MANAGEMENT OF EARLY BLIGHT OF POTATO THROUGH SELECTED BOTANICALS & CHEMICAL FUNGICIDES.

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CERTIFICATE

This is to certify that the thesis entitled, **" MANAGEMENT OF EARLY BLIGHT OF POTATO THROUGH SELECTED BOTANICALS & 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 **MD. ZAYEDUL KABIR ZAHID** bearing **Registration No. 10-04129** 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.

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ABSTRACT

Early blight is one of the most common and devastating disease of potato which is caused by the fungus, *Alternaria solani*. The antifungal activity of three plants extracts namely *Azadirachta indica* (Neem), *Carica papaya* (Papaya), *Calendula officinalis* (Marigold) and Four Chemical fungicides namely Topgan 50 WP(Copper oxychloride), Dithane M 45(Mancozeb), Bavistin 50 WP(Carbendazim) and Rovral 50 WP(Ipridione) as a treated check, was tested for the management of *Alternaria solan*i in field condition. In the present investigation the maximum reduction of plant infection(45.74,43.37) and leaf infection (71.20, 73.57%) were observed from the Papaya and Marigold leaf extracts, respectively.The fungicides Bavistin and Topgan showed reduction of plant infection by 85.70% and 83.87%,respectively.Whereas leaf infection were reduced by 85.33% and 83.78% in case of Dithane M 45 and Topgan, respectively. In case of PDI, the Papaya leaf extracts (59.03%) and Rovral (85.70%) showed the maximum reduction of disease severity at 80 days after planting. The maximum yield increased was observed with Rovral (120.94%), Dithane M 45 (105.43%) and Papaya leaf extracts (80.92%) against the pathogen. All treatments significantly reduced the early blight disease incidence as well as increased the yield of potato compared to the infected control under field conditions.The present study revealed that Papaya leaf etracts and the chemical fungicides Rovral 50 WP and Dithane M 45 proved to be effective for the management of early blight of potato caused by *Alternaria solani*.

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CHAPTER I
INTRODUCTION

The potato (*Solanum tuberosum*) is one of the most important vegetable crops in the world. It is belonging to the family solanaceae and is an important starchy food crop in both sub-tropical and temperate regions. Even in tropical regions it is widely grown during winter season. Potato is a native of South America (Hijmans and Spooner, 2001). Potato (*Solanum tuberosum L.*) is the fourth most important world crop, next to rice, wheat, and maize (Spooner and Bamberg, 1994). Potato is one of the most important crops in the world and is planted in 18.2 million ha and a total annual yield reached 314.1 million ton (FAO, 2010).India is the second largest potato producer after China which produced 45,000,000 tons in 2012 (FAOSTAT, 2014). 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 (Kour *et al.*, 2004). The potato chips and wafers are popular processed food items that give considerable value addition to potato. It is a rich food in carbohydrate, protein, vitamins C, B1, B6, folic acid, potassium, magnesium, zinc and copper.

Potato plants are subjected to attack by numerous diseases wherever the crop is grown. Among them, early blight of potato caused by *Alternaria solani* (Ellis and Martin) Jones and Grout is of major cause of concern in potato production at present. Early blight occurs in most potato growing regions world-wide (Shtienberg *et al.*,1990; Vander walls *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 vary by location, cropping season, cultivar, and the stage of potato maturity. Early blight causes 20-50% yield loses, it produces small, darkened lesions on the plants that spread into growing black spots of dead tissue. The disease often occurs initially on older, less productive foliage, followed by a gradual upward progression within the canopy, resulting in premature leaf senescence (Franc and Christ, 2001; Rotem, 1994). If the inoculum load is high during favourable environmental conditions, early blight may become severe enough to cause significant reductions in yield (Kapsa and Osowski, 2003;Patel et al., 2004; Shtienberg et al., 1996; Teng and Bissonnette, 1985; Van der Waals et al. 2001). The pathogen *Alternaria solani* over winters 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, crop rotation, tillage, removal and burning of infected plant debris, and eradication of weed hosts reducing the inocula level for subsequent plantings, using resistant cultivars and foliar fungicides are considered as substantial options.

The most common and effective method for the control of early blight is the application of foliar fungicides, but the fungicides treatment pollute environment, effect health vulnerability in humans and when these harmful chemicals enter into the food chain become hazardous to all living entities. Botanical derivatives are environmentally safe and may be used as an alternative to commercial fungicides for controlling pathogenic fungi. The

present study is designed to evaluate the antifungal activity of plant extracts viz. chemical fungicides as well as *Azadirachta indica* (Neem), *Eucalyptus chamadulonsis* (Eucalyptus), *Ocimum tenuiflorum* (Tulsi), *Nerium oleander* (Kaner), and *Calotropis procera* (Madar) against destructive plant pathogenic fungus *Alternaria solani* causing early blight of potato.

Under severe conditions, frequent applications of protectants are often required to reduce foliar damage and subsequent tuber yield loss.

Under the above facts, the present investigation was undertaken to achieve the following objectives-

i. To isolate and identify *Alternaria solani* causing early blight of potato.

ii. To evaluate the efficacy of selected plant extracts and chemical fungicides in controlling the early blight disease of potato in field conditions.

CHAPTER II

REVIEW OF LITERATURE

Rahmatzai *et al.* (2017) investigated to evaluate different botanical oils on the radial growth of *A. solani* and reduction of early blight incidence and severity in the field condition. Oils from various plant sources such as Jojoba (*Simmondsia chinensis*), Ginger *(Zingiber officinale* Roscoe), Garlic (*Allium sativum*), Clove (*Syzygium aromaticum*), Sesame (*Sesamum indicum*), Eucalyptus (*Eucalyptusglabulus*), Cinnamon (*Cinnamon zylanicum*), Castor (*Ricinu communis),* lemon (*Citrus limon*) and mustard (*Brassica nigra*) were tested at concentration of 0.1%, 1% and 3% to determine their effects on the mycelia growth of *A. solani*. The 3% dosage of oil of ginger, lemon and castor inhibited the maximum radial growth of *A. solani* by 29.6%, 29% and 27%, respectively. Meanwhile, the 1% concentration of lemon oil was also recorded the maximum growth inhibition of the pathogen by 27%. Moderate to lowest inhibition of the fungal growth was observed with cinnamon oil (21.6%) followed by oil of mustard (21.6%), jojoba (21%), sesame (21%) and garlic 20%. In *vivo*, at 1% concentration, the least disease incidence of 29.7% and 29.8% were achieved on plants treated with oil of garlic and lemon, respectively. Severity of early blight was significantly reduced by 34.9% of clove oil followed by 34.3% and 34.2% of eucalyptus and garlic, respectively. Fruit yield of tomato was totally increased with all oil treatment, clove oil significantly improved plant height and increased fruit yield by 58.3Kg/plot.

Navarrete *et al.* (2017) evaluated the yield loss due to early blight of potato (*Alternaria solnai*). They surveyed 11 farmers' fields in Ecuador in 2010 to determine incidence and severity of pathogens and pests affecting foliage and seed tubers, and to determine the influence of altitude and seed sources over seed health quality (pathogen and pest diversity in/on the seed tuber). Additionally, a field experiment was planted in CIP-Quito using assessed seed tubers collected from surveyed farmers' fields, during 2010 and 2011, to determine yield responses to seed health quality. Results showed that foliage was mainly affected by late blight and flea beetle damages while seed tubers were predominantly affected by black scurf, weevil damages, potato virus S and potato virus X. Seed health quality was similar among farmers' seed sources, and detected that increase in altitude decreased seed-borne virus diversity. Only seed-borne pathogens and presence of mechanical damages were found to explain yield variation. Seed borne pathogens affecting yield variation were black scurf on seed tubers, potato virus S, and potato yellow vein virus.

Ganie *et al.* (2016) studied the perpetuation of *Alternaria solani*, causing early blight of potato in Kashmir valley during 2009 and 2010. The perpetuation of the fungus *A. solani* was studied on diseased leaves by placing the leaves on ground surface and at 20 cm depth, as well as on diseased potatoes kept in ambient store. The pathogen perpetuated as mycelium and conidia throughout winter on diseased leaves left on the ground surface and on diseased potatoes kept in ambient store. The number of spores cm^{-2} leaf area and the viability of spores decreased with increase in depth of placement in soil. Maximum spores production on over wintered

leaves was observed during first fortnight of June during 2009 and 2010, with maximum number of 294 and 323 spores, respectively. However, by the first fortnight of July, the number gradually declined to 160 and 220 spores, respectively. The highest spore viability of 44.3 and 49.3 per cent in leaves on ground surface was recorded in the first fortnight of June, 2009 and 2010, respectively. In potatoes kept in ambient store the average number of spores increased upto first fortnight of June, both in 2009 and 2010, with a maximum number of 430 and 508 spores, respectively. The number gradually declined to 216 and 263 spores, respectively, till last observation recorded in the second fortnight of July.

