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Integrated Management of Stem Canker and Black Scurf of Potato

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ABSTRACT

The study was conducted to evaluate the efficacy of integrated management of stem canker and black scurf disease affecting the potato plant. The integrated management options were: T_1 = Poultry manure (PM) + seed trématent (ST) with Azoxystrobin (0.05%), T_2 = PM + ST-Azoxystrobin (0.10%), T_3= PM+ST-Boric acid (3.0%), T_4 = PM + ST-Carboxin (0.20%), T_5 = PM + ST- Carbendazim (0.10%), T_6 = PM + soil drenching (SD) - Azoxystrobin (0.05%), T_7 = PM + SD-Azoxystrobin (0.10%), T_8 = PM + SD-Carboxin (0.20%), T_9 = PM + SD-Carbendazim (0.10%) and T_{10} = Untreated control. The integrated management significantly influenced the disease incidence, yield attributes and yield of potato. The lowest disease incidence (11.2%) and percentage of disease index (4.58) were found in T_7 (poultry manure at 5 t ha^{-1} before 25 days of planting, DAP + soil drenching with Azoxystrobin at 0.10% during sowing and 45 DAP) followed by T_6 (PM 5 t ha^{-1} + soil drenching with Azoxystrobin at 0.05%). The minimum weight of russet (480 g $plot^{-1}$), deformed (450 g $plot^{-1}$) and Sclerotia infected (150 g $plot^{-1}$) tubers were also recorded in T_7. The highest healthy tuber (1900.05 g $plot^{-1}$) and tuber yield (22.4 t ha^{-1}) were found in the same treatment. Therefore, poultry manure 5 t ha^{-1} before 25 DAP + soils drenching with Azoxystrobin at 0.10% during sowing and 45 DAP can be recommended to produce healthy tubers and maximum tuber yield of potato.

Keywords: Potato, stem canker, black scurf, fungicide, poultry manure

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INTRODUCTION

Potato (*Solanum tuberosum*) is an important food crop in Bangladesh and has contributed to the nutrition of the poor in Bangladesh, who suffer from malnutrition. Potato has also contributed to the recent development of the Agro and Food industries in Bangladesh (Islam et al., 2013). The area under this crop is increasing gradually and farmers are adapting it as a cash crop. During 2014-2015, about 9.25 million tons of potato were produced from 0.47 million hectares of land and the national yield was 19.65 metric tons per hectare (BBS, 2015), which is lower compared to that of other potato-growing countries like North America and the Netherlands (Swaminathan, 2000). The main limiting factors for production of potato in Bangladesh are poor quality seeds, management factors, insect-pests and diseases. BARI Alu-7 (cv *Diamant*), the most popular variety of potato in Bangladesh, was used as a test variety; however, its disease resistance capacity is similar to that of other varieties. This variety is also susceptible to late blight disease.

In Bangladesh, a total of 39 diseases (both biotic and abiotic) of potato have been recorded (Ali & Khan, 1990). The major soil and tuber-borne diseases are black scurf, stem canker, bacterial wilt and common scab. Among them, stem canker and black scurf caused by *Rhizoctonia solani* (Kuhn) is the most common and destructive disease (Bains et al., 2002) and the pathogen is widespread in all potato-growing countries (Ali & Dey, 1994; Jager et al., 1996; Bains et al., 2002; El-Bakali & Martin, 2006). *Rhizoctonia solani* infects the underground stem and produces necrosis called stem canker, while tuber infection produces symptoms on the skin in the form of black sclerotia, called black scurf. Canker is commonly known as black scurf. In Bangladesh, fungicides on potato crops generally show little effect on *R. solani* attack under field conditions. Therefore, Azoxystrobin (trade name Amistar), a broad-spectrum fungicide from the strobilurin group, was tested along with poultry manure. Djelbali and Belhassen (2010) reported that the applications of Pencycuron and Azoxystrobin on seed potato and/or in-furrow have reduced the percentage of infection of Nicola progeny tubers by *R. solani* black scurf. The application of Azoxystrobin on seed potato and in-furrow proved to be of superior efficacy in reducing the percentage and the level of infection of Nicola progeny tubers by *R. solani* black scurf.

