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Eco-Friendly Management of Chilli Anthracnose (*Colletotrichum capsici*)

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ABSTRACT

An investigation was carried out to determine the efficacy of some organic materials to manage anthracnose (*Colletotrichum capsici*) of chilli (*Capsicum annuum* L.) under natural field condition at Bangladesh Agricultural University, Mymensingh, Bangladesh. Plant extracts of neem (*Azadirachta indica*), mahogany (*Swietenia mahagoni*), koromcha (*Carissa carandas*) and garlic (*Allium sativum*) applied as foliar spray, singly or in combination to find out their efficacy and profitability compared with control (no spray) and chemical fungicide Ridomil 50 WP (as a positive control). All the treatments controlled the disease significantly providing higher yield compared to control. As chemical, the combined application of neem, mahogany and garlic extracts also showed significant impact on disease reduction as well as on yield of chilli. Relatively, this organic cocktail gave a higher benefit (BCR = 3.97) with minimum production cost and this approach is proposed to the chilli-growing farmers to mitigate the chilli anthracnose. So, organic combination might be a better option to control anthracnose of Chilli rather than chemical control as it is cost-effective and environment friendly.

Key words: Integrated management, anthracnose, chilli, cost effective

INTRODUCTION

Chilli (*Capsicum annuum* L.) under the family of Solanaceae is one of the important spice crops not only in Bangladesh but also in many countries of the world. In Bangladesh, 41000 acres of land occupied under its cultivation during Kharif (summer) season and total production is 21000 mt (approximate average yield, 0.51 mt acre^{-1}), and in Rabi (winter) season, 199000 acres of land occupied under cultivation and total production is 105000 mt (approximate average yield, 0.52 mt acre^{-1}) in the year 2011-12 (BBS., 2013). The annual total requirement of this spice is very high. This crop is grown throughout the year in our country and several chilli cultivars are grown.

Colletotrichum is one of the vital phytopathogen worldwide causing the economically important disease anthracnose in a wide range of hosts including cereals, legumes, vegetables, perennial crops and tree fruits (Jeger and Bailey, 1992). Among these hosts, chilli is a core economic crop worldwide (Poulos, 1992), which is severely infected by *Colletotrichum capsici*, causal agent of anthracnose of chilli that may cause yield losses up to 50% during high severity (Pakdeevaraporn *et al*., 2005).

Therefore, like other countries in Bangladesh, chilli anthracnose reduces the annual production, which ultimate affect the total requirements and as such large quantity is to be imported every year. Typical anthracnose symptoms caused by *Colletotrichum capsici* appear as sunken necrotic tissues, with concentric rings of acervuli on chilli fruit. Anthracnose causes extensive pre- and postharvest damage to chilli fruits causing anthracnose lesions. Even fruits showing small anthracnose lesions affect on chilli marketability (Manandhar *et al*., 1995). It is found that around 27°C temperature, about 80% relative humidity and soil pH 5-6 promote favorable infection and disease progress of chilli anthracnose (Roberts *et al*., 2001). During rainy weather, severe losses occur because the spores are washed or splashed to other fresh fruits resulting in more infections (Roberts *et al*., 2001). In Bangladesh, anthracnose of chilli is frequently observed in summer and winter.