Ariafar and Zacharia (2016)performed a research to evaluate the efficacy of five plants extracts namely *Azadirachta indica* (Neem*), Eucalyptus chamadulonsis* (Eucalyptus), *Ocimum tenuiflorum* (Tulsi), *Nerium oleander* (Kaner), and *Calotropis procera* (Madar) at 10 % concentration and Carbendazim 0.1% concentration, was tested for management of *Alternaria solani in vitro* and *in vivo*. In the present investigation the highest inhibition of mycelial growth of *Alternaria solani* was achieved by fresh aqueous extract of *Eucalyptus chamadulonsis,Ocimum tenuiflorum and Azadirachta indica* caused the highest reduction of mycelial growth of *A. solani*(57.35, 50.0 and 44.12%, respectively), while *Nerium oleander,* and *Calotropis procera* caused the lowest inhibition of mycelial growth of the pathogen as compared to treated check and untreated check. The highest reduction of disease severity was achieved by applying extracts of *Eucalyptus chamadulonsis* and *Ocimum tenuiflorum*, at 10% concentration (35.80%, 45.68%)as compare to treated check carbendazim at 0.1% concentration (25.93%) and treated check T0 (95.06%). All treatments significantly

reduced the early blight disease severity as well as increased the plant height number of branches and yield of potato compared to the infected control under field conditions.

Singh *et al.* (2016) evaluated the botanical extracts and added tothe culture media at two concentration viz. 10 % and 30 % and tested by poisoned food technique. Among the four botanical extract evaluated Neem Seed Kernel Extract was significantly superior over the control and other botanical extract. The Result reveals that Neem Seed Kernel Extract was best botanical extract and found highly inhibiting the mycelia growth of *Alternaria solani* at both the concentration viz. 10% and 30% (50% and 99.33% inhibition respectively). This was followed by Neem Leaf Extract, Madar Leaf Extract and Neem Bark Extract accordingly at both concentrations.

Ambroziak*et al.* (2015) conducted an experiment with the following treatments: 1) biological control − mycorrhizal *Glomus* spp. inoculum was applied to the roots, − tubers were dressed and plants were sprayed with Polyversum three times during the growing season, 2) chemical control – at two-week intervals, plants were sprayed with the following fungicides: Infinito 687.5 SC and Tanos 50 WG, Valbon 72 WG and Tanos 50 WG. In the control treatment, potato plants were not protected against pathogens. During the growing season, the severity of late blight and early blight was evaluated on a nine-point scale. The composition of fungal communities colonising potato stems was analysed. The fungistatic properties of the fungicides used in the field experiment were evaluated in an *in vitro* test. The symptoms of infections caused by *Phytophthora infestans* and

Alternaria spp. were significantly reduced with the treatments on the integrated chemical and biological control were used. The least diverse fungal community was isolated from fungicide-treated plants. In the *in vitro* test, fungicides at all analysed concentrations inhibited the linear mycelial growth of selected pathogens.

Murmu*et al.* (2015) studied the early blight of potato to test the efficacy of four plant extracts (tea, garlic, onion and neem leaf extract) and four bio-control agents (*Trichoderma viride*, *Pseudomonas fluorescence*, *Streptomyces graseoviridis* and *Bacillus substilis*) in controlling early blight of potato under field and in *in vitro* condition. These antifungal compounds were applied 3 times at 7days interval after first appearance of the disease in the field. Among the bio control agents *T. viride*was found highly effective in per cent disease reduction (52.39%) of disease over control treatment. The tuber yield (25.51 t/ ha.) was also highest in this treatment compared to control treatment (19.53 t/ha). This was followed by treatment T2 i.e. *P. fluorescens* where per cent incidence and intensity of disease were (65.00%) and (19.10%) respectively with 38.97% reduction of disease over control with tuber yield 23.65 t/ha. It was followed by *S. graseoviridis* where per cent incidence and intensity of disease were (68.00%) and (22.90%) respectively with 26.30% reduction of disease over control with tuber yield 21.07 t/ha. Among plant extracts, only neem leaf extract exhibited per cent reduction of disease (33.18%) over control treatment in field condition and inhibition of radial growth (59.85%) and spore germi-nation (81.95%) in *in vitro* condition.

Sadana and Didwania (2015) investigated the seven fungicides (mancozeb, captan, thiram, coppersulphate, carbendazim, zineb and copper oxychloride) reduce the disease severity as compared tountreated check. The highest reduction in the disease was achieved by applying mancozeb (1500 ppm) that caused 86.4 percentinhibition of mycelial growth in A1 strain of *Alternaria solani*. Bioefficacy of fifteen plant extracts (*Polyalthia longifolia, Azadirachta indica, Datura stramonium, Ocimum sanctum, Calotropis procera, Crotalaria juncea, Eucalyptus obliqua, Cassia fistula, Agele marmelos, Croton bonplonadium, Pergularia daemia, Cleome viscose, Phyllanthus amarus, Bauhinia purpurea, Euphorbia hirta)* were evaluated under *in vitro* conditions. Among plant extracts evaluated, fresh aqueous extract of *Eucalyptus oblique* (15%) was effective in causing 88 percent inhibition of mycelial growth in A1 strain of *A. solani*. Followed by *Datura stamonium, Azadirachta indica, Calotropis procera* and *Polyalthia longifolia*.

Guchi (2015) reported that late blight of potato can be managed using the following management (control) strategies: use of biological control agents, use of resistant varieties, intercropping, use of certified disease-free seed, use of selective fungicides and cultural practices such as destruction of cull piles by freezing or deep burying, destruction of volunteer potato plants in nearby fields throughout the season, destruction (desiccate, disc and desiccate) of infected plants to avoid spread, reduction of periods of leaf wetness and high humidity within the crop canopy by appropriately timing irrigation, application of a recommended fungicide spray program (the program should start prior to the arrival of the pathogen) and desiccation of vines prior to harvest.

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.). The treatments comprised of seed treatment and foliar spray (once and twice)of bio agents *Trichoderma harzianum* and *Pseudomonas fluorescens* while fungicide takenup was mancozeb and control (spray of plain water). Observation for per centdisease 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.

Henrique *et al.* (2014) reported that three field experiments were carried out to assess the level of resistance of several cultivars to early blight (EB) and to examine the association between host resistance and either foliage maturity or tuber skin types. A total of 26 cultivars were used in Exps. 1 and 2, and 24 in Exp. 3. Plants were inoculated with isolates of *Alternariagrandis*at 31 days after planting. EB severity was quantified in each plot every seven days. The approach to determine the resistance levels of potato cultivars was based on multivariate analysis techniques. The tested cultivars responded as either resistant, moderately resistant, moderately susceptible or susceptible to EB. Most of the cultivars were classified as susceptible or moderately susceptible to EB. Resistant cultivars were mid-season, mid-late or late maturity. None of the susceptible cultivars were later

maturity (mid-late or late maturity). In most cases, susceptible cultivars were earlier maturity (early or mid-early maturity). Most resistant cultivars had rough, mid-rough or smooth skin. None of the susceptible cultivars had rough skin. In most cases, susceptible or moderately susceptible cultivars had smooth skin. Obtaining potato cultivars that are resistant to this destructive disease will help reduce production costs and the need for costly fungicides.

Tsedaley (2014) reviewed with an objective of reviewing the economic importance of early blight of potato crop disease and its management options. Potato early blight disease, caused by two species of genus *Alternaria* (*A.solani*and *A.alternata*), is the major bottleneck in potato production in the world as well as in Ethiopia. Early blight of potato is prevalent worldwide wherever potatoes, tomatoes, peppers, and eggplants are grown. The disease can damage both potato foliage and tubers and can causes yield losses of 5-50%. Early blight is a poly cyclic disease that can cause more than one disease epidemics within a single cropping season. It is difficult to control because of its capacity to produce huge amounts of secondary inoculum. Since the disease is very important in causing economic losses of yields on potato crop, developing and using effective and appropriate management options is unquestionable. Using good cultural practices and applying chemical fungicides are important in reducing as well as managing of early blight disease of potato.

Shtienberg (2014) described the results of field experiments suggested that *A. solani* intensifies towards the end of the season, in mature plants and that the yield was reduced and application of fungicides was profitable in the autumn but not in the spring seasons. Based on these experiments an integrated strategy was developed for management of both early and late blights. In observations carried out in commercial fields it was found that necrotic lesions appear suddenly in large areas, often after heavy rain events and that the phenomenon was more common in crops growing in sandy soils. *Alternaria alternata* was isolated from necrotic lesions and the Koch postulates were completed and proved the pathogenicity of that fungus. Based on these observations it was hypothesized that heavy rains wash the nitrogen fertilizer from the root zone and that necrotic lesions appear in plants suffering from stress imposed by sudden reduction in nitrogen content in the foliage. These hypotheses were tested and it was found that necrotic lesions develop primarily in nitrogen deficient plants and that applying supplemental N fertilization reduces necrotic lesion severity.

