleven fungicides by poisoned food technique at three different concentrations showed that Propiconazole (Tilt 25 EC), Difenconazole (Score 25 EC), Hexaconazole (Contaf 5 EC), Copper oxychloride (Blitox 50 WP), Mancozeb (Dithane M-45 75 WP) and Propineb (Antracol 70 WP) were highly fungitoxic to *Alternaria alternata*. Under field condition six fungicides were evaluated against Alternaria leaf spot disease of chilli [*Alternaria alternata* (Fr.) Keissler] under natural environmental conditions. Minimum per cent disease intensity and maximum per cent disease control was achieved in the treatment of Propiconazole (Tilt) (0.1 %) Difenconazole (Score) (0.1%) and Mancozeb (Dithane M-45) (0.2 %) were also proved effective.

Ganie *et al*. (2013a) tested the five non-systemic fungitoxicants viz., Chlorothalonil 50 WP, Mancozeb 75 WP, Captan 50 WP, Propineb 70 WP and Copper oxychloride 50 WP at six concentrations (1000, 1500, 2000, 2500, 3000 and 3500 ppm) each and five systemic fungi toxicants viz., Thiophenate methyl 70 WP, Carbendazim 50 WP, Hexaconazole 5 EC, Fenarimol 12 EC and Difenconazole 25 EC at six concentrations (100, 150, 200, 250, 300 and 350 ppm) each were evaluated in vitro against *Alternaria solani* (Ellis and Martin) Jones and Grout causing early blight of potato through poisoned food technique. Among non-systemic fungi toxicants Mancozeb 75 WP, irrespective of concentration was most effective and inhibited a maximum mean mycelial growth inhibition of 75.46% over check, followed by Propineb 70 WP, Captan 50 WP, Chlorothalonil 75 WP, and Copper oxychloride 50 WP with mycelial growth inhibition of 68.09, 66.07, 58.89, and 57.81% respectively. Among systemic fungi toxicants Hexaconazole 5 EC was most effective and exhibited a maximum mean mycelial growth inhibition of 84.19% over check. Under in vivo conditions seed treatment with Mancozeb 75WP (0.3 %) + foliar spray with Hexaconazole 5 EC (0.1%) + foliar spray with Datura (50%) + foliar spray with *Trichoderma harzianum* (1 × 107 spore/ml) were highly effective in controlling the disease severity as compared to control.

Mane *et al*. (2014) conducted an experiment to evaluate the effect of bio agents (*Trichoderma harzianum* and *Pseudomonas fluorescens*) and fungicides (Mancozeb) against early blight of potato caused by *Alternaria solani* (Ell. and Mart.) at the experimental field of Department of Plant Protection, Sam Higginbottom Institute of

Agriculture, Technology and Sciences, Allahabad, during Rabi Season of 2013-2014. Seven treatment including control with three replications were taken up using RCBD. The treatments comprised of seed treatment and foliar spray (once and twice) of bio agents *Trichoderma harzianum* and *Pseudomonas fluorescens* while fungicide taken up was Mancozeb and control (spray of plain water) was applied. Observation for percent disease intensity was recorded at 60 and 80 days after sowing. Lowest disease intensity was recorded in Mancozeb (15.07% and 18.40%, respectively) as compared to control which recorded highest disease intensity (20.91% and 33.80%, respectively). Mancozeb not only reduced disease intensity but also recorded highest yield (253.00 q/ha) as compared to control which recorded 157.83 q/ha.

Koley and Mahaputra (2015) were conducted an experiment in Department of Plant Pathology, College of Agriculture, Orissa University of Agriculture & Technology, Bhubaneswar-751003 (Odisha), India on early blight of potato named as In vitro testing of four non-systemic fungicides and six systemic fungicides against the fungus revealed that Propineb @ 0.1% among the non-systemic chemicals and Propiconazole @ 0.05% among the systemic chemicals were the best resulting in cent percent and 96.91% growth inhibition of *Alternaria solani*, respectively. 0.3% concentration of non-systemic chemicals and 0.15% of systemic chemicals showed the highest growth inhibition (87.50% and 75.61%, respectively) of the fungus. As regards to the interaction effect between the tested chemicals and their concentrations, it was found that Mancozeb @ 0.3% was statistically at par with Copper oxychloride @ 0.2% and Difenoconazole @ 0.15% was statistically at par with Propiconazole @ 0.05%.

Ghazanfar *et al.* (2016) were conducted an experiment where five fungicides were tested against *Alternaria solani.* Early blight of tomato caused by *Alternaria solani* (Ellis & Martin) Sorauer is the most destructive disease that hampered its successful production all over the world. In the present study, fungi toxic activity of fungicides, namely Propineb (Antracol 70 WP), Thiophanate-methyl (Topsin-M 70 WP), Chlorothalonil (Kavach 75 WP), Mancozeb (Dithane M-45 80 WP) and Copper oxychloride (Blitox 50 WP) was evaluated by poisoned food technique for the management of early blight of tomato. All the tested chemicals significantly ($P \leq 0.01$) inhibited the mycelial growth of a pathogen when compared with control. However, among all five tested fungicides, Dithane M-45 80 WP (89.83%) was significantly superior over other treatments followed by Antracol 70 WP (87.40%), Topsin-M 70 WP (87.10%), and Blitox 50 WP (79.21%). This reduction was gradually increased by increasing the incorporated concentration. Least inhibition was observed in Kavach 75 WP (70.40%). Overall results demonstrated that all tested concentrations of Dithane M-45 80 WP were found significantly effective for controlling early blight of tomato.

Thejakumar and Devappa (2016) were conducted an experiment in vitro condition to test the efficacy of fungicides against *Alternaria alternata* causing leaf spot disease of chilli. Among the ten fungicides evaluated in *in-vitro* condition against *Alternaria alternata* causing leaf spot disease of chilli revealed that propiconazole at all concentration *viz.*, 500, 1000 and 2000 ppm was showed complete inhibition of mycelial growth followed by mancozeb at 1000 and 2000 ppm and difenconazole at 2000 ppm.

Sings *et al*. (2018) was conducted an experience to test the efficacy of fungicides and bio-control agents in vitro against *Alternaria solani* causing early blight of tomato. Seven fungicides viz., four systemic (Propiconazole, Azoxystrobin, Thiophanate methyl and Carbendazim) and three non-systemic (Mancozeb, Captan and Zineb) at four concentrations i.e. 50, 100, 150 and 200 ppm were evaluated through poison food technique. Among the systemic fungicides, Propiconazole was proved to be highly effective and recorded cent percent inhibition at their all concentrations while among the nonsystemic, Mancozeb was proved to be effective at their all concentrations but recorded 100 percent inhibition only at their higher concentration *i.e.* 400 ppm.