Various methods have been practiced to control the diseases such as inter-cropping, adjustment of time of sowing, rouging etc. physical methods like seed selection, hot water treatment, solar heat treatment and chemical treatments etc. Use of plant extracts like neem (*Azadirachta indica*), mahogany (*Swietenia mahagoni*), koromcha (*Carissa carandas*), garlic (*Allium sativum*), zinzer (*Zingiber officinale*), marigold (*Tagetes erecta*), allamonda (*Allamonda cathertica*) etc. (Ashrafuzzaman and Khan, 1992; Freeman *et al*., 2001; Rashid *et al*., 2007, 2010; Masuduzzaman *et al*., 2008; Amin *et al*., 2009; Perello *et al*., 2013a,b; Kabir *et al*., 2014) and the use of bio-fungicide *Trichoderma* spp., *Bacillus subtilis* (Moretto *et al*., 2001; Verma *et al*., 2007; Boonratkwang *et al*., 2007; Lahlali *et al*., 2013; Fitsum *et al*., 2014) might be useful in controlling different fungal diseases of various agricultural crops. The effect of certain plant extracts on the management of some diseases of chilli such as dieback, fruit rot and anthracnose were reported. Management and control of the anthracnose disease are still under extensive research (Yoon *et al*., 2004). Fungicide is being used to control this disease now. But the practice is highly risk for public health as the green fruit is eaten with or without cooking. These toxic chemicals directly enter into human tissue, get deposited and at critical concentration cause serious health disorder. This realization emphasizes the importance of finding materials and products, which are safe for human health as well as environment. Therefore, an integrated management practice and use of plant and natural products leading to organic production of chilli may guarantee for safe and healthy production. Besides, fungicides are responsible for air, soil and water pollution. These are sold at such a high price, which increases cost of production. Removal of diseased foliage can be conditioned for their effective use for eco-friendly disease management in the field either alone or as a component of integrated disease management. But integrated disease management is most effective, economic and environment friendly (Kashyap *et al*., 2010; Mondal and Mondal, 2012; Kabir *et al*., 2014).

Use of plant extracts against plant disease control is however a recent approach to plant disease management and it has drawn the special attention of the plant pathologists all over the world. Many researchers reported about plant extracts having potential to be used against many causal organisms of plant diseases.

In view of the above facts, the present research was undertaken to determine the efficacy of plant extracts individually or in combination facing anthracnose disease of chilli as an environmental friendly management practice and to explore the best approach in case of benefit-cost ratio.

MATERIALS AND METHODS

The experiment was conducted at the Plant Pathology Field Laboratory of Bangladesh Agricultural University, Mymensingh during Rabi season (October-March). The experimental area belongs to the old Brahmaputra flood Plain in Agro-ecological Zone-9 (area 7230 km^2) (FAO., 1988). The macro-climate of the experimental area (BAU farm area) is subtropical in nature. The Local variety of chilli cultivar Balijuri collected from the Horticulture Centre, Mymensingh, Bangladesh was used for this experiment. Cowdung at the rate of 20 t ha^{-1} and fertilizers Urea, TSP (Triple Super Phosphate) MOP (Muriate of Potash) at the rate of 250, 200 and 150 kg ha^{-1}, respectively were used. The whole amount of TSP and half amount of urea and MOP were applied as basal dose before transplanting of seedlings. The rest amount of urea and MOP were applied at 30 Day After Transplanting (DAT). The experiment was laid out in a Randomized Complete Block Design (RCBD). Treatments were assigned to each block at random. The space between the blocks and between the plots was 1.00 and 0.50 m, respectively. Thirty days old day seedlings were transplanted maintaining a row to row distance of 25 cm and plant to plant distance of 30 cm. Light irrigation was given immediately after transplanting. The transplants were shaded for a few days with the half of banana leaf sheath to protect them from scorching sunshine. The transplants however were kept open at night to allow them to receive dew. The treatments were control (no spray), field sanitation, extracts of neem (*Azadirachta indica*), mahogany (*Swietenia mahagoni*), koromcha (*Carissa carandas*), garlic (*Allium sativum*) and combined extracts of neem-mahogany-koromcha and neem-mahogany-garlic and a broad-spectrum chemical fungicide Ridomil (active ingredient; metal axyl and copper oxychloride) 50 WP @ 0.2%, which was used as a positive control.

Plant extraction: The plant parts listed in Table 1 were used in this study and these were collected from the Horticulture centre, Bangladesh Agricultural University, Mymensingh. Procedure of making the plant extracts and application rate to plants was followed as described by Kabir *et al*. (2014). In brief, plant parts were washed with distilled water, blended in a blender machine and these extracts were sieved through a thin cloth. The plant extracts were diluted with water at 1:10 (w/v) dilution. The prepared fungicide and plant extracts were sprayed first at 21 day after transplanting and after that sprayed at 15 day intervals. The symptom bearing diseased leaves/infected plants serve as a source of inoculums, which were collected, removed and destroyed maintaining zero tolerance, therefore field sanitation was used as a treatment.