Runno-paurson *et al.* (2014) reported that the early blight was evaluated in 2010 and 2011 on the plants of a potato cultivar 'Reet' in an organic farming experiment. Both growing seasons were very favourable for early blight development. Significant differences between the two cultivation technologies were found ($F1, 12 = 4.84$, $p = 0.048$). In 2010, the area under disease progress curve (AUDPC) value was 303 on cover crop (CC) plots and 990 on CC + M (manure) plots that was three times higher, whereas in 2011, the AUDPC value was 967 on CC plots and 1195 on CC + M plots. Results confirmed that potato early blight has become a serious problem in North-East European organic potato fields and thus susceptible potato

cultivars cannot be recommended for growing in an organic farming system. However, it was possible to influence the development severity of early blight by selecting the proper growing technology.

Ganie *et al.* (2013a) observed thefive 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 fungitoxicants 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 toxicant shexaconazole 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.

Ganie *et al.* (2013b) in a survey during 2009 and 2010 found the overall mean disease incidence and intensity ranged from 24.54 to 28.23% and 13.84 to 15.98%, respectively. The highest disease incidence (39.09%) and intensity (22.54%) was recorded in district Budgam. The lowest level of disease was in district Shopian (14.89 and 8.05%, respectively). The pathogen associated with the disease was identified as *Alternariasolani* (Ellis and Martin) Jones and Grout. In early stages of disease development, small irregular to circular dark brown spots on lower leaves appear, measuring 0.5 mm in size. Upto fourth week of June concentric rings form as a result of irregular growth patterns by the organism 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.

Tickoo *et al.* (2004) investigated the different combinations of *Brassica juncea*oil meal were compared for their volatile compound in hydrated form that was fungicidal to *Alternaria solani*. Indian potato (*Solanum tuberosum*) variety KufriJyoti was selected as an indicator crop for the treatment of *Alternariasolani.* Among the samples tested the volatile substrate in the oil meal of mustard (*Brassica juncea* (L.) *Coss. & Czern.*)with 50% carrier showed the strongest fungicidal effect. Allylisothiocyanate was the predominant fungicidal compound detected in the hydrated oilmeal of all treatments. Among 6 carrier combinations tested for seed treatment with ground mustard oil meal, carrier-5A (C-5A)containing Indian charcoal trema (50%), calcium carbonate (1%), barley flour (30%), rice bran (10%) and gum arabic (9%) was the most effective for the seed treatment at 1:1 oil meal and carrier ratio. Seed potato treated with a mixture of mustard oil

mealand Carrier-5A (1:1) at 7% (w/w) resulted in a significant reduction in incidence of *Alternaria solani* with no harmful effects to the germination of treated seeds. Effective control of *Alternaria solani* by the seeds treatment with Carrier-5A mixture was also obtained in a large scale experiment conducted on a field level. This study suggests that the mustard oil meal and carrier–5A(C-5A) mixture has potential for use in the commercial seed treatment for early blight of potato.

Waals *et al.* (2001) stated that the early blight of potatoes, causal agent *Alternaria solani*, causes major yield losses in most potato growing areas of the world. Leaf symptoms are characteristic dark brown to black lesions with concentric rings. In this review morphological, physiological and molecular characters of the pathogen as well as the disease cycle, epidemiology and control of the disease was discussed. The early blight situation on potatoes in South Africa was also summarised.

Ynar *et al.* (2011) evaluated the antifungal activities of 27 plant extracts were tested against *Alternaria solani* (E. & M.) Jones and Grout using radial growth technique. While all tested plant extracts produced some antifungal activities, the results revealed that *Circiumarvense, Humuluslupulus, Laurisnobilis*and *Salvia officinalis* showed significant antifungal activities. The leaf extract of *L. nobilis*was most effective in inhibiting the mycelial growth of *A. solani* (79.35%) at 4% concentration, followed by *S. officinalis, H. lupulus*, and *C.arvense* with 76.50, 61.50 and 55.83% inhibition, respectively. The other tested plant extracts exhibit edmodarate activity and average mycelial growth inhibition of fungus varied from 9.15 to 50.58%.

The lowest antifungal activity was observed on *Hypericum perforatum* extract. The antifungal activity of extracts of *C. arvense*, *H. lupulus*, *L. nobilis* and *S. officinalis* were further evaluated at different concentrations (0.2, 0.4, 2, 4 and 8% (w/v)) against *A. solani*. Inhibitory effects of these extracts wereincreased with increasing concentration. The minimum inhibitory concentration (MIC) of *H. lupulus*, *L. nobilis*and *S. officinalis* were 8% (w/v). Further studies on isolation and characterization of the active (antifungal) compound before the possible use of the tested extracts in control strategies of this fungus.

Mantecón (2009) studied the control of potato early blight (*Alternaria solani*). Uncut virus-free seed tubers of potato (*Solanum tuberosum*) cv. Pampeana PNTA that were susceptible to early blight and resistant to late blight were machine planted in 0.20-m intervals in rows spaced 0.8 mapart. Each plot consisted of 4 rows that were 5 meters long. Difenoconazole (Bogard 25EC) was sprayed weekly at a rate of 0.25 L· ha^{-1} or bi-weekly at a rate of 0.50 L· ha^{-1} on a preventive program and on a curative program. The same treatments and rates were also applied when forecast (Specware 6.02) reached 300 P-Days after emergence, and applications were then repeated thereafter every 7 EAST severity values. Disease severity was rated using the 0-50 rating scale (0 = no infection; 50 = maximum infection). Each plot were harvested and graded into two categories, either marketable (>60 g) or undersize tubers "seeds" (<60 g), and weighed for total yield. Climatic conditions were very favorable for disease development.

Pasche *et al.* (2004) collected isolates in 1998, prior to the introduction of azoxystrobin, were tested to establish the baseline sensitivity of the fungus to this fungicide. Isolates collected in subsequent years, not necessarily from the same sites as baseline isolates, were tested to determine if populations of *A. solani* had become less sensitive to azoxystrobin. Azoxystrobin sensitivity was determined utilizing an in vitro spore germination assay. The effective fungicide concentration that inhibited spore germination by 50% (EC50) was determined for each isolate. Mean azoxystrobin EC50 values of *A. solani*isolates collected in 2000 and 2001 were significantly higher compared with means from previous years, and mean azoxystrobin EC50 values from 2001 were significantly higher than means from isolates collected in 2000. A subset of 54 *A. solani*i solates was evaluated in vitro for cross-sensitivity to pyraclostrobin and trifloxystrobin. A highly significant and strong correlation among the isolatestested for fungicide cross-sensitivity was detected between azoxystrobin and pyraclostrobin; however, the correlation between azoxystrobin and trifloxystrobin, and between trifloxystrobin and pyraclostrobin, was significant but weak. Disease severity was not statistically different between azoxystrobin reduced-sensitive and sensitive *A. solani*isolates on plants treated with trifloxystrobin.

Kapsa (2004) assessed the efficacy of six selected fungicides in early blight control examined in field conditions. Field trials located in two sites – at Bonin and Stare Olesno revealed much slower development of early blight on these fields where chemical protection was applied as compared to untreated control. Efficacy of plant protection program carried out in Bonin

over three years varied from 40% to 63.9%. Effectiveness of selected products was higher in Stare Olesno at higher infection pressure, and ranged from 49.8% to 66.6%. However, efficiency of chemical protection in early blight suppressing is not as satisfactory as in late blight control. In field experiments good control of early blight resulted in tuber yield increase. In Bonin yield increase varied from 5.5 to 24.2% and in Stare Olesno from 12.2 to 34.4%.

Shitienberg (2001) Potatoes are grown in Israel in two growing seasons, autumn and spring. Two foliar diseases, early blight (*Alternaria solani*) and late blight (*Phytophthora infestans*) threaten the crop and if not managed properly, may induce substantial yield losses. Concepts for the integration of genotype resistance, age-related resistance and fungicide type for the suppression of both pathogens were developed based on the epidemiology of the pathogens and in relation to their interactions with the host. The concepts were evaluated in 7 field experiments from 1994 to 1998. Analysis of disease progress curves revealed that in plots managed according to the integrated management concepts, early blight was suppressed as good as in plots treated with a specific fungicide against *A. solani*, and late blight was suppressed as good as in plots treated with specific fungicides against *P. infestans*. Less sprays and lower quantities of fungicidal active ingredients were applied in plots treated according to the integrated management strategy. Yield in the integrated management treatment did not differ, or was significantly higher, than yield in the other treatments.

CHAPTER III

MATERIALS AND METHODS

3.1 Experimental site

The experiment was conducted in the Plant Pathology Laboratory and in the Central Farm of Sher-e-Bangla AgriculturalUniversity (SAU), Sher-e-Bangla Nagar, Dhaka-1207.

3.2 Experimental period

The experiments were conducted in the winter season started from November 2015 to May 2016.

3.3 Field experiment

3.3.1 Climate

The experimental area was under the sub-tropical climate which characterized bythe comparatively low rainfall, low humidity, low temperature, relatively short day during November to March 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 was30.34^{o}C and 21.21^{o} C, respectively with mean temperature of 25.17^{o}C. (Appendix II)Temperature during the cropping period ranged from 12.2^{o}C to 31.2^{o}C. The humidity varied from 73.52% to 81.2%. The day length ranged from 10.5-11.0hours only and there was no rainfall during the experimental period.

3.3.2 Soil type

The soil of the experimental site belongs to the Agro-Ecological Region of"MadhupurTract" (AEZ No. 28). It was Deep Red Brown Terrace soil andbelongs 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.