Siva Prasad *et al.* (2018) were conducted an experiment, where eleven fungicides viz., Thiram, Captan, Copper oxychloride, Mancozeb, Chlorothalonil, Carbendazim, Hexaconazole, Propiconazole, combination products of Carbendazim + Mancozeb, Captan + Hexaconazole and Azoxystrobin (each at recommended dose, 500 ppm below their recommended dose and 500 ppm above their recommended dose) were evaluated *in vitro* against *Alternaria macrospora* causing leaf spot of cotton. All the treatments significantly inhibited mycelial growth of *Alternaria macrospora* over untreated control. Among different fungicides, Mancozeb, Carbendazim, Hexaconazole, Propiconazole and Carbendazim + Mancozeb at all the test doses completely inhibited (100%) the growth of *A. macrospora* followed by Captan + Hexaconazole (89.74%), Thiram and Captan (78.89%) and Azoxystrobin showed least inhibition (56.81%) compared to untreated control.

Ali *et al.* (2018) were conducted an experiment where eight fungicides namely Pipertax 50 WP (Copper Oxychloride), Mancothane 80 WP (Mancozeb), Meena 80 WP (Mancozeb), Sazid 70WP (Mancozeb + Metalaxyal 7%), Media 80 WP (Mancozeb), Win 77 WP (Copper Hydroxide), Bicozeb 80 WP (Mancozeb) and Rovral 50 WP (Iprodion) were tested for their effectiveness against early blight (*Alternaria solani*) of tomato (*Lycopersicon esculentum*). The fungicides were applied as foliar spray at the rate 0.2% suspension in water for 4 times at 12 days interval starting from first appearance of symptoms. All the fungicides significantly reduced disease severity and increased fruit yield and yield components compared to control. Among the fungicides tested the highest disease reduction with maximum fruit yield and yield components were obtained with Bicozeb, which was similar to Rovral as a standard check. Reduction of disease severity and increase of fruit yield in different farms by Bicozeb ranged 58-70% and 27-49% respectively. Rovral also gave 58-70% disease reduction and 27-57% yield increase. Other fungicides reduced disease severity by 44-69% and increase in fruit yield by 4-44% over control.

CHAPTER III

MATERIALS AND METHODS

3.1 Experimental site

The field experiment was conducted at the farm field of Sher-e-Bangla Agricultural University and laboratory experiment was conducted in Plant Disease Clinic, Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka-1207.

3.2 Time of experiment

The experiment was conducted from November 2016 to November 2017.

3.3 Selection of variety

There are several varieties of potato in Bangladesh. Among the varieties BARI Potato-7 (Diamond) was collected from Bangladesh Agricultural Research Institute, Joydebpur, Gazipur and used in the experiment.

3.4 Design of the experiment

The field experiment was conducted following Randomized Complete Block Design (RCBD) with three replications.

3.5 Climate

The experimental area was under the sub-tropical climate which characterized by the comparatively low rainfall, low humidity, low temperature, relatively short day during November to May and high rainfall, high humidity, high temperature and long day period during April to September. The annual precipitation and potential evapotranspiration of the site were 2152 mm and 1297 mm, respectively. The average maximum and minimum temperature was 30.34° C and 21.21° C, respectively with mean temperature of 25.17°C. (Appendix II) Temperature during the cropping period ranged from 12.2° C to 31.2° C. The humidity varied from 73.52% to 81.2%. The day length ranged from 10.5-11.0 hours only and there was no rainfall during the experimental period.

3.6 Soil type

The soil of the experimental site belongs to the Agro-Ecological Region of "Madhupur Tract" (AEZ No. 28). It was Deep Red Brown Terrace soil and belongs to "Nodda" cultivated series. The top soil is slightly clay loam in texture. Organic matter content was very low (0.82%) and soil pH varied from 5.5-6.5.

3.7 Fertility status of field soil

The soil of experimental site was analyzed in Soil Resource Development Institute (SRDI), Dhaka and found as loamy soil which contains total Nitrogen 0.061(%), Phosphorus 35022 microgram per gram of soil, Sulphur 22.60 microgram per gram of soil, Potassium 0.030 miliequivalent per 100 gram soil and Calcium 2.67 miliequivalent per 100 gram soil.

3.8 Layout of the design

The field layout was done as per experimental design on 1st November; 2016. The field was divided into three blocks each of which representing replication. There were 7 treatments including control with 3 replications which results in total 21 plots in experimental field. The plots were designed complete Randomized Complete Block Design method with three replications. The size of the unit plot was 6m^2 (2m×3m). The distance between two adjacent plots was 0.5m and one replication to another replication was 0.5m. The total size of the experimental field was 209m^2 (19m×11m).

3.9 Details of the experiment setup

The experimental plots were arranged in Randomized Complete Block Design (RCBD) with three (3) replications (Appendix-I). The experiment details are presented below:

- Total area : 209m^2 (19m×11m)
- No. of plot: 21
- Plot size : (2m×3m)6 m^2
- Block to block distance : 0.5m
- Plot to border distance : 0.5 m
- Plot to plot distance (Length wise) : 0.5 m
- Plot to plot distance (Breath wise) : 0.5m
- Plant to plant spacing : 20 cm
- Row to row spacing : 50 cm
- Total no. of plant : 756
- No. of plant in a unit plot : 36(12x3)
- Total 3 row in a unit plot and 12 plants in a row

3.10 Land preparation

A piece of medium high land with well drainage system was selected. The experimental field was first ploughed on 1st November 2016. The land was ploughed thoroughly with a power tiller and then laddering was done to obtain a desirable tilt. The clods of the land were hammered to make the soil into small pieces. Weeds, stubbles and crop residues were cleaned from the land. The final ploughing and land preparation was done on 7th November 2016.

3.11 Application of manures and fertilizer

The following dose of fertilizers and manures were applied for the potato cultivation as per recommendation of Bangladesh Agricultural Research Institute (BARI):

- Urea= 6.105 kg(300kg/ha)
- TSP= 3.0525 kg(150 kg/ha)
- MOP= 5.0875 kg(250 kg/ha)
- Gypsum= 0.922 kg(40 kg/ha)
- Cowdung= 203.5 kg(10 tons/ha)
- The 1/3rd Urea and whole amount of other fertilizers were applied as basal dose during land preparation.
- Rest 2/3rd Urea will be applied at 30 days after planting and 50 days after planting followed by irrigation.

3.12 Plantation of potato tuber

Selected healthy and disease free potato seeds were planted in the experimental field. Planting was done with the help of *khurpi* (a hand operated implement). For planting, a hole was made with *khurpi*, so that the seed of potato was dipped in soil, but must be touching with surface soil. The hole was completely covered with the help of thumb finger. This planted potato seeds need were watered after seven days with the help of watering cane.

3.13 Treatments

There were 7 treatments in the experiment with 3 replications. Following treatments were used for spraying of potato field:

SL. No.	Trade Name	Active Ingredient	Dose
1.	Sazid 70 WP	Mancozeb + Metalaxyl 7%	@ 0.2%
2.	Tilt 25 EC	Propiconazole	@ 0.2%
3.	Win 77 WP	Copper Hydroxide	@ 0.1%
4.	Rovral 50 WP	Iprodione	@ 0.1%
5.	Pipertax 50 WP	Copper Oxychloride	@ 0.2%
6.	Bicozeb 80 WP	Mancozeb	@ 0.2%
7.	Control	-	-

3.14 Intercultural operation

3.14.1 Plant protection

The crop was protected from the attack of insect-pest by spraying insecticide Ektara. The insecticide spraying was done as required following the recommended dose.