Data collection: Disease reactions such as disease incidence and severity were calculated as described by Than *et al*. (2008).

Number of infected plants per plot: The plants which had spot(s) at least one leaf was considered as infected. Total number of infected plants was recorder in each plot.

$$\text{Plant infection } (\%) = \frac{\text{Number of infection plants}}{\text{Total number of plants}} \times 100$$

Number of infected leaves per plant: Total number of leaves and number of infected leaves from the plants of each plot was calculated. The disease incidence was calculated as the following formula:

Table 1: Medicinal plant species and their parts used

Botanical names	Common names	Family names	Plant parts used
Azadirachta indica	Neem	Meliaceae	Leaf
Swietenia mahagoni	Mahogany	Meliaceae	Seed
Allium sativum	Garlic	Amaryllidaceae	Clove
Carissa carandas	Koromcha	Apocynaceae	Fruit

$$\text{Leaf infection } (\%) = \frac{\text{Number of infection leaves}}{\text{Total number of leaves}} \times 100$$

Percent leaf area diseased (LAD%): Disease severity was recorded as percent leaf area diseased. Eight infected plants were selected from each plot at random and twenty infected leaves of these infected plants were selected at random in each plot due to measure percent damaged area. The average values were used. The disease severity was calculated by the following formula:

$$\text{Leaf area diseased } (\%) = \frac{\text{Area of plant tissue affected by disease}}{\text{Total area}} \times 100$$

Harvesting: Flowerings of chilli plants were started at 40-45 day after transplanting. Plants were produced flowers and fruits continuously upto 3-4 months after transplanting. But all fruits didn't mature and ripe at a time. Those fruits were ripened, were harvested and continued by turns. After 4 months of transplanting, rest of the chilli fruits were ripened, harvested and weighed.

Cost and return analysis: The cost of production was analyzed in order to find out the most economic treatment of different integrated management practices. All input costs, including the cost for lease land and interest on running capital were considered for computing the cost of production. The interests were calculated @ 13% per year for 6 months. Cost and return analysis were done according to the procedure of Mondal and Mondal (2012) and Kabir *et al.* (2014). The Benefit Cost Ratio (BCR) was calculated as follows:

$$\text{Benefit Cost Ratio (BCR)} = \frac{\text{Gross return per ha (Tk)}}{\text{Total cost of production per ha (Tk)}}$$

Analysis of data: The collected data were statistically analyzed for analysis of variance (ANOVA) following Randomized Completely Block Design (RCBD) to verify the level of significance. Duncan's Multiple Range Test (DMRT) was done to compare the effect of the treatments (Gomez and Gomez, 1984).

RESULTS

Percent plant infection: All the treatments reduced the incidence of anthracnose of chilli disease significantly in regarding to plant infection compared to the control (untreated i.e. no spray) at 40, 80 and 120 Days After Transplanting (DAT). Among the treatments, the highest chilli plant infection 70.73-85.5% by anthracnose was observed in control at the observation dates 40, 80 and 120 DAT, while the lowest plant infection was obtained from Ridomil treated plots (14-24%) followed by combined application of neem (*Azadirachta indica*), mahogany (*Swietenia mahagoni*) and garlic (*Allium sativum*) or koromcha (*Carissa carandas*) (21-33%) treated plots. Highest

Table 2: Percent plant infection per plant due to at anthracnose of chilli at different days after transplanting as in influenced by some management practices

Treatments	Plant infection at DAT (%) 40	80	120	Reduction of plant infection over control treatment at 120 DAT (%)
Control	70.73[a]	74.38[a]	85.50[a]	-
Sanitation	62.66[b]	66.57[b]	69.16[b]	19
Neem	39.62[d]	43.45[c]	51.18[d]	40
Mahogany	44.44[c]	48.00[c]	55.35[c]	35
Koromcha	40.66[d]	44.56[c]	54.21[cd]	37
Garlic	32.14[e]	34.84[d]	45.73[e]	47
N-M-K	24.66[f]	31.31[de]	33.55[f]	61
N-M-G	21.43[f]	28.60[e]	32.52[f]	62
Ridomil	14.00[g]	18.50[f]	24.00[g]	72
LSD (0.05)	3.784	4.904	3.717	
CV (%)	5.62	6.53	4.28	