3.3.3 Fertility status of the 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.

3.3.4 Selection of variety

There are several varieties of potato grown in Bangladesh. Among the varieties BARI Potato-7 (Diamond) was collected from Bangladesh Agricultural Development Corporation (BADC) of Dhaka.

3.3. 5 Design of the experiment

The experiment was carried out in Randomized Complete Block Design (RCBD) with three replications.

3.4. Layout of experiment

The field layout was done as per experimental design on 1 December, 2015.The field was divided into three blocks each of which representing

application. The unit plot size was 1m × 4 m and plot to plot distance was 0.4 m and block to block distance was 0.75 meter.

3.4.1Experimental design

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

• Total area : 183.75 m^2
• No. of plot : 30
• Plot size : (1 ×4) m^2
• Block to block distance : 0.75m
• Plot to border distance : 0.75 m
• Plot to plot distance (Length wise) : 0.4 m
• Plot to plot distance (Breath wise) : .0.4 m
• Plant to plant spacing : 15 cm• Row to row spacing : 20 cm

3.4.2 Land preparation

A piece of medium high land with well drainage system was selected. The experimental field was first ploughed on 18 November 2016. The land was ploughed thoroughly with a power tiller and then laddering was done to obtain a desirable tilth. 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 plugging and land preparation was done on 30 November 2015.

3.4.3 Plantation of potato tubers

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.

3.4.4 Treatments

T_1 = Neem(*Azadirachta indica*) leaf extract @ 1:3 (w/v)

T_2 = Papaya(*Carica papaya*) leaf extract @ 1:3 (w/v)

T_3 = Marigold(*Calendula officinalis*) leaf extract @ 1:3 (w/v)

T_4 = Topgan(Copper oxychloride) @ 0.7 %

T_5 = Dithane M 45(Mancozeb) @ 0.45 %

T_6= Bavistin(Carbendazim) @ 0.1%

T_7= Rovral(Ipridione) @ 0.2%

T_8= Control

3.5 Intercultural Operation

3.5.1 Plant protection

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

3.5.2 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 moment.

3.5.3 Irrigation

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

3.5.4 Weeding

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

3.6 Collection of fungicides and plant extracts

Three fungicides namely Bavistin, Rovral, Topgan and Dithane M-45 were collected from local market. For the plant extracts, the leaf of neem and papaya and marigold were collected from Sher-e -Bangla Agricultural University campus.

3.6.1 Preparation of fungicidal suspension

Recommended doses of fungicidal solution were prepared by mixing thoroughly with required quantity of fungicide and water. It was required Topgun (7gm/L), Dithane M 45 (4.5gm/L), Bavistin (1gm/L) and Rovral (0.01%) for preparation of solution for recommended concentration.

3.6.2Application of fertilizers and manures

The following dose of fertilizers and manures were applied for the potato cultivation with the dose of Urea (300 kg/ha), TSP (150 kg/ha), MOP (250 kg/ha), Gypsum (40 kg/ha) and Cowdung (10 tons/ha).The 1/3rd Urea and whole amount of other fertilizers were applied as basal dose and rest 2/3rd Urea was applied at 30 DAP and 50 DAP followed by an irrigation.

3.6.3 Preparation of plant extracts

The plant extracts were prepared by using the method exercised by Ashrafuzzaman and Hossain (1992). For preparation of extracts, collected leaves were weighted in an electric balance and then washed in the water. After washing the big leaves were cut into small pieces. For getting extract, weighted plant parts were blended in a mortar and pastel, then distilled water was added into the mortar. The pulverized mass was squeezed through 3 folds of fine cotton cloth. For getting 1:3 (w/v) ratio 300 ml of distilled water was added with 100g plant parts. The particulars of the botanicals used for the experiment are listed in Table 3.

3.6.4 Application of fungicides and plant extracts

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 7 spraying were done with 7 days intervals with a hand sprayer. To avoid the drifting of the fungicides during application, spraying was done very carefully,

specially observing air motion. A control treatment was maintained in each block where spraying was done with plain water only.

3.7 Data collection

The data were recorded on the following parameters at regular intervals.

1. Disease Incidence (% plant infection & % leaf infection)
2. Disease Severity (%leaf area diseased)
3. Yield (ton/ha)

3.8 Laboratory experiment

3.8.1 Collection of diseased samples

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

3.8.2 Sterilization of materials and equipments

For surface sterilization, 0.1 %sodium hypochlorite (NaOCl) was used for plant materials such as leaf, stem etc., and rectified spirit was used for sterilization other equipment's like inoculation-needles, inoculation chamber, forceps, hands etc.

Fig. 1: Application o fungicides (A) to control disease and Placing of infected potato leaves on a petridish (B) after surface sterilization.

3.8.3 Identification of pathogen of early blight of potato caused by *Alternaria solani*.

Diseased leaf samples were brought to the laboratory. Sample surface was sterilized by dipping in 0.1 % Hg_2Cl_2 solution for 30 second and rinsed with sterile water. Leaf samples were placed on moist blotter paper on petridish, incubated at 20 ± 2^0 C for 2 days in 12 hours with alternate light and darkness. For sporulation, the inocula 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 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 *et al.*(1996), Simmons (2007) and Chowdappa and Lakshmi (2013).

Calculation of disease incidence of different treatment

Percent disease incidence was calculated using the following formula:

$$\text{(\%) disease Incidence} = \frac{\text{Number of diseased plant/leaf}}{\text{Number of total plants/leaves inspected}} \times 100$$

3.8.4 Leaf Area Diseased (LAD)/plant in different treatment

Leaf area diseased of the ten selected plants in each plot against each treatment were measured and recorded by eye estimation. Mean percentage of leaf area diseased was calculated by dividing number of total observation and used for PDI (percent disease index) estimation with the following scale.

0=No disease symptoms.

1= A few spots towards the tip, covering less than 10% leaf area.

2= Several dark purplish brown patches covering 10%to less than 20 % leaf area.

3= Several patches with paler outer zone, covering 20% to 40% leaf area.

4= Long streaks covering 40% to 75% leaf area .

5= Complete drying of the leaves / stems or breaking of the leaves/stems. from the base.

The percent disease index (PDI) was calculated using the following formula (Islam, 2003):

$$PDI = \frac{\text{Total sum of numerical ratings}}{\text{Number of observation} \times \text{Maximum grade in the scale}} \times 100$$

3.9 Statistical analysis

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

CHAPTER IV

RESULTS AND DISCUSSION

The effects of different fungicides and botanicals 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 botanicals and fungicides are discussed in this chapter.

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

Spots begin 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 tissue. A yellowish or greenish-yellow ring was often seen bordering the growing spots. As the spots become very large, they often caused the entire leaf to become yellow and die. This was especially true on the lower leaves, where spots usually occured first and was abundant. The dead leaves do not usually fall off. Dark brown to black spots was occured 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. As the disease advanced, the

potato flesh often becomes water soaked and yellow to greenish yellow. Early blight spots were less likely to become rotted by secondary organisms.

4.2 Identification of Causal Organism of Early Blight of Potato

The several temporary and semi permanent slides were prepared to observe the micro organisms under microscope. Morphological observations of the fungus were recorded by adopting slide culture technique. The fungus produced profuse mycelial growth on PDA. Initially, the mycelium was hyaline that turned to grey- brownish, multicelled, septate and irregularly branched. Fungus colonies were dark to grey-black and conidiophores arising singly or in small groups produced spores in chains. Conidiospores were large with longitudinal and transverse septa and a short beak typical for *Alternaria solani* under microscope. The fungus had septate, branched, and melanised mycelia (Rotem, 1994).The organism grown on moist blotter paper and potato slices were observed directly under sterio 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).

Fig. 2: Symptoms of early blight of potato showing blighting of leaves with brownish color.