3.14.2 Gap filling

After plantation of potato seeds in the field some gaps had been found either for missing plantation or drying out of the germinated seedlings. For maintaining optimum number of plant population gaps filling were done properly as required.

3.14.3 Irrigation

Irrigation was done at 10-15 days interval as per requirement for the field condition.

3.14.4 Weeding

Weeding was done fourth time in the experimental period starting from 25 days after planting, 35 days after planting, 50 days after planting and 70 days after planting.

3.15 Collection of fungicides

Six fungicides namely Win 77 WP, Tilt 25 EC, Rovral 50 WP, Pipertax 50 WP, Bicozeb 80 WP and Sazid 70 WP were collected from local market.

3.15.1 Preparation of fungicidal suspension

Recommended doses of fungicidal solution were prepared by mixing thoroughly with required quantity of fungicide and water. It was required Dithane M 45(4.5gm/L), Win 77 WP (1gm/L), Tilt 25 EC (1gm/L), Pipertax 50 WP (2gm/L), Bicozeb 80 WP (2gm/L) and Rovral 50 WP (1gm/L) for preparation of solution for recommended concentration.

3.15.2 Application of fungicides

At recommended doses, the suspensions/solutions of fungicides were prepared by mixing thoroughly with requisite quantity of normal plain water.

Spraying was started from one month after transplanting. Totally 3 spraying were done with 10 days intervals with a hand sprayer. To avoid the drifting of the fungicides during application, spraying was done very carefully, especially by observing air motion. A control treatment was maintained in each block where spraying was done with plain water only.

3.16 Data collection

Data were collected based on the following parameters:

- Disease Incidence(%) = (Number of plant diseased x 100) / Number of plant inspected.
- Leaf spot incidence(%) = (Numbers of infected leaves x100) / Numbers of leaves inspected
- Disease severity(%) = (Area of tissues infected x 100) / Area of tissues inspected
- % LAD (Leaf area diseased) = (Area of leaf tissues infected × 100) / Area of leaf inspected
- Number of tuber/plant
- Tuber weight
- Yield (ton/ha)

3.17 Laboratory experiment

3.17.1 Collection of diseased samples

Diseased samples of potato (*Solanum tuberosum*) and potato leaves were collected from the Farm field of Sher-e-Bangla Agricultural University, Dhaka- 1207. Collected samples were put in polyethylene bags immediate after collection to protect from drying.

Plate 1. Plants Infected by *Alternaria solani* in the Field

Plate 2. Collected diseased leaf samples from the field

3.17.2 Isolation and Identification of the Pathogen

Diseased leaf samples were brought to the laboratory and washed thoroughly to clean different parts and cut into small pieces by keeping infected and healthy tissues and sterilized by dipping in 0.1 % NaOCl solution for 30 second and rinsed three times with sterile water. Leaf samples were placed on moist blotter paper on petridis which was incubated at 20±2^{0}C for 2 days in 12 hours with alternate light and darkness. For sporulation, the inocula from the incubated infected leaf was placed on potato slices and incubated for 20 days at 20±2^{0}C in the normal lab condition. After incubation when the whitish mycelium was grown and then a bit of mycelia was taken with the help of sterilized needle and transferred on sterile solid PDA plates and kept in an incubator at 25±1^{0}C for growth. The fungus was observed on the potato slices. Temporary slides were prepared for identification under compound microscope. The incubated potato slices were also observed under stereoscopic microscope. The *Alternaria solani* was identified following the key out lined by Alexopoulos (1996), Simmons (2007); Chowdappa and Lakshmi (2013).

Plate 3. Placing of infected potato leaves on moist blotting paper in a petridish after surface sterilization

3.18 Calculation of disease incidence and disease severity

Disease incidence is the number of proportion of the plant units diseased in relation to the total number of units examined. Plant units mean the leaves, stems, fruits, tubers, rhizomes, and bulbs etc. that show any symptoms. In some cases, the plant unit represents the plant as a whole. Disease severity is the proportion of amount of plant tissues infected in relation to the total amount of tissue examined.

Percent disease incidence and severity was calculated by using following formula:

$$\textbf{Disease Incidence (\%)} = \frac{\text{Plant units diseased} \times 100}{\text{Plant units examined}}$$

$$\textbf{Disease severity (\%)} = \frac{\text{Area of tissues infected} \times 100}{\text{Area of tissues inspected}}$$

3.19 Statistical Analysis

The recorded data were compiled, tabulated and subject to statistical analysis. Analysis of variance was done with the help of computer package program MSTAT-C. The mean differences were adjudged by Ducan's New Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

CHAPTER IV

RESULT

Early blight of potato caused by *Alternaria solani* is a disease of economic importance. The effects of different fungicides on the disease incidence, disease severity and yield of potato affected by *Alternaria solani* responsible for early blight of potato was presented in this chapter. The incidence was recorded as percentage of the infected plants and leaves in each treatment and the severity of the diseases were noted as the percentage of leaf area infected by the pathogen and the percentage of yield increased by the application of fungicides are discussed in this chapter.

4.1 Symptoms of early blight of potato caused by *Alternaria solani*

Spots appeared as small, dark, dry, papery flecks, which grown to become brown-black, circular-to-oval areas. The spots were often bordered by veins that made them angular. The spots usually had a target appearance, caused by concentric rings of raised and depressed dead tissues.

Plate 4. Symptoms of early blight of potato showing leaf spot with concentric ring

Plate 5. Symptoms of early blight of potato showing blighting of leaves

A yellowish or greenish-yellow ring was seen bordering the growing spots. As the spots become very large, they caused infection in the entire leaf to become yellow and die.

This was especially true on the lower leaves, where spots usually occurred first and was abundant. Dark brown to black spots was occurred on stems.

Tubers were affected, as well, with dark, circular to irregular spots. The edges of the spots were often raised and purple to dark metallic gray in color. When the tuber was sliced open, the flesh under the spots was usually brown, dry, and leathery or corky in texture.