N: Neem, M: Mahogany, K: Koromcha, G: Garlic, N-M-K and N-M-G, integrated applications. Means followed by the same letter(s) in a column did not differ at 5% level by DMRT, DAT: Different days after transplanting

Table 3: Percent leaf infection per plant due to anthracnose of chilli at different days after transplanting as influenced by integrated management practices

Treatments	Leaf infection at DAT (%) 40	80	120	Reduction of leaf infection over control treatment at 120 DAT (%)
Control	24.98[a]	28.86[a]	32.32[a]	-
Sanitation	20.22[b]	24.00[b]	28.76[b]	11
Neem	18.12[c]	20.20[cd]	21.50[cd]	33
Mahogany	17.5cd	20.32[cd]	22.00[cd]	32
Koromcha	20.09[b]	22.16[bc]	24.00[c]	26
Garlic	16.00[de]	18.14[de]	20.06[d]	38
N-M-K	15.34[e]	16.42[e]	17.09[e]	47
N-M-G	10.20[f]	12.00[f]	14.40[e]	55
Ridomil	5.56[g]	6.760[g]	8.13[f]	75
LSD (0.05)	1.606	2.120	2.913	
CV (%)	5.64	6.53	8.05	

Means followed by the same letter(s) in a column did not differ at 5% level by DMRT, DAT: Different days after transplanting

reduction of percent plant infections at 120 DAT were obtained from Ridomil 50 WP spraying (71.9%) plots followed by combined organic combinations (60-62%) spraying plots (Table 2). This result indicates that all the treatments reduce the plant infection. Albeit the chemical Ridomil showed highest reduction, the combined plant extract applications also worked as good as chemical fungicide.

Percent leaf infection: Effects of different treatments on disease incidence were presented in Table 3. At all the observation dates (40, 80 and 120 DAT), leaf infections were reduced significantly by all the treatments compared to the control treatment. After treating the plants with Ridomil and combined plant extracts, lowest leaf infections (5-17%) were obtained from all the observation dates. The highest infection (32.32%) was measured in control plot, which was reduced highest (74.8%) by Ridomil and 47-55% by integrated application of neem, mahogany, and garlic or koromcha at 120 DAT (Table 3), indicating that other than chemical, highest leaf infection of chilli anthracnose was reduced, when the plant extracts were used as cocktail (in mix). This result suggests that the disease incidence of chilli anthracnose can be minimized by the combined application of plant extracts.

Leaf area diseased: Leaf Area Diseased (LAD) i.e. disease severity presented in Table 4 showed that the treatments had significant effect on percent leaf area diseased compared to control. At 40,

Table 4: Percent leaf area disease (LAD %) due to anthracnose of chilli at different days after transplanting as influenced by integrated management practices

Treatments	Leaf area at disease DAT (%) 40	80	120	Reduction of leaf infection over control treatment at 120 DAT (%)
Control	35.00[a]	40.62[a]	50.12[a]	-
Sanitation	32.56[b]	34.45[b]	42.75[b]	15
Neem	25.22[c]	27.40[c]	31.22[d]	38
Mahogany	24.44[c]	28.21[c]	34.84[c]	30
Koromcha	26.18[c]	28.48[c]	32.42[cd]	35
Garlic	19.86[d]	22.50[d]	26.31[e]	48
N-M-K	14.03[e]	18.38[e]	20.22[f]	60
N-M-G	10.12[f]	12.14[f]	14.12[g]	72
Ridomil	8.32[f]	10.08[g]	12.16[g]	76
LSD (0.05%)	2.361	1.499	2.515	
CV (%)	6.27	3.51	4.95	

Means followed by the same letter(s) in a column did not differ at 5% level by DMRT, DAT: Different days after transplanting, LAD: Leaf area disease

Table 5: Percent infected fruits per plot due to at anthracnose of chilli at different days after transplanting as in influenced by some management practices