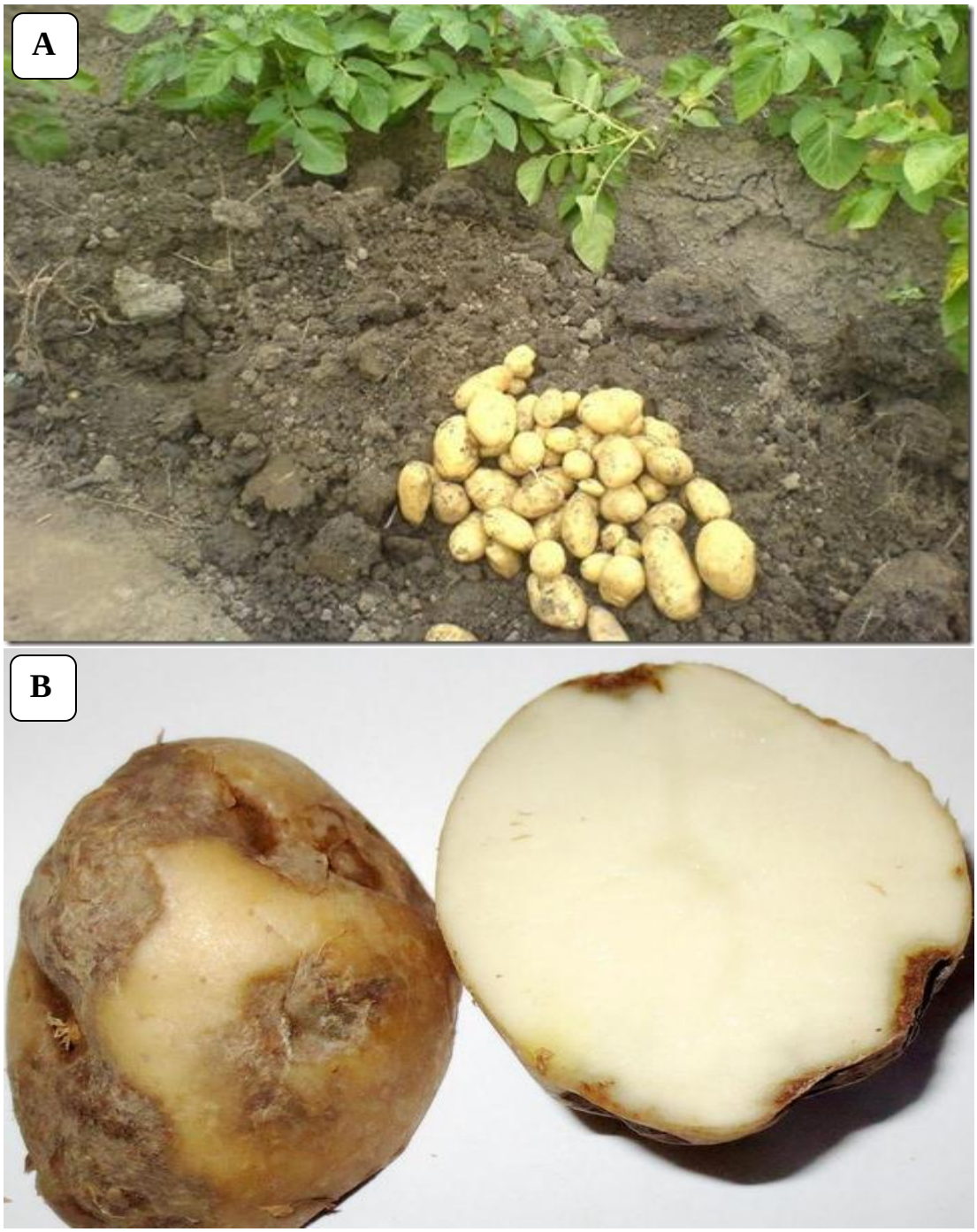

Fig. 3: Harvested Potato (A), Infected Potato (B).

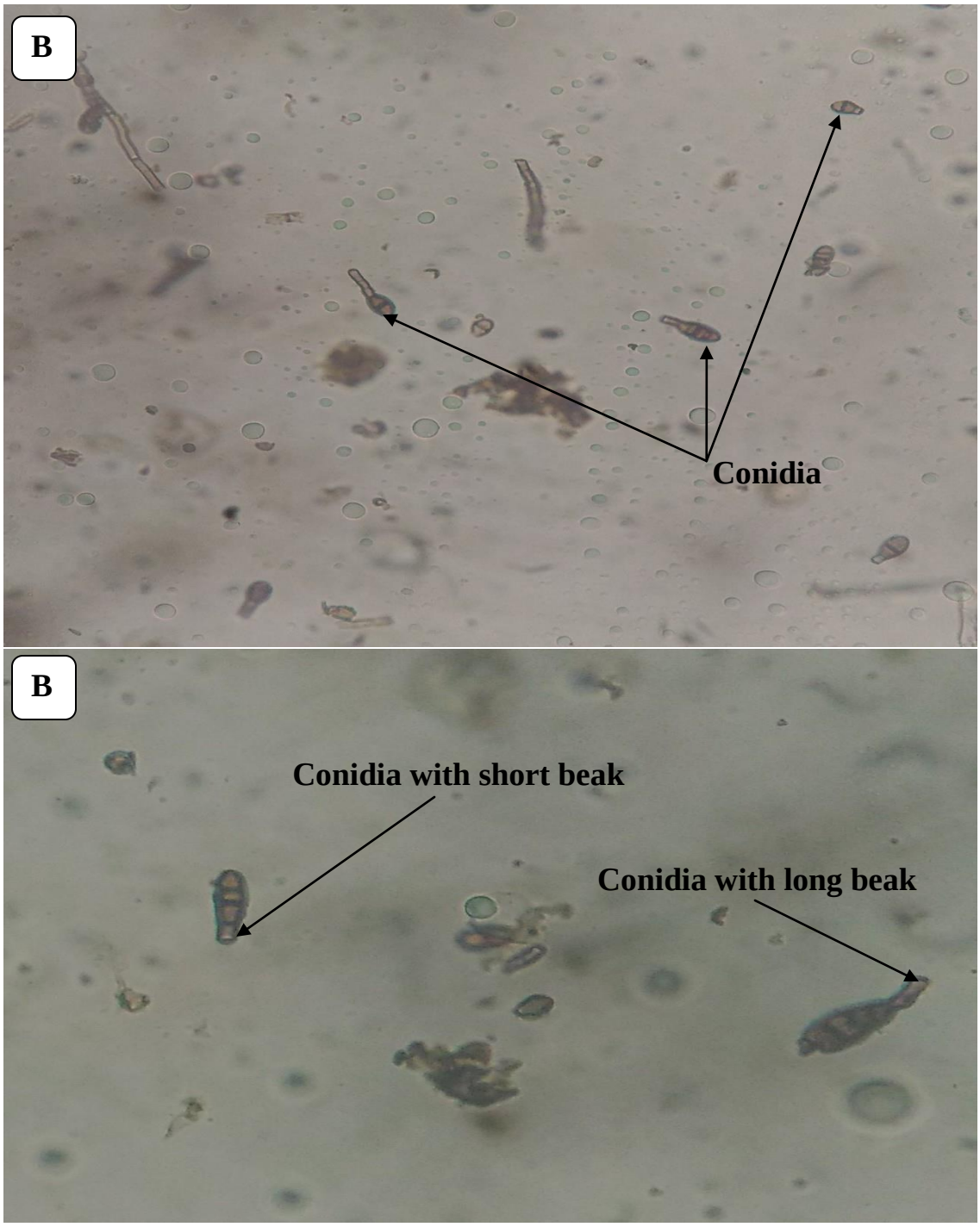

Fig. 4: Conidia (A) of *Alternariasolani*with short and long beak (B).

4.3 Effects of different treatments in reducing the plant infection caused by *Alternaria solani.*

The effect of selected plant extracts and fungicides against *Alternaria solani* causing early blight of potato was presented in Figure 5 and Table 1. The treatments showed promising performance in reducing the disease incidence (plant infection) at different Days after planting (DAP).

The application of different selected plant extracts were observed and evaluated at regular intervals of 60, 70 and 80 days after planting of potato tubers. At 60 DAP, the effect of different treatments found to differ significantly in respect of plant infection. Among the plant extracts, the papaya leaf extracts showed the lowest infection followed by marigold and neem extracts. In case of fungicides, the lowest plant infection (18.73%) was recorded in Rovral 50WP followed by Bavistin (21.64%), Dithane M 45 (20.63%) and Topgan (27.20%).

The highest plant infection (84.95%) was recorded in control (Table 1 and Fig. 5). 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 (86.63%) was recorded in control and the lowest plant infection (14.47%) was recorded in Rovral 50 WP followed by Dithane M 45 (18.19%), Bavistin (18.49%) and Topgan (22.57%).

At 80 DAP, the lowest plant infection was also recorded in case of Rovral (14.30%) followed by Dithane M 45 (16.13%), Bavistin (17.25%) and Topgun (17.87%). Among the plant extracts, the lowest plant infection was

recorded in case reduced in papaya leaf extracts (54.26%) followed by marigold extracts (56.63%) and neem leaf extracts (62.45%).

The reduction of plant infection due to the application of different treatments were calculated based on the plant infection recorded in 80 DAP. The highest reduction of plant infection was yielded by Rovral 50WP (85.70%) followed by Dithane M 45 (83.87%) and Top gun (82.13%). Among the plant extracts , the highest reduction of plant infection was noted in case of neem extracts (37.55%) followed by marigold extracts (43.37%) and papaya leaf extracts (45.74%).

Table 1: Efficacy of different leaf extracts and fungicides in reducing of plant infection of potato by early blight pathogen under field condition.