The common scab of potato (*Streptomyces scabies*) was effectively managed by an organic amendment through poultry manure (@ 2 t ha^{-1}) with bio-agent *Pseudomonas fluorescens* (Chaudari et al., 2003). The weight of black scurf tubers was minimum when the integrated approaches of poultry manure (PM) + seed Carbendazim (0.1%) and drenching was applied. Integration of PM + Carboxin (0.2%) soil drenching was found to be effective (Hossain et al., 2009). Hossain et al. (2007) reported that use of poultry manure and seed treatment with Carboxin and poultry manure and soil drenching with Carbendazim showed better performance in reducing stem canker and black scurf disease of potato. *Rhizoctonia* does not contest very well with other microbes in the soil. Increasing the rate of poultry manure decomposition decreases the growth rate of *Rhizoctonia*. Poultry manure decomposition also releases carbon dioxide, which reduces the competitive ability of the pathogen. The fungus is not an efficient cellulose decomposer, so soil populations are greatly reduced by competing microflora and less disease is observed (Phillip & Elisabeth, 2017).

Many researchers have attempted to control black scurf and stem canker of potato. The single approach of a control measure in many cases was not adequate for controlling the disease. In Bangladesh, there is no report on the research of any aspect of integrated management of the disease. Under the circumstances, developing a package of integrated management of the diseases is of prime need. Economic and eco-friendly methods of controlling black scurf and stem canker of potato are urgently needed. Considering the above facts, the present study was initiated to formulate integrated management of stem canker and black scurf of potato.

MATERIALS AND METHOD

Experimental Location and Crop Characteristics

An experiment was conducted at Tuber Crops Research Centre, Bangladesh Agricultural Research Institute (BARI), Bogra during the 2009-2010 cropping season. The experimental site was located in Tista Meander Floodplain Soil (AEZ-3) at about N-24^0 78´ and E-89^0 35´; it has a mean elevation of 22 m above sea level. The experiment location was on high land and had sandy loam soil. The soil was acidic (pH 5.6) in nature. Potato is grown here in the Rabi season (November to March). The test crop was potato (*Solanum tuberosum* L.) cv. BARI Alu-7 (Diamant), collected from the Breeder Seed Production Centre, Debigonj. BARI Alu-7 tubers are white, oval, medium-to-large, smooth skinned, light yellow in flesh, shallow eyed. Its yield is 25-35 t ha^{-1} and it is the most popular variety of potato in Bangladesh**.** It is susceptible to late blight disease.

Experimental Design, Fertilizer Application, Treatment and Intercultural Operation

The experiment was laid out in a randomised complete block design (RCBD) with four replications. Urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum, zinc sulphate and boric acid were applied at the rate of 360, 220, 250, 120, 14 and 6 kg per hectare, respectively. The entire amount of TSP, MoP, gypsum, zinc sulphate, boron and half of urea were applied at the time of final land preparation. The remaining amount of urea was applied at 30 DAP (days after planting). The integrated treatments were: T_1 = Poultry manure (PM) + seed trématent (ST) with Azoxystrobin (trade name Amistar) (0.05%), T_2 = PM +

ST-Azoxystrobin (0.10%), T_3 = PM + ST-Boric acid (3.0%), T_4 = PM + ST-Carboxin (trade name Provax) (0.20%), T_5 = PM + ST-Carbendazim (trade name Bavistin) (0.10%), T_6 = PM + SD-Azoxystrobin (0.05%), T_7 = PM + SD-Azoxystrobin (0.10%), T_8 = PM + SD-Carboxin (0.20%), T_9 = PM + SD-Carbendazim (0.10%) and T_{10} = Untreated control. The chemicals were used both as seed treatment (ST) and soil drenching (SD). After treatment, the tubers were kept in the shade for 24 hours. The chemicals were drenched just after sowing in furrows at 45 DAP (days after planting). The poultry manure (5 tha^{-1}) was incorporated into the soil and mixed properly before 25 DAP. Intercultural operations such as weeding and mulching were done as and when required. Irrigation was carried out four times during the whole growing season. The first irrigation was light, applied at 7 DAP to ensure proper germination. The second irrigation was carried out at 30 DAP followed by earthing and side-dressing (urea fertilisers). The third and fourth irrigation was done at 48 and 63 DAP, respectively. Dithen M45 2 g L^{-1} was sprayed at 50 DAP to prevent late blight disease.

Potato Tuber Planting

The study was conducted in previously *Rhizoctonia solani* infested soil. Potato seed tubers were planted with a spacing of 60 cm × 25 cm on 20 November, 2009 and a crop was was harvested on 25 February, 2010.