Treatments	Infection fruits per plot at DAT (%) 80	120	Reduction of leaf infection over control treatment at 120 DAT (%)
Control	35.12[a]	52.12[a]	-
Sanitation	26.32[b]	29.42[b]	44
Neem	22.06[c]	24.12[cd]	54
Mahogany	24.06[bc]	25.50[c]	51
Koromcha	21.38[c]	23.41[d]	55
Garlic	23.69[bc]	25.53[c]	51
N-M-K	16.38[d]	20.82[e]	60
N-M-G	14.65[d]	18.27[f]	65
Ridomil	10.72[e]	12.25[g]	76
LSD (0.05)	2.564	1.957	
CV (%)	6.86	4.40	

Means followed by the same letter(s) in a column did not differ at 5% level by DMRT, DAT: Different days after transplanting

80 and 120 DAT, the highest leaf area diseased 35-50% was obtained from control treatment. At all the observations, the lowest LAD was observed in Ridomil (8-12%) and integrated application of neem, mahogany and garlic (10-14%) treated plots, which was significantly differed from control along with rest other treatments. The highest LAD inhibition 75.7% was measured from the chemical treatment Ridomil followed by 71.8% in organic cocktail treatment of neem, mahogany and garlic (Table 4), indicating that fungal infection was highly reduced as chemical by spraying of plant extracts as integration. The result suggests that integrated application of plant extracts is most efficient to reduce disease severity of chilli anthracnose, as chemical than single application of plant extract.

Fruit infection: The most devastating symptoms of anthracnose of chilli are expressed in the fruits. The symptoms of this disease appeared on ripened fruits, and therefore, sometimes the disease is called “ripe-fruit rot”. Circular and sunken lesions with black margins appeared on the ripe fruits. A pinkish mass of fungal spores covered the sunken-spot. In the advanced stage of the disease, the concentric rings with dark acervuli appeared on the affected parts. The spotted fruits dropped down prematurely and heavy losses resulted. Effect of different treatments on percent fruit infection at 80 and 120 DAT, all the treatments showed statistically significant effect on reducing percent fruit infection compared to control. The highest percent of fruit infection was observed in control 35-52%. The lowest percent of fruit infection was measured in Ridomil (10-12%) followed

Table 6: Effect of application of plant extracts against anthracnose disease on the yield performance of chilli (t ha^{-1})

Treatments	Yield (t ha^{-1})	Yield increase over control (%)
Control	0.75^{e}	-
Sanitation	1.000^{d}	0.25
Neem	1.280^{bc}	0.53
Mahogany	1.450^{ab}	0.7
Koromcha	1.250^{c}	0.5
Garlic	1.520^{a}	0.77
N-M-K	1.640^{a}	0.89
N-M-G	1.650^{a}	0.9
Ridomil	1.560^{a}	0.81
LSD (0.05)	0.1896	
CV (%)	8.05	

Means followed by the same letter(s) in a column did not differ at 5% level by DMRT

Table 7: Cost and return of chilli due to different management practices

Treatments	Yield (t ha^{-1})	Gross return (Tk ha^{-1})	Total cost of production (Tk ha^{-1})	Net return (Tk ha^{-1})	BCR
Control	0.750	75000	39545	35455	1.90
Sanitation	1.000	100000	40883	59117	2.44
Neem	1.280	128000	41006	86994	3.12
Mahogany	1.450	145000	41066	103934	3.53
Koromcha	1.250	125000	41563	83437	2.01
Garlic	1.520	152000	41330	110670	3.68
N-M-K	1.640	164000	41463	122537	3.96
N-M-G	1.650	165000	41522	123478	3.97
Ridomil	1.560	156000	44452	111548	3.35

Sale of dried chilli at Tk.100000 t^{-1}, Gross return: Total yield (t ha^{-1}) ×Tk. 100000, BCR: Benefit cost ratio

by 14-18% in combined application of neem, mahogany and garlic treatment, which was significant different from control as well as other treatments. At 120 DAT, maximum reduction of fungal infection on fruit was determined in Ridomil treated plot (76.5%) followed by integrated application of neem, mahogany and garlic or koromcha (60-65%) (Table 5), indicating that lower disease severity results lower fruit infection in chemical as well as combined treatments. The result suggests that plant extracts have the ability to reduce fruit infection on chilli, and the reduction ability is increased when more than one plant extracts are used in integration.