Disease Incidence (% Plant Infection)				(%)Reduction of disease incidence at 80 DAP
Treatments	60 DAP	70 DAP	80 DAP	
Neem leaf extract	79.76 b	74.70 b	62.45 b	37.55
Papaya leaf extract	65.97 d	62.34 d	54.26 c	45.74
Marigold leaf extract	75.07 c	69.54 c	56.63 c	43.37
Topgan	27.20 e	22.57 e	17.87 d	82.13
Dithane M 45	20.63 f	18.19 f	16.13 d	83.87
Bavistin	21.64 f	18.49 f	17.25 d	82.75
Rovral	18.73 f	14.47 g	14.30 d	85.7
Control	84.95 a	86.63 a	100 a	
$LSD_{(0.05)}$	3.430	3.204	4.063	
CV (%)	4.13	3.83	3.67	
Significance	**	**	**	

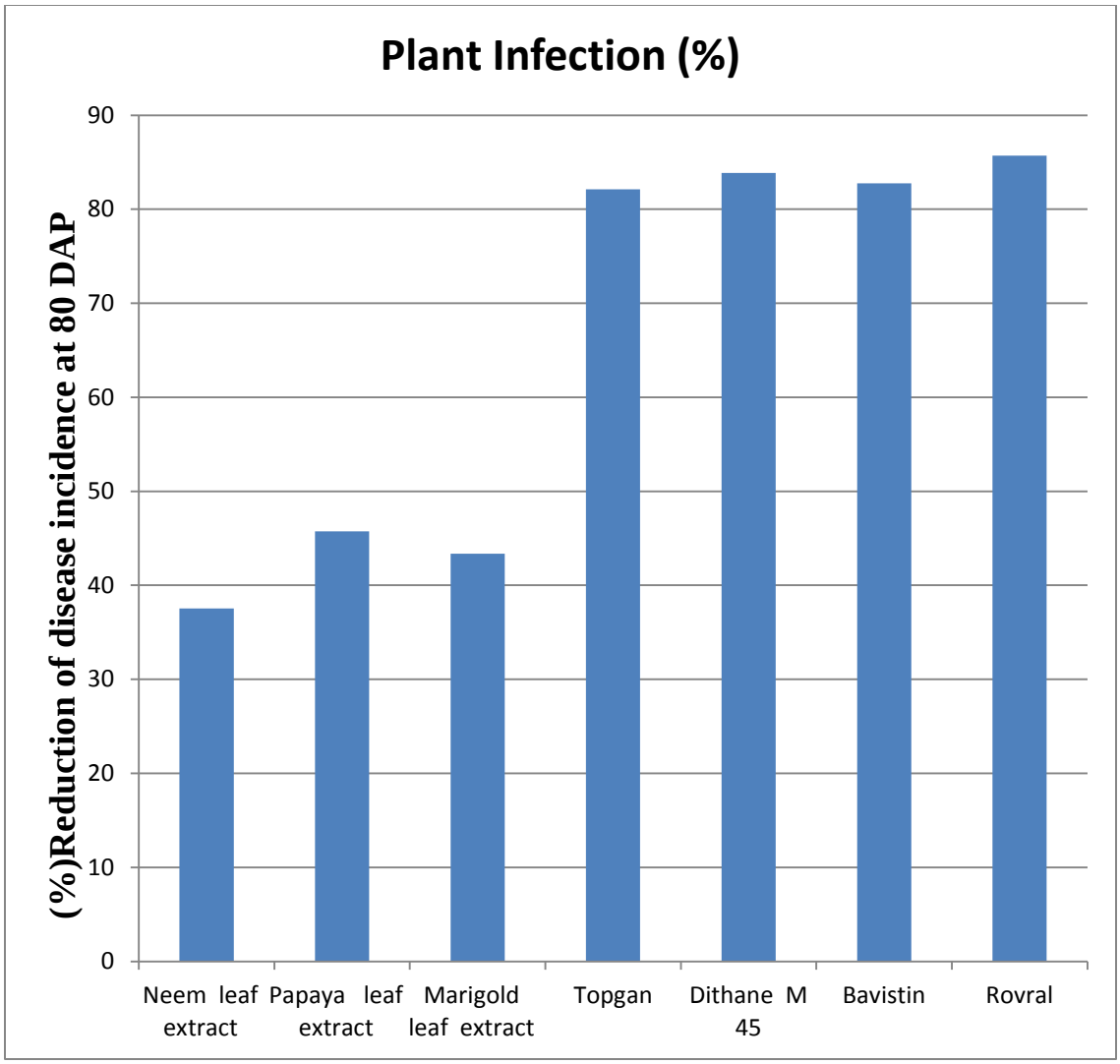

Fig. 5: Efficacy of plant extracts and fungicides in reducing disease incidence of plants infection against *A. solani***.**

4.4 Effects of different treatments on the Leaf infection caused by *Alternaria solani*

The effect of plant extracts and fungicides on leaf infection were found more or less similar with that of plant infection (Table 1 and 2). The performance of different plant extracts and fungicides recorded at different days after planting found to be varied significantly.

At 60 DAP, the lowest leaf infection (17.86%) was recorded in Rovral followed by Dithane M 45 (20.53%), Bavistin (23.72%) and Topgun (25.52%). In case of plpant extracts, the papaya leaf extracts yielded the lowest leaf incidence (35.08%).

At 70 DAP, the lowest leaf infection (15.74%) was also noticed in case of Rovral followed by Dithane M 45 (19.17%), Topgun (18.16%) and Bavistin (20.93%) while papaya leaf extracts yielded (31.44%) leaf infection of early blight of potato.

At 80 DAP, the treatments applied showed similar trend of results in reducing the leaf infection. The lowest leaf infection (14.67%) was recorded in case of Rovral significantly. The second highest performance were yielded by Dithane M 45 (16.33%) and Bavistin (16.22%). Marigold leaf extracts showed the lowest leaf infection (26.43%) among the plant extracts.

The reduction of leaf infection was estimated on the performance of the treatments recorded at 80 DAP. The highest reduction (85.33%) of leaf infection was noted down in case of Rovral followed by Dithane M 45 (83.67%), Topogun (83.78%), Bavistin (76.87%) and the plant extracts papaya (71.20%).

Table 2: Efficacy of different leaf extracts and fungicides in reducing of leaf infection of potato against early blight under field condition.

Disease Incidence (% Leaf Infection)				**% Reduction of disease incidence at 80 DAP**
Treatments	60 DAP	70 DAP	80 DAP	
Neem leaf extract	44.99 b	39.58 b	32.62 b	67.38
Papaya leaf extract	35.08 d	31.44 c	28.80 c	71.20
Marigold leaf extract	41.05 c	37.13 b	26.43 cd	73.57
Topgan	25.52 e	18.16 de	23.13 d	83.78
Dithane M 45	20.53 g	19.17 d	16.33 e	83.67
Bavistin	23.72 f	20.93 d	16.22 ef	76.87
Rovral	17.86 h	15.74 e	14.67 f	85.33
Control	56.79 a	58.85 a	62.49 a	-
$LSD_{(0.05)}$	2.129	2.566	3.374	
CV (%)	3.97	4.42	3.76	
Significance	**	**	**	