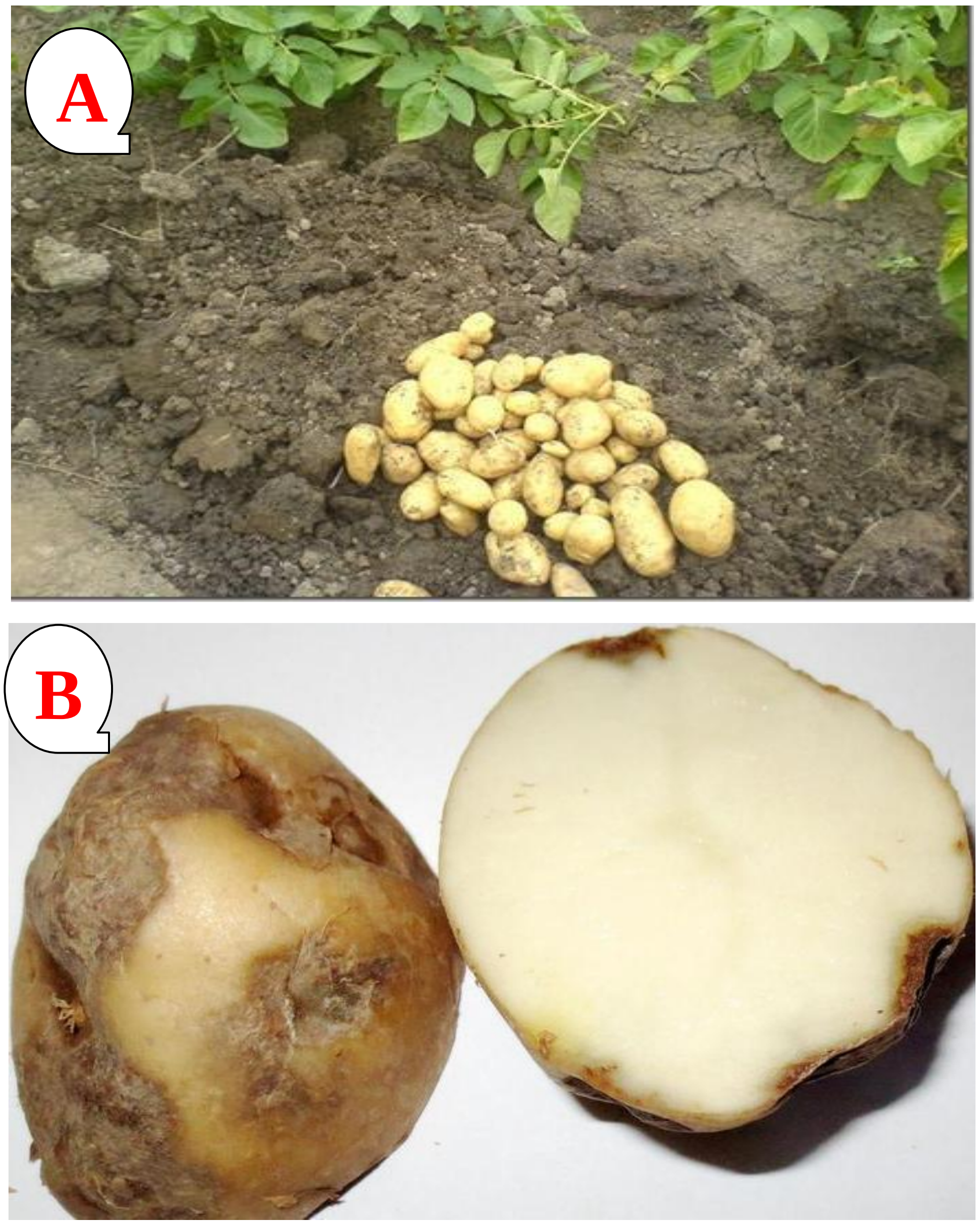

Plate 6. Symptoms showing in the tuber; (A) Harvested Potato; (B) Infected Potato

4.2 Identification of causal organism of early blight of potato

The several temporary and semi-permanent slides were prepared to observe the microorganisms under compound microscope. Morphological observations of the fungus were recorded by adopting slide culture. The fungus produced profuse mycelial growth on PDA medium. Initially, the mycelium was hyaline that turned to grey-brownish. Fungus colonies were dark to grey-black and conidiophores arising singly or in small groups produced spores in chains. Muriform conidia were large with longitudinal and transverse septa and a short beak typical for *Alternaria solani* observed under microscope. The organism grown on moist blotter paper and potato slices were observed directly under stereo microscope and under compound microscope by preparing semi-permanent slide and identified as *Alternaria solani* following the key outline stated by Alexopoulos (1961), Agrios (2005) and Rohilla and Salar (2012).

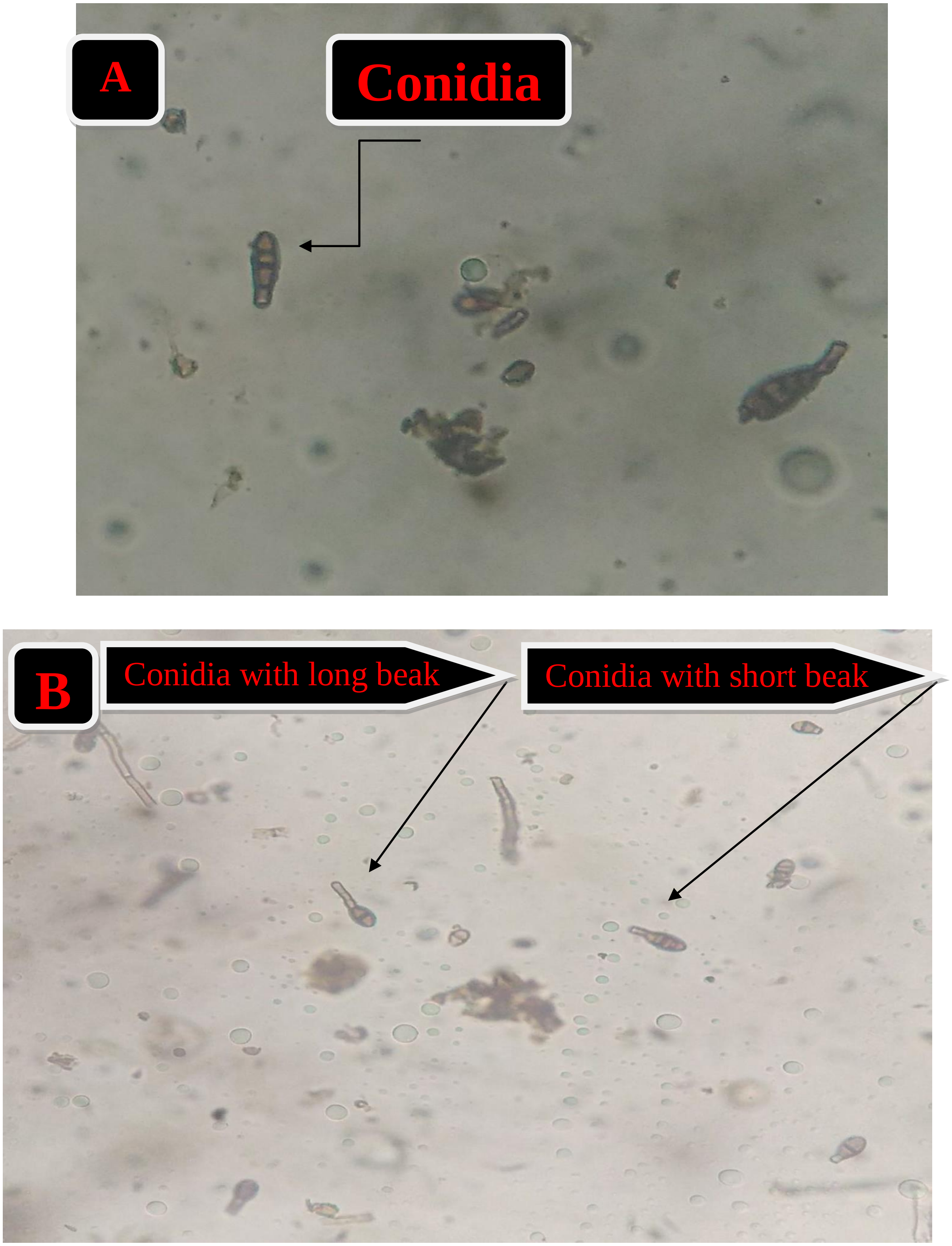

Plate 6. Conidia of *Alternaria solani* under compound microscope (10X)