Fruit yield (t ha^{-1}): Effect of different treatments on yield of chilli in terms of dry weight (tons/hectare) was determined. Yield of chilli profoundly varied from one treatment to another treatment ranging from 0.75-1.65 t ha^{-1}. It was found that the highest yield 1.64-1.65 t ha^{-1} was recorded in combined application of plant extracts neem, mahogany and garlic or koromcha followed by 1.56 t ha^{-1} in Ridomil and 1.52 t ha^{-1} in garlic treatments and these treatments showed statistically similar effect among them, but statistically significant different from control as well as other treatments. The highest yield cv. 0.9% of chilli was found in integrated application of plant extracts (Table 6), indicating that yield of chilli increased due to decrease fruit infection. This result suggests that integrated application of plant extracts are more effective approach to restrict pathogen ingress efficiently, which increase yield of chilli fruit.

Benefit cost ratio: Besides the yield data, strict book-keeping was maintained on sale proceeds. Intensive care was taken in every steps of operation. All the values were transformed on unit hectare of agricultural land. Similarly total cost of production in taka per hectare had computed. Using the respective data, Benefit Cost Ratios (BCR) were measured in each of the treatments shown in Table 7. The results from the cost benefit analysis revealed that the maximum gross return (Tk. 165000) was obtained from the integrated application of neem, mahogany and garlic and corresponding cost of production was Tk. 41522. Thus, the highest benefit cost ratio, BCR 3.97

was obtained from this treatment. The second highest BCR 3.96 was also obtained from another combined application of neem, mahogany and koromcha. On the contrary, the chemical treatment showed BCR 3.35 and the control treatment showed the lowest BCR 1.9. These results indicated that integrated application of plant extracts reduced fungal ingress and cost of production, which ultimately increase fruit production and gross return.

DISCUSSION

Chilli is a profitable cash crop in Bangladesh. Like Indian sub-continent countries, chilli is also a popular member of spices and condiments for its special taste, flavour, colour and even long-term storage ability etc. in our country. Anthracnose disease of chilli caused by *Colletotrichum* spp. is one of the most devastating diseases of chilli in Bangladesh as well as chilli growing countries.

It is well understood that chemical fungicides are harmful to human health and environment; essential steps are being made, all over the world, to utilize plant extracts or bio-agents to control plant diseases. The best and effective measure to control this disease could be developing high yielding resistant cultivars. But so far, goal to incorporate sustainable resistance with minimum cost of yield reduction couldn't be explored. Thus, as in other sections of medicine, plant pathologist around the world is making efforts to replace the use of toxic chemicals by more environments friendly with harmless substances. By this time some plant extracts have already been found very effective and strong fungicidal effect, in some cases, more than that of chemical pesticides. Out of many reported promising plants, on the simple basis of availability garlic (*Allium sativum*), neem (*Azadirachta indica*), mahogany (*Swietenia mahagoni*) and koromcha (*Carissa carandas*) have been selected in this study to evaluate their combat ability against anthracnose disease of chilli caused by *Colletotrichum capsici* and find out the cost effective eco-friendly approach.

An experiment was conducted to find out the efficacy of integrated management approaches using various plants extracts on the incidence and severity of anthracnose disease of chilli. Determine the maximum benefitted approach was also aimed. Different application practices like sanitation, foliar spray of neem, mahogany, koromcha and garlic, singly and in combination (neem-mahogany-koromcha, neem-mahogany-garlic) along with negative control (no spray) and a positive control Ridomil @ 0.2% were applied. Plant infection, leaf infection, leaf area diseased (disease severity), fruit infection and yield (t ha^{-1}) data were collected in this study. To observe the effect on pathogenesis, three observations, 40, 80 and 120 Days After Transplanting (DAT) were made. Fruit disease was observed on the last two observation dates and the yield data was a cumulative of all the fruit collection from the respective plots. The chilli plants treated with chemical fungicide Ridomil @ 0.2% had shown the lowest disease intensity as well as severity parameters. The sanitation had shown the weakest disease control potential but significantly superior to the control. The plant extract treatments have shown significantly better control than control treatment, though they varied widely amongst themselves. The combined treatments neem-mahogany-koromcha and neem-mahogany-garlichad shown very strong response than single treatments, though lesser than the Ridomil in controlling anthracnose of chilli. In this study, all the treatments had significant effect on reducing this disease either in vegetative or reproductive stage and increased the yield.