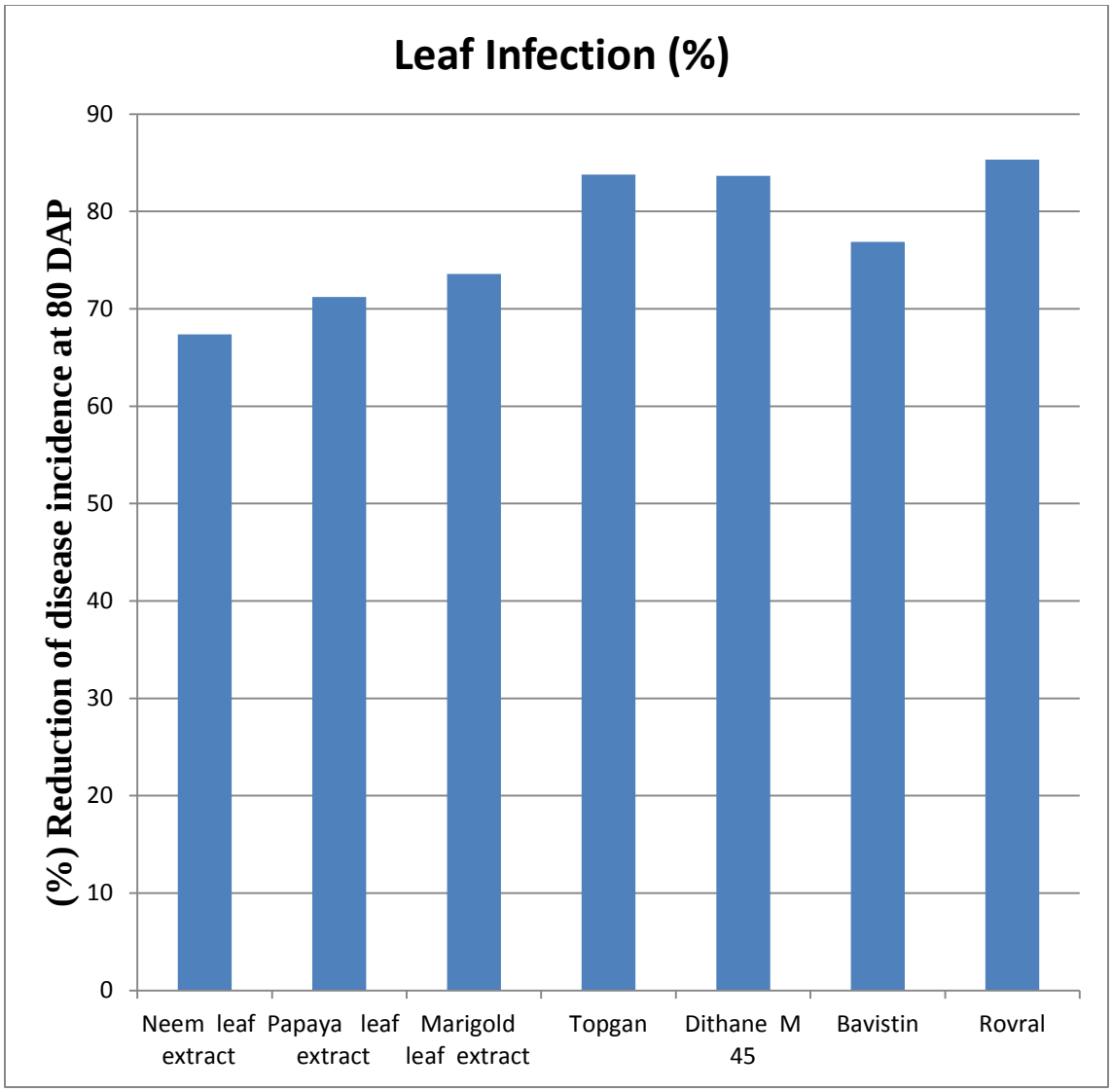

Fig. 6: Efficacy of plant extracts and fungicides in reducing disease incidence of leaves infection against*A. solani***.**

4.5 Effects of different treatments on Percent Disease Index (PDI) caused by *Alternaria solani*

The treatments explored in the experiment showed different performance in reducing the disease severity (PDI). The performances of the treatments in different days after planting (DAP) viz. 60 DAP, 70 DAP and 80 DAP in reduction of disease severity found to be in similar trend irrespective of different DAP. As per the last recording data at 80 DAP, the Rovral showed the highest performance (85.70%) in reduction of disease severity. The second highest reduction of disease severity was recorded in of Dithane M 45 (82.50%) followed by Bavistin (79.16%) and Topgun (76.71%). The neem leaf extracts and the marigold leaf extracts showed more or less similar performance against the early blight of potato disease that reduced the severity by 53.64% and 53.32%, respectively.

Table 3: Efficacy of different Plant leafextracts and fungicides in reducing of Percent Disease Index (PDI) of potato against early blight under field condition.

Percent Disease Index				% Reduction of disease severity at 80 DAP
Treatments	60 DAP	70 DAP	80 DAP	
Neem leaf extract	39.98 c	46.36 c	44.96 b	53.64
Papaya leaf extract	32.30 d	35.78 d	40.97 c	59.03
Marigold leaf extract	51.31 b	53.81 b	46.68 b	53.32
Topgan	12.83 e	12.39 ef	23.29 d	76.71
Dithane M 45	10.37 ef	10.53 f	17.50 e	82.50
Bavistin	9.123 f	13.53 e	20.84 d	79.16
Rovral	8.303 f	11.04 f	14.30 f	85.70
Control	56.73 a	59.71 a	86.08 a	-
$LSD_{(0.05)}$	3.324	1.984	2.720	
CV (%)	6.95	5.83	4.27	
Significance	**	**	**	

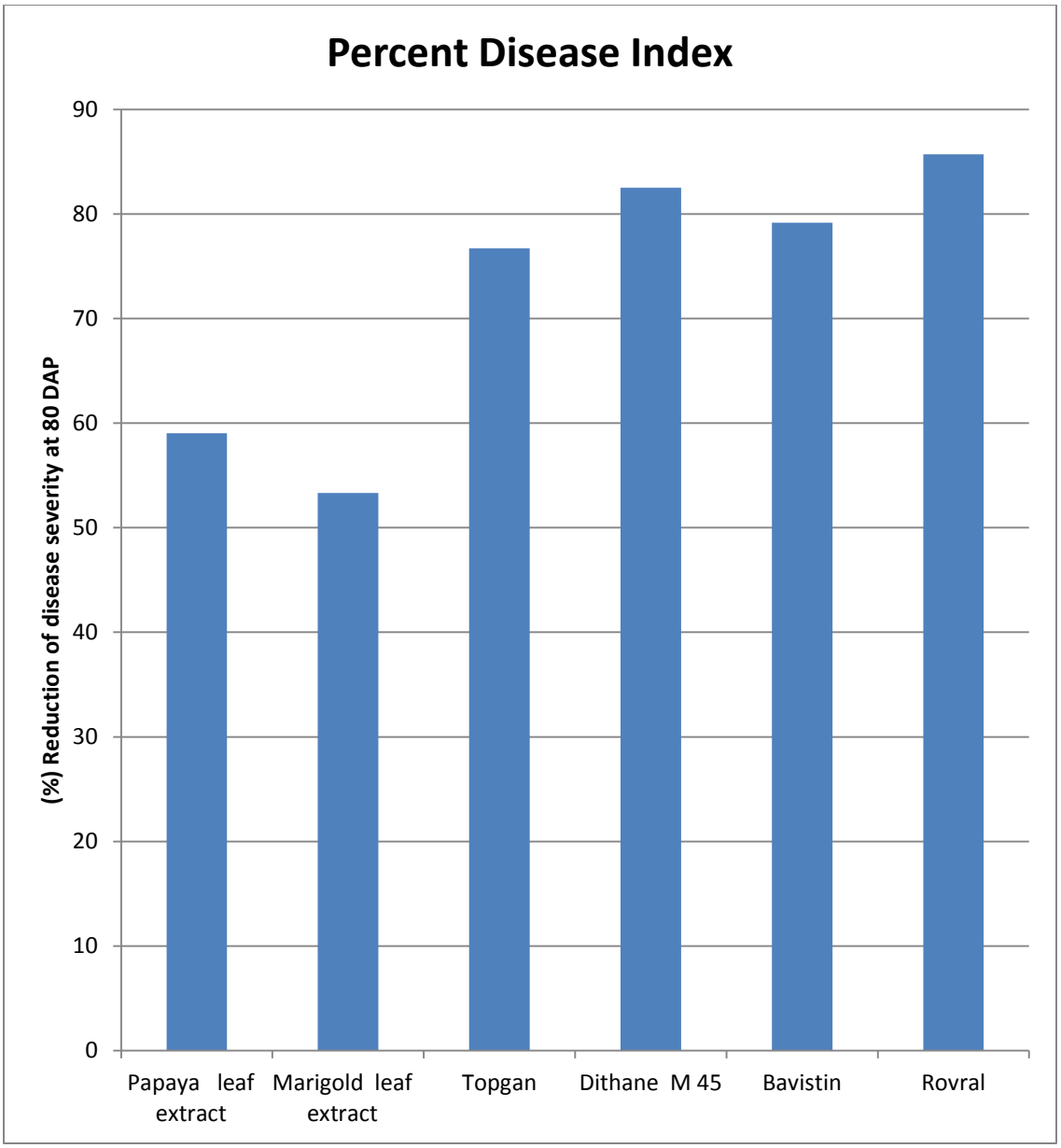

Fig. 7: Efficacy of plant extracts and fungicides in reducing PDI of plants infection against *A. solani***.**

4.6 Effects of different treatments on Yield of potato caused by *Alternaria solani*

The highest tuber yield (27.22 t ha^{-1}) of potato was observed from the plot treated by Rovral, whereas similar (25.31t ha^{-1}) yield was harvested from the plot applied by Dithane M 45. The yield of potato 23.67 t $ha^{-1}$and 23.62 t ha^{-1} were found from the plots treated with Topgun and Bavistin (Table 4 and Figure 8).

The plant extracts yielded the similar amount from the treated experimental field. Due to application of neem leaf extracts, 20.58 t ha^{-1}yieldwas harvested while 22.29t $ha^{-1}$was harvested from the papaya leaf extracts treated plots and 21.60t $ha^{-1}$was harvested from marigold leaf extracts treated field.

The chemical fungicides showed significantly better performance than the botanical fungicides. The chemical and botanical fungicides also increased the considerable yield than the control. The highest increase in percentage of yield was 120.94% when the field was applied by Rovral 50WP. The nearest yield (105.43%) was harvested from the application of Dithane M 45. The tuber yield 91.72 and 92.13% were increased by the application of Topgun and Bavistin, respectively. Application of botanical fungicide namely neem leaf extract showed 67.04% of yield increase over the control. Papaya leaf extracts also showed 80.92% increase of potato yield, whereas 75.32% increase of yield was recorded from the application of marigold leaf extracts

Table 4:Efficacy of different leaf extracts and fungicides in reducing yield of potato against early blight under field condition.