4.3 Effects of different fungicidal treatments on plant infection due to early blight disease of potato caused by *Alternaria solani*

The effect of selected fungicides against plant infection of early blight disease of potato caused by *Alternaria solani* is presented in Table 1. Plant infection varied significantly among the treatments. The applied treatments showed promising performance in reducing the disease incidence (plant infection) at different days after planting (DAP). The experiment was conducted under natural epiphytic condition. Thus, spraying was started from 60 DAP after disease occurred naturally. Fungicides were applied at regular intervals of 60, 70 and 80 days after planting of potato tubers. At 60 DAP, the effect of different treatments found to be differed significantly in respect of plant infection. Among the fungicides, the lowest plant infection (17.65%) was recorded in case of Bicozeb 80WP followed by Rovral 50WP (18.70%), Sazid 70 WP (20.42%), Win 77WP (21.54%), Pipertax 50WP (22.05%) and Tilt 25 EC (23.20%). The highest plant infection (83.75%) was recorded in control plot (Table 1).

At 70 DAP, the trend of results of different treatments against plant infection found to be more or less similar to the results of 60 DAP. The highest plant infection (85.52%) was recorded in control and the lowest plant infection (14.32%) was recorded in case of Bicozeb 80WP application followed by Rovral 50WP (14.75%), Sazid 70 WP (18.32%), Win 77WP (20.05%), Tilt 25 EC (21.45%) and Pipertax 50WP (21.95%).

Again, at 80 DAP, the lowest plant infection was also recorded in Bicozeb 80WP (13.05%) followed by Rovral 50WP (14.55%), Sazid 70 WP (16.13%), Win 77WP (17.95%), Pipertax 50WP (18.28%) and Tilt 25 EC (18.87%).

The reduction of plant infection owing to the application of different fungicides over control were calculated based on the plant infection recorded in 80 DAP (Figure 1). The highest disease incidence reduction was observed in Bicozeb 80 WP (86.95%), which was statistically identical with Rovral 50WP (85.45%) and Sazid 70 WP (83.87%).

Table 1: Efficacy of different fungicides on plant infection due to early blight of potato at different DAP under field condition

Disease Incidence (% Plant Infection)				**%Reduction of Plants Infection at 80 DAP**
Treatments	**60 DAP**	**70 DAP**	**80 DAP**	
Sazid 70WP	22.42 bc	18.32 c	16.13 bc	83.87
Tilt 25EC	25.20 b	21.45 b	18.87 b	81.13
Win 77WP	23.54 b	20.05 bc	17.95 b	82.05
Rovral 50WP	20.70 c	14.75 d	14.55 c	85.45
Pipertax 50WP	22.05 bc	21.95 b	18.28 b	81.72
Bicozeb 80WP	19.65 c	14.32 d	13.05 c	86.95
Control	73.75 a	78.52 a	82.56 a	-
LSD $_{(0.05)}$	3.430	3.204	4.063	-
CV (%)	4.13	3.83	3.67	-
Significance	**	**	**	-

Figures with similar letters of a column do not differ significantly.

* DAP - Days after planting

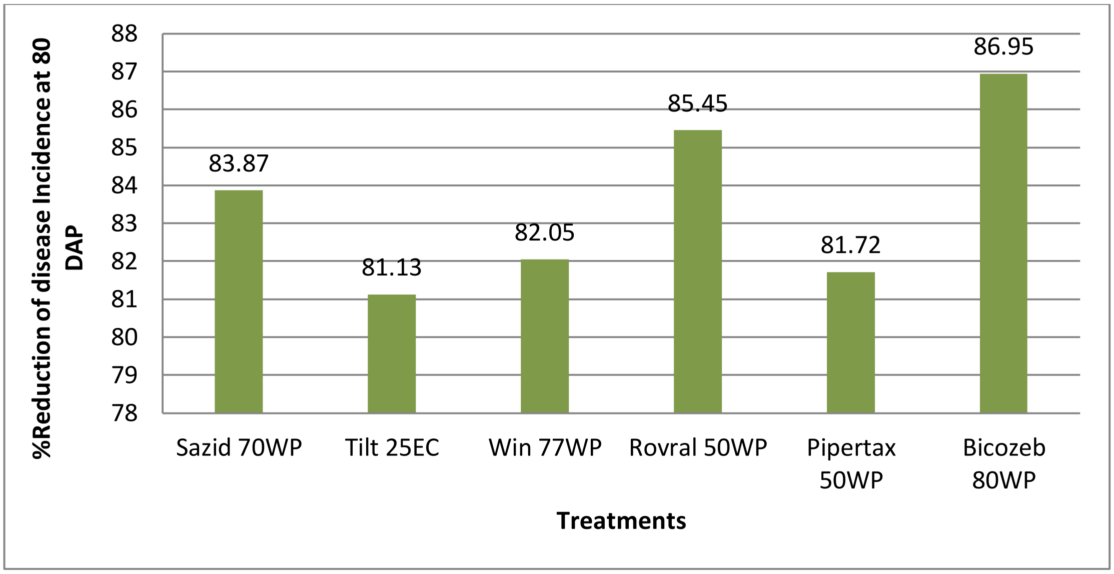

Figure 1: Reduction of % disease incidence over control due to application of fungicides at 80 DAP

4.4 Effects of different treatments on leaf infection of early blight disease of potato caused by *Alternaria solani*

The effects of fungicides on leaf infection were found more or less similar with that of plant infection (Table 1). The performance of different fungicides against disease was recorded at different days after planting found to be varied significantly.

At 60 DAP, among the fungicides, the lowest leaf infection (17.67%) was recorded in case of Bicozeb 80WP followed by Rovral 50WP (18.20%), Sazid 70 WP (20.56%), Win 77WP (21.34%), Pipertax 50WP (22.55%) and Tilt 25 EC (23.07%). The highest leaf infection (82.73%) was recorded in control plot (Table 2).

At 70 DAP, the trend of results of different treatments against leaf infection found to be more or less similar to the results of 60 DAP (Table 2). The highest leaf infection (85.73%) was recorded in control and the lowest leaf infection (14.46%) was recorded in case of Bicozeb 80WP followed by Rovral 50WP (15.74%), Sazid 70 WP (18.56%), Win 77WP (20.24%), Pipertax 50WP (21.87%) and Tilt 25 EC (22.35%).

At 80 DAP, the treatments applied showed similar trend of results in reducing the leaf infection. The lowest leaf infection was also recorded in case of Bicozeb 80WP (13.17%) followed by Rovral 50WP (15.28%), Sazid 70 WP (16.22%), Win 77WP (17.93%), Pipertax 50WP (18.23%) and Tilt 25 EC (18.76%).