Numbers of plant and leaf expressing anthracnose symptom were obtained highest in control and the lowest in the combined application of plant extracts of neem, mahogany and garlic or koromcha and in the chemical Ridomil 50WP at all the observation dates 40, 80 and 120 day after transplanting (Table 2 and 3). The maximum reduction of plant as well as leaf infection was obtained from Ridomil and combined approaches of plant extracts, similar results was obtained by Kabir *et al*. (2014), where they reported that organic treatments in mixed application reduced more *Alternaria*-causing plant and leaf infections in broccoli than individual applications. In general, combined effects of different approaches were more effective than individual approach in reducing disease incidence and severity in plants. This finding was also consistently in corroboration to the suggestions given by many researchers (Ashrafuzzaman and Khan, 1992; Rashid *et al*., 2007, 2010; Nashwa and Abo-Elyousr, 2012; Suratuzzaman *et al*., 1994; Perello *et al*., 2013a,b).

Reduction of disease severity (leaf area diseased, LAD) by anthracnose was found by all the treatments compared to control and the highest reduction was measured from the combined application of plant extracts of neem, mahogany and garlic on beside of chemical treatment Ridomil (Table 4). The results revealed that botanical extracts are capable of reducing anthracnose of chilli, quite significant even when applied singly. This result is in corroboration with some previous research works (Lakshmanan *et al*., 1990; Miah *et al*., 1990; Achimu and Schloesser, 1992; Nashwa and Abo-Elyousr, 2012; Ademe *et al*., 2013; Kabir *et al*., 2014). However, combinations of botanical extracts were more strong and effective even to a level that with minimum risk, such treatment can replace a highly effective chemical fungicidal treatment. The results reported recently by Kabir *et al*. (2014) with different botanicals in combination for controlling alternaria blight disease of broccoli are also in strong evidence with the present findings.

The highest reduction of fruit infection was measured from the chemical and integrated approaches of plant extracts, and the lowest from the control treatment. As a result, low yield was found in control plots and high yields in the plots where chemical as well as combined plant extracts were applied. The combined treatments neem-garlic-mahogany and neem-mahogany-koromcha showed highly significant effect on the yield of broccoli reported by Kabir *et al*. (2014). The fruit yield of different crops was increased by the use of different plant extracts are in agreement with the results of earlier investigations (Ngullie *et al*., 2010; Nashwa and Abo-Elyousr, 2012; Ademe *et al*., 2013).

The result from the benefit cost ratio analysis revealed that highest financial benefit was obtained from the combined treatments; BCR 3.96 in neem-mahogany-koromcha and BCR 3.97 in neem-mahogany-garlic (Table 7), which is in agreement with Kabir *et al*. (2014). The chemical treatment showed the lower return compared to integrated treatments due to high input cost of chemical. Kabir *et al*. (2014) revealed that the chemical approaches might be the fruitful in reducing anthracnose disease of chilli, the integrated application of plant extracts also controlled the disease efficiently and raised the yield as chemicals. It was manifest from the obtained results that comparatively low yields were accountable for the lower gross return and a lower BCR against each treatment. The results obtained through this study indicated that a judicially designed combined organic treatment even may be profitable than a chemical fungicide treatment.

CONCLUSION

These findings suggest that the incidence and severity of anthracnose of chilli disease can significantly be reduced by the combined use of neem (*Azadirachta indica*), mahogany (*Swietenia mahagoni*) and garlic (*Allium sativum*) @ 1:10 diluted suspension at least three times foliar spray after initiation of disease symptoms in order to have a higher profitable yield and eventual higher economic return without health risk as well as environmental pollution. However, meticulous with higher potency or efficacy must go on as the pathogenicity of the causal agent is quite dynamic. Therefore, the farmers may be advised to take an integrated approach, which should to raise a profitable production without polluting the environment and adding toxins in the food chain.

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