Treatments	Yield (ton/ha)	**Increase of yield (%)**
Neem leaf extract	20.58 d	67.04
Papaya leaf extract	22.29 cd	80.92
Marigold leaf extract	21.60 cd	75.32
Topgan	23.67 bc	91.72
Dithane M 45	25.31 ab	105.43
Bavistin	23.62 bc	92.13
Rovral	27.22 a	120.94
Control	12.32 e	-
CV (%)	6.56	
$LSD_{(0.05)}$	2.502	
Significance	**	

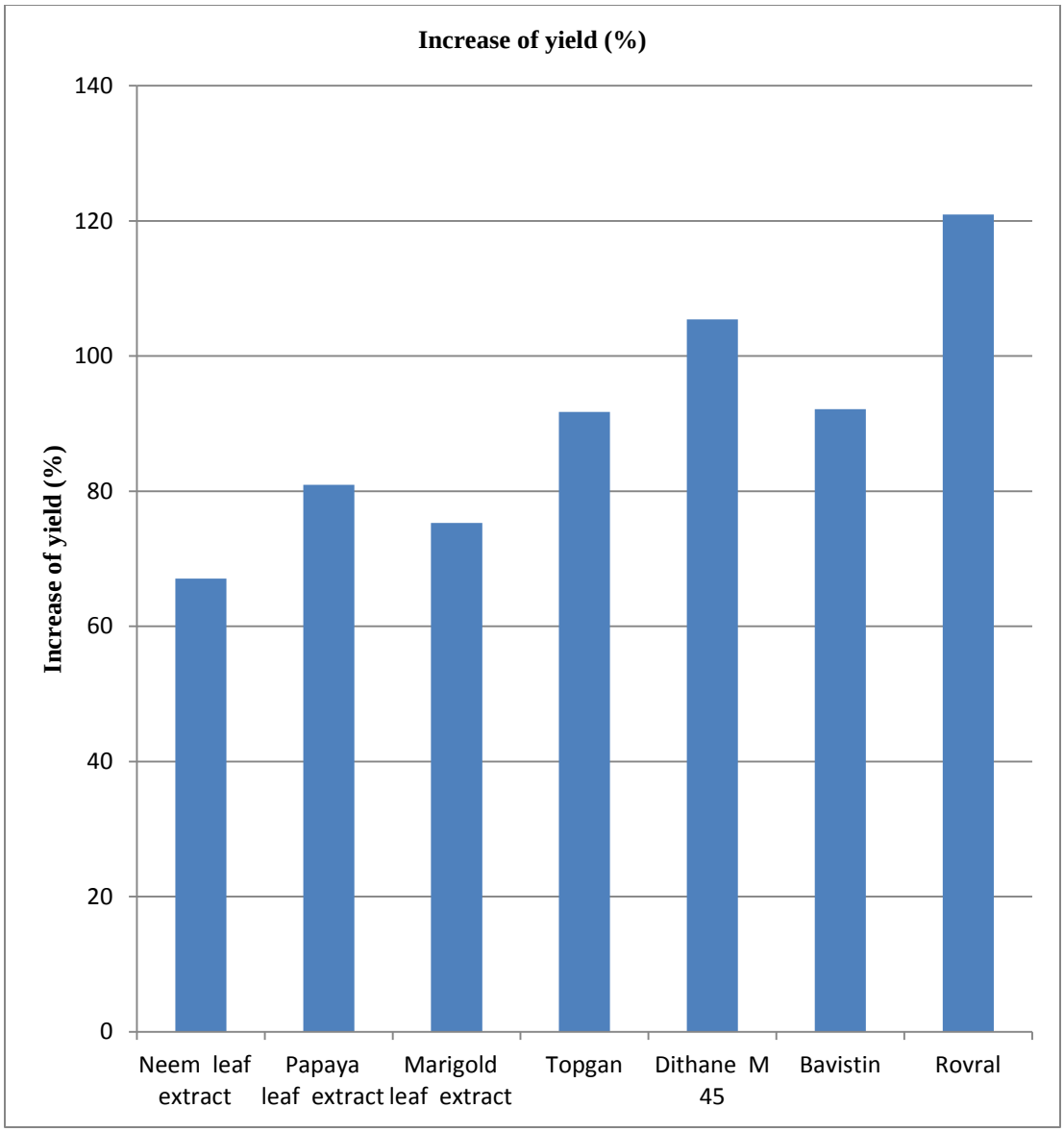

Fig. 8: Efficacy of plant extracts and fungicides in increasing yield (tha^{-1}) against *A. solani***.**

DISCUSSION

The cultivation of potato plays an important role in supplying vegetable throughout the year and solve the nutritional problems to a great extent for the lower income people. Potato is one of the important vegetable crops due to its high value for human nutrition in the world (Desjardins *et al*., 1995; FAO, 2010). The potato cultivation is hampered in every year by the early blight caused by *Alternaria solani* resulting lower yield in our country. The chemical and botanical fungicides were applied to the experimental field to evaluate the infection of plants and leaves by the causal organism of early blight of potato.

The highest reduction percentage of plant infection was 85.7 when the plot was sprayed with Rovral. The nearest reduction of plant infection (83.87 and 82.75%) were observed from the application of Dithane M 45 and Topgun, respectively. Papaya leaf extracts also showed 45.74% reduction of potato plant infection, whereas 43.37% reduction of plant infection wasfound from the application of marigold leaf extracts.

The highest reduction percentage of leaf infection was 85.33% when the plot was sprayed with Rovral. whereas 73.57% reduction of leaf infectionwas found from the application of marigold leaf extracts. At 80 days of planting, the PDI values were observed and found that the maximum PDI was calculated from the control (86.08%). In case of plant extracts, the PDI values were 44.96, 40.97 and 46.68% for the neem, papaya and marigold leaf extracts, respectively. The highest reduction percentage of PDI value was 85.70% when the plots were sprayed with Rovral. Papaya leaf extracts also decreased 59.03% PDI value.

However, the effect of chemical fungicides showed significantly better performance than the botanical fungicides. The chemical and botanical fungicides also increased the yield considerable than the control. The highest yield increase was 120.94% when the field was applied by Rovral 50 WP. The nearest yield (105.43%) was harvested from the application of Dithane M 45. The yield 91.71 and 91.13% were increased by the application of Topgun and Bavistin, respectively.

Application of botanical fungicide namely neem leaf extract showed 67.04% of yield increase over the control. Papaya leaf extracts also showed 80.92% increase of potato yield, whereas 75.32% increase of yield was estimated from the application of marigold leaf extracts.

Similar kinds of results have been reported by several other researchers (Ariafar and Zacharia, 2016; Singh *et al.*, 2016; Murmu *et al.*, 2015; Sadana and Didwania, 2015). Ariafar and Zacharia (2016) evaluated the efficacy of different plant extracts against *Alternaria solani* and reported that Neem leaf extract (*Azadirachta indica*) reduced the highest mycelia growth of that fungus. Sing et al. (2016) also reported that neem seed kernel extracts found to be highly effective against *Alternaria solani*. Sadana and Didwania (2015) while working with different fungicides, reported that Mancozeb (Dithane M 45) showed promising effect against *Alternaria solani* that reduced 86.40% mycelia growth of the fungus.

CHAPTER V

SUMMARY AND CONCLUSION

In terms of global production, potato (*Solanum tuberosum* L.) is the fourth most important food crop after corn, rice and wheat. This crop is grown throughout the world. Present world production is 321 million tons fresh tubers from 19.5 million ha. Asia and Europe are the world's major potato producing regions, accounting for more than 80% of world production. The potato plays a strong role in developing countries with its ability to provide nutritious food for the poor and hungry. The demand for potato is growing as both a fresh and processed food. The decreasing availability of land for area expansion means that yields will have to be improved.

The primary damage of early blight is due to premature defoliation of the plant. Photosynthesis rates decreased and respiration rates increased in early blight infected potato plants. In the present investigation the highest reduction of plant infection was yielded by Rovral 50WP (85.70%) followed by Dithane M 45 (83.87%) and Top gun (82.13%). Among the plant extracts , the highest reduction of plant infection was noted in case of neem extracts (37.55%) followed by marigold extracts (43.37%) and papaya leaf extracts (45.74%).The reduction of leaf infection was estimated on the performance of the treatments recorded at 80 DAP. The highest reduction (85.33%) of leaf infection was noted down in case of Rovral followed by Dithane M 45 (83.67%), Topogun (83.78%), Bavistin (76.87%) and the plant extracts papaya (71.20%). In case of disease severity, Rovral showed the highest performance (85.70%) in reduction of disease severity.

The second highest reduction of disease severity was recorded in of Dithane M 45 (82.50%) followed by Bavistin (79.16%) and Topgun (76.71%). The neem leaf extracts and the marigold leaf extracts showed more or less similar performance against the early blight of potato disease that reduced the severity by 53.64% and 53.32%, respectively.

The chemical fungicides showed significantly better performance than the botanical fungicides. Most of the chemicals and botanicals increased the considerable yield than the control. The highest increase of yield was 120.94% when the field was sprayed with Rovral 50WP. The nearest yield (105.43%) was harvested from the application of Dithane M 45. The tuber yield 91.72 and 92.13% were increased by the application of Topgun and Bavistin, respectively. Application of botanical fungicide namely neem leaf extract showed 67.04% of yield increase over the control. Papaya leaf extracts also showed 80.92% increase of potato yield, whereas 75.32% increase of yield was recorded from the application of marigold leaf extracts. On the basis of the present findings, the potato growers may be suggested to use Rovral 50 WP as a chemical fungicide and papaya or marigold or neem extract as botanicals for the management of early blight of potato.

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