Table 2: Efficacy of different fungicides on leaf infection due to early blight of potato at different DAP under field condition

Disease Incidence (% Leaf Infection)				%Reduction of Plants Infection at 80 DAP
Treatments	**60 DAP**	**70 DAP**	**80 DAP**	
Sazid 70 WP	20.56 c	16.56 bc	14.22 bc	85.78
Tilt 25EC	23.07 b	20.35 b	16.76 b	83.24
Win 77WP	21.34 bc	20.24 b	15.93 b	84.07
Rovral 50WP	18.20 d	13.74 c	13.28 c	86.72
Pipertax 50WP	22.55 bc	19.87 bc	16.23 b	83.77
Bicozeb 80WP	17.67 d	12.46 d	11.17 d	88.83
Control	66.73 a	73.73 a	81.59 a	-
LSD $_{(0.05)}$	2.129	2.566	3.374	-
CV (%)	3.97	4.42	3.76	-
Significance	**	**	**	-

Figures with similar letters of a column do not differ significantly.

* DAP - Days after planting

The reduction of leaf infection over control due to the application of different fungicides were calculated at 80 DAP (Figure 2). The highest reduction of leaf infection was estimated by Bicozeb 80 WP (86.83%) which was statistically similar with Rovral 50WP (84.72%) and Sazid 70 WP (83.78%).

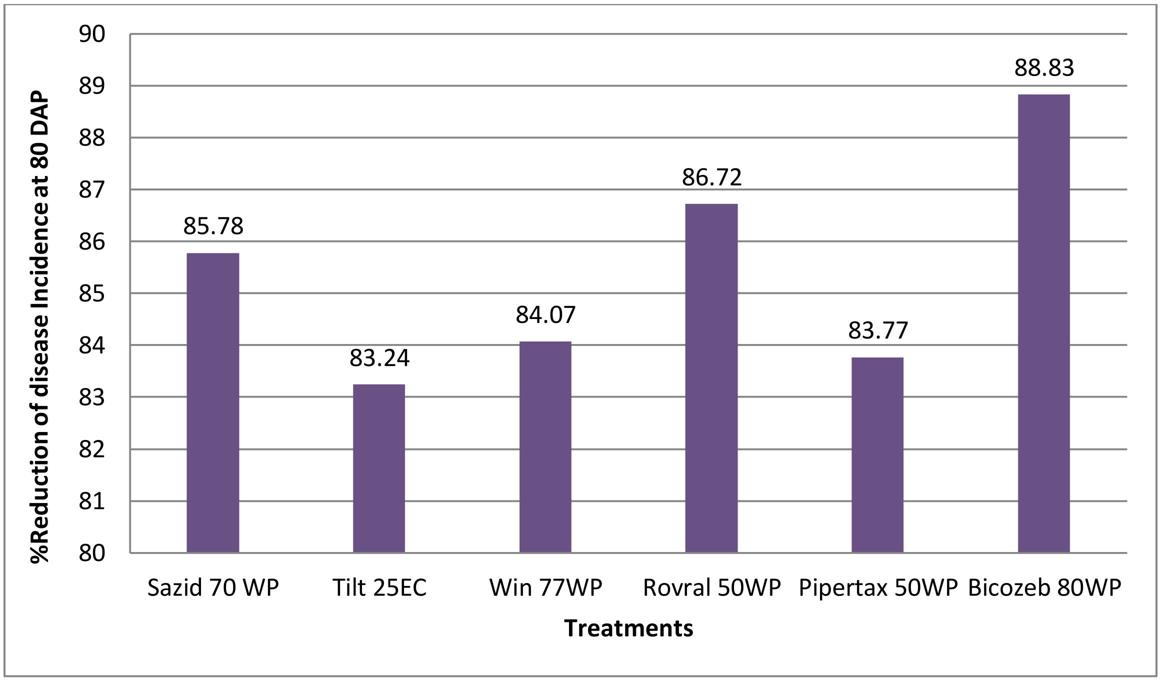

Figure 2: Reduction of % leaf incidence over control due to application of fungicides at 80 DAP

4.5 Effects of different treatments on disease severity of early blight disease of potato caused by *Alternaria solani*

The treatments explored in the experiment showed different performance in reducing the disease severity of early blight disease of potato. The performances of different treatments was recorded at different days after planting (DAP) viz. 60 DAP, 70 DAP and 80 DAP.

At 60 DAP, among the fungicides, the lowest disease severity (5.55) was recorded in case of Bicozeb 80WP followed by Rovral 50WP (6.23), Sazid 70 WP (6.57), Pipertax 50WP (8.55), Win 77WP (8.07), and Tilt 25 EC (8.52). The disease severity (46.57) was recorded in control plot (Table 3).

At 70 DAP, the trend of results of different treatments was more or less similar to the results of 60 DAP (Table 3). The highest disease severity (58.63) was recorded in control and the lowest disease severity (2.82) was recorded in case of Bicozeb 80WP followed by Rovral 50WP (3.07), Sazid 70 WP (4.32), Win 77WP (3.93), Pipertax 50WP (3.23) and Tilt 25 EC (5.07).

At 80 DAP, the lowest disease severity was also recorded in case of Bicozeb 80WP (1.30) followed by Rovral 50WP (2.08), Sazid 70 WP (3.80), Win 77WP (3.76), Pipertax 50WP (3.23) and Tilt 25 EC (3.93). The highest disease severity (62.92) was recorded in control plot (Table 3).

Table 3: Efficacy of different fungicides on disease severity of early blight disease of potato at different DAP under field condition

Treatments	Disease Severity 60 DAP	70 DAP	80 DAP	%Reduction of disease severity at 80 DAP
Sazid 70 WP	6.57 bc	4.32 bc	3.80 bc	93.95
Tilt 25EC	8.52 b	5.07 b	3.76 bc	94.02
Win 77WP	8.07 b	5.05 b	3.93 bc	93.75
Rovral 50WP	6.23 c	3.07 c	2.08 c	96.69
Pipertax 50WP	8.55 bc	5.53 b	3.23 b	94.86
Bicozeb 80WP	5.55 c	2.82 c	1.30 c	97.93
Control	46.57 a	58.63 a	62.92 a	-
LSD $_{(0.05)}$	3.324	1.984	2.720	-
CV (%)	3.95	3.83	2.87	-
Significance	**	**	**	-

Figures with similar letters of a column do not differ significantly.

* DAP - Days after planting

As per the last recording data at 80 DAP, the Bicozeb 80 WP showed the highest performance (97.93%) in reduction of disease severity over control (Figure 3). The second highest reduction of disease severity was recorded in of Rovral 50WP (96.69%).

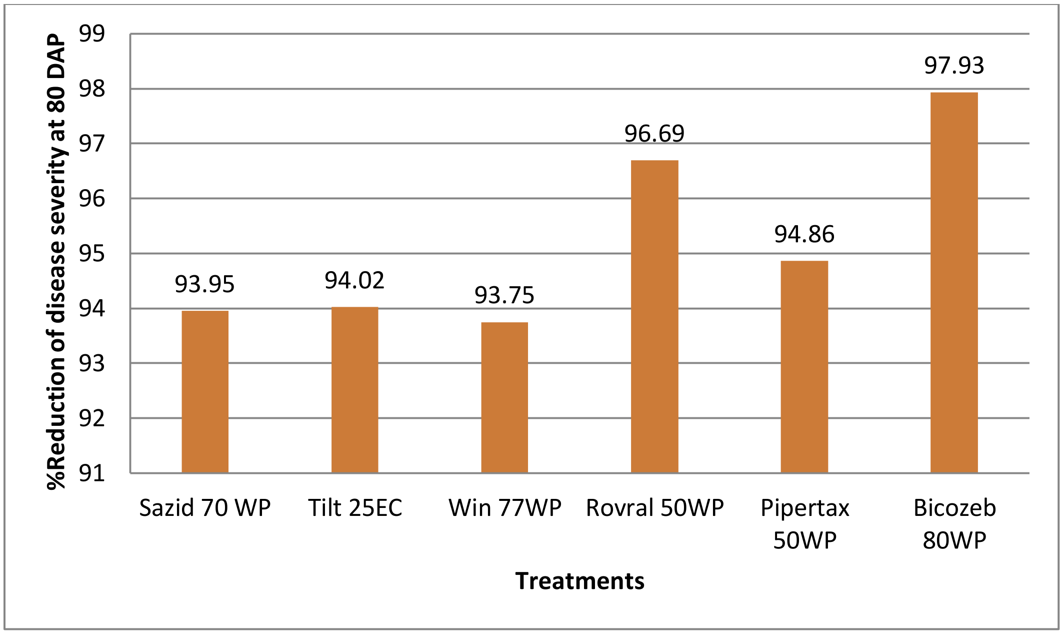

Figure 3: Reduction disease severity over control due to application of fungicides at 80 DAP

4.6 Effects of different treatments on yield of potato against early blight disease of potato caused by *Alternaria solani*

The highest tuber yield (27.78 t ha^{-1}) of potato was observed from the plot treated by Bicozeb 80WP, whereas significantly similar yield (26.58 t ha^{-1}) was harvested from the plot applied by Rovral 50WP. The yield of potato 25.11 t ha^{-1}, 22.77 t ha^{-}1, 24.67 t ha^{-1} and 23.86 tha^{-1} were found from the plots treated with Sazid 70 WP, Tilt 25 EC, Win 77 WP and Pipertax 50 WP, respectively (Table 4). However, the tuber yield (12.56 t ha^{-1}) of potato was recorded from the control plot.

Table 4: Efficacy of different fungicides on yield of potato against early blight disease under field condition

Treatments	Yield (ton/ha)	Increase of yield over control (%)
Sazid 70 WP	25.11 bc	99.92
Tilt 25EC	22.77 c	81.29
Win 77WP	24.67 bc	96.46
Rovral 50WP	26.58 ab	111.63
Pipertax 50WP	23.86 c	89.97
Bicozeb 80WP	27.78 a	121.18
Control	12.56 d	-
CV (%)	6.56	-
LSD $_{(0.05)}$	2.502	-
Significance	**	-

Figures with similar letters of a column do not differ significantly.

* DAP - Days after planting

The yield of potato tuber showed significantly better performance by spraying of chemical fungicides than the control plot. The chemical fungicides increased the considerable yield than the control. The highest increase of yield was 121.18% when the field was applied by Bicozeb 80 WP. The nearest yield was (111.63%) harvested from the application of Rovral 50 WP. The tuber yield 99.92%, 81.29%, 96.42% and 89.97% were increased by the application of Sazid 70 WP, Tilt 25 EC, Win 77 WP and Pipertax 50 WP, respectively (Figure 4).

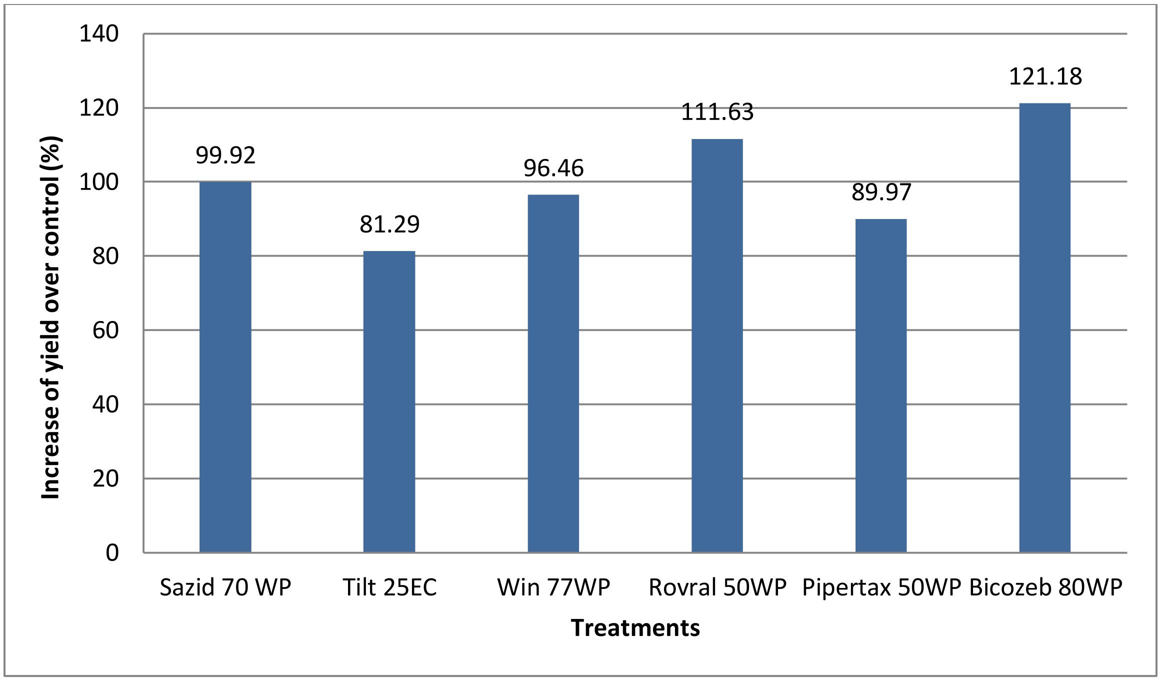

Figure 4: Efficacy of fungicides in increasing yield (t ha^{-1}) of potato over control against early blight disease of potato

DISCUSSION

The potato cultivation is hampered in every year by early blight disease caused by *Alternaria solani* resulting lower yield in our country. So the present study was undertaken for the management of early blight of potato in field condition by using six different fungicides as foliar spray. Altogether there were seven treatments viz. Bicozeb 80WP @ 0.2%, Rovral 50WP @ 0.1%, Win 77WP @ 0.1%, Sazid 70 WP @ 0.2%, Pipertax 50WP @ 0.2% and Tilt 25 EC @ 0.2% and a control. The experiment was conducted under natural epiphytic condition following randomized complete block design with three replications.

Alternaria solani was isolated from infected leaves of potato having typical symptoms (target like spot) of early blight of potato. Ellis and Gibson (1975) reported that first symptoms of early blight are small, dark, necrotic lesions that usually appear on the older leaves and spread upward as the plant become older. As lesions enlarge, they commonly have concentric rings with a target-like appearance, and they are often surrounded by a yellowing zone. Muriform conidia of *Alternaria solani* have solitary, golden brown and beaked nine to eleven transverse and a few or no longitudinal septa Waals *et al.* (2001).

The highest reduction percentage of plant infection (86.95%) and leaf infection (86.83%) were recorded from the plots applied by Bicozeb 80 WP (Mancozeb). Other treatments also gave better results compared to control. This results partially supported by Prasad and Naik (2003). They tested the efficacy of non-systemic fungicides (Iprodione, mancozeb, copper oxychloride and SAAF), systemic fungicides (thiphante methyl, triademefon, benomyl and carbendazim) in controlling early blight of tomato and observed that Mancozeb gave the highest cost benefit ratio of 1: 1.14 in addition to reducing the disease incidence. The application of foliar fungicides was the most effective method to control early blight disease of potato in the field (Wharton & Kirk, 2012; Horsefield *et al.*, 2010). Several studies have reported that leaves were more susceptible to disease in control and compared to fungicides treatments (Green and Bailey, 2000; Hong and Fitt, 1995; Aveling *et al.*, 1994).

In case of reduction of disease severity, the highest performance (86.70%) was recorded from the plots applied by Bicozeb 80 WP (Mancozeb), whereas maximum PDI was calculated from the control (86.92%). Other treatments also gave better results compared to control. This results partially supported by Mane *et al.* (2014). They conducted an experiment to evaluate the effect of bio agents (*Trichoderma harzianum* and *Pseudomonas fluorescens*) and fungicides (mancozeb) against early blight of potato caused by *Alternaria solani* (Ell. and Mart.). Observation for percent disease intensity was recorded at 60 and 80 days after sowing. Lowest disease intensity was recorded in mancozeb (15.07% and 18.40%, respectively) as compared to control which recorded highest disease intensity (20.91% and 33.80%, respectively). Mancozeb not only reduced disease intensity but also recorded highest yield (253.00 q/ha) as compared to control which recorded 157.83 q/ha.

The yield of potato tuber was also significantly increased over control. Application of fungicides control disease that helps to increase yield of tuber. The highest tuber yield (27.78 t ha^{-1}) of potato was observed from the plot treated by Bicozeb 80WP, whereas the tuber yield (12.56 t ha^{-1})

of potato was observed from the control plot. Other treatments also gave better results compared to control. The highest increase of the percentage of yield was 121.18% when the field was applied by Bicozeb 80 WP in compared to control. This results partially supported by Sinha and Prasad (1991). They tested seven fungicides in the field against *Alternaria solani* infecting tomato over three seasons and reported that Mancozeb @ 0.2% was the best and cost effective treatment with the highest yield. Ali *et al* (2018) were conducted an experiment where eight fungicides namely Pipertax 50 WP (Copper Oxychloride), Mancothane 80 WP (Mancozeb), Meena 80 WP (Mancozeb), Sazid 70WP (Mancozeb + Metalaxyal 7%), Media 80 WP (Mancozeb), Win 77 WP (Copper Hydroxide), Bicozeb 80 WP (Mancozeb) and Rovral 50 WP (Iprodion) were tested for their effectiveness against early blight (*Alternaria solani*) of tomato (*Lycopersicon esculentum*). All the fungicides significantly reduced disease severity and increased fruit yield and yield components compared to control. Among the fungicides tested the highest disease reduction with maximum fruit yield and yield components were obtained with Bicozeb, which was similar to Rovral as a standard check. Reduction of disease severity and increase of fruit yield in different farms by Bicozeb ranged 58-70% and 27-49% respectively over control. However, MacDonald *et al.* (2007) reported effectiveness of fungicides like Azoxystrobin and Pyraclostrobin in suppressing early blight of potato caused by *Alternaria solani* and improving potato tuber yield over control.

CHAPTER V

SUMMARY AND CONCLUSION

Early blight of potato is one of the important causes of lower yield of potato in many countries. Management of early blight of potato caused by *Alternaria solani* is required to maintain the quality and quantity of potato tuber production. Different agronomic approaches led to rely on chemical fungicides. Increased usage of similar fungicides had led to the increase in overall expenditure of crop production and may cause emergence of new virulence races of fungi showing resistant to fungicides.

The research plan included the identification and isolation of the causal organism for confirmation of disease and for selection of fungicides treatments. The study focused on the efficacy of six chemical fungicides in controlling early blight disease of potato and evaluation their impact on the yield of potato.

In this study a field experiment was conducted in the field of Central Farm, SAU and laboratory experiment was carried out in Plant Disease Clinic of Department of Plant Pathology, Sher-e-bangla Agricultural University, Dhaka-1207, during the period of 1st November, 2017 to 1st December, 2018. Six different fungicides named as Bicozeb 80WP, Rovral 50WP, Win 77WP, Sazid 70 WP, Pipertax 50WP and Tilt 25 EC were tested against early blight disease of potato caused by *Alternaria solani*.

The primary damage of early blight is premature defoliation of the plant. Due to disease, photosynthesis rates gradually decreased and respiration rates increased in early blight infected potato plants. In the present investigation the highest reduction of plant infection (86.95%) was recorded by the application of fungicides Bicozeb 80 WP. The nearest reduction of plant infection was found in Rovral 50WP (85.45%), Sazid 70 WP (83.87%), Win 77WP (82.05%), Pipertax 50WP (81.72%) and Tilt 25 EC (81.13%).

The highest reduction percentage of leaf infection was found 86.83% when the field was sprayed by Bicozeb 80 WP. However, nearest leaf infection reduction was recorded in Rovral 50WP (84.72%), Sazid 70 WP (83.78%), Win 77WP (82.07%), Pipertax 50WP (81.77%) and Tilt 25 EC (81.24%).

At 80 days after planting, the PDI values were observed and found that the maximum PDI was calculated from the control (86.92%). At 80 DAP, the Bicozeb 80 WP showed the highest performance (86.70%) in reduction of disease severity. The second highest reduction of disease severity was recorded in case of Rovral 50WP (85.92%) followed by Sazid 70 WP (84.72%), Win 77WP (82.07%), Pipertax 50WP (81.77%) and Tilt 25 EC (81.24%).

However, the chemical fungicides were also increased the considerable yield of potato tuber than the control. The highest tuber yield (27.78 t ha^{-1}) of potato was observed from the plot treated by Bicozeb 80WP, that was statistically similar with the yield (26.58 t ha^{-1}) harvested from the plot applied by Rovral 50WP. The yield of potato was 25.11 t ha^{-1}, 22.77

t ha^{-1}, 24.67 t ha^{-1} and 23.86 tha^{-1} in the plots treated with Sazid 70 WP, Tilt 25 EC, Win 77 WP and Pipertax 50 WP, respectively. The lowest tuber yield (12.56 t ha^{-1}) of potato was observed from the control plot.

Similarly, the highest increase of yield was 121.18% when the field was applied by Bicozeb 80 WP. The nearest increase of yield was (111.63%) harvested from the application of Rovral 50 WP. The tuber yield 99.92%, 81.29%, 96.42% and 89.97% were increased by the application of Sazid 70 WP, Tilt 25 EC, Win 77 WP and Pipertax 50 WP, respectively.

On the basis of the present findings, the potato growers may be suggested to use Mancozeb group fungicide to control early blight disease of potato in field conditions.

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