Data Collection

The germination percentage, number of stems per hill and plant height were recorded at 30, 50 and 60 DAP, respectively. The yield data were noted at harvest. The disease incidence (%) and percent disease index (PDI) were assessed at 70 DAP. Twenty plants were randomly selected from each unit plot at 70 DAP, uprooted carefully, washed under running tap water and checked for infection to record the disease incidence. The numbers of infected and healthy plants were counted and the percent disease incidence was calculated based on the total number of plants checked according to the formulae:

$$\textit{Disease incidence}\ (\%) = \frac{\text{Number of infected plants}}{\text{Total number of plants checked}} \times 100$$

At 70 DAP, the severity of stolon infection was indexed on a 0-6 indexing scale (Bakr et al., 2010), where 0 = No symptom on stolon, 1 = Minute brown lesion on stolon or root, 2 = Moderately brown lesion on stolon and curling tendency on central leaf, 3 = Stolon symptom discoloured accompanied by brown discolouration on roots, 4 = Brown to black discolouration on underground parts, tissue discolouration and curling of growing leaves, 5 = Profuse emerging of auxiliary leaves, leaf size reduced markedly and pale green on leaf margin, and 6 = Production of aerial tuber with the colour green. Finally it was converted into percent disease index (PDI) following the formulae outline by Dey et al. (2010).

Statistical Analysis

The analysis of variance (ANOVA) for various crop characteristics and disease incidence was performed following the F test. When F was significant at the $p<0.05$ level, treatment means were separated using the DMRT (Steel & Torii, 1960) test. Data were analysed following standard procedure using SAS software (version 9.3). Computation and preparation of graphs were done using the Microsoft Excel 2003 Programme.

RESULTS

Integrated disease management significantly influenced plant growth, disease incidence, tuber quality and tuber yield of potatoes.

Effect of Integrated Disease Management on Plant Growth

Tuber germination (%) and plant growth were significantly influenced by the integrated management of black scurf and stem canker.

Table 1
Effect of integrated management of black scurf and stem canker on germination and growth parameters of potato

Treatment Combination	Germination (%)	No. of Stem Hill^{-1}	Plant Height (cm)
T_1 = PM + ST-Azoxystrobin (0.05%)	90.41 ^{abc} (71.96)	4.75 ^{abc}	55.17
T_2 = PM + ST-Azoxystrobin (0.10%)	91.25 ^{abc} (72.82)	4.60 ^{abc}	56.40
T_3 = PM + ST-Boric acid (3.0%)	89.16 ^{bc} (70.78)	4.38 ^{abc}	55.70
T_4 = PM + ST-Carboxin (0.20%)	92.08 ^{ab} (73.80)	4.95 ^{abc}	55.80
T_5 = PM + ST-Carbendazim (0.10%)	91.66 ^{abc} (72.42)	4.28 ^{cd}	51.63
T_6 = PM + SD-Azoxystrobin (0.05%)	92.49 ^{abc} (74.38)	4.80 ^{abc}	57.95
T_7 = PM + SD-Azoxystrobin (0.10%)	94.17^{a} (76.27)	5.25 ^{a}	58.65
T_8 = PM + SD-Carboxin (0.20%)	91.66 ^{abc} (72.42)	4.95 ^{abc}	56.95
T_9 = PM + SD-Carbendazim (0.10%)	89.58 ^{abc} (71.17)	4.98 ^{ab}	53.38
T_{10} = Untreated control	87.50 ^{c} (69.39)	3.88 ^{d}	57.50
CV%	1.78	10.59	9.56

Means followed by the same letter within a column did not differ significantly at the 5% level of DMRT.
Note: PM = Poultry manure, ST = Seed tuber treatment, SD = Soil drenching

Maximum germination (94.2%) was found in T_7 (PR + SD-Azoxystrobin, 0.10%), followed by T_6 (PR + SD-Azoxystrobin, 0.05%) and T_4 (PR + SD-Carboxin, 0.20%). Minimum germination (87.5%) was recorded in the untreated control. Similarly, T_7 showed the highest number of stem hill^{-1} (5.25) and plant height (58.65 cm) followed by T_6. The lowest stem hill^{-1} (3.88) and plant height (51.6 cm) were noted in the control (Table 1).

Incidence of Stem Canker and Percent Disease Index (PDI)

The incidence of stem canker and percent disease index (PDI) were significantly varied among the treatments. The highest disease incidence (%) of stem canker (28.75%) was found in the control, which was significantly higher than that of the other treatments (Table 2 and Figure 1).

T_7: Integrated management of poultry manure + T_{10}: Untreated Control soil drenching (Azoxystrobin 0.10%)

Figure 1. Effect of integrated management on the incidence of stem canker

T_3 (PR + ST-Boric acid, 3.0%) showed the second highest incidence of stem canker (22.50%), followed by T_9 (PR + SD Carbendazim, 0.10%). The control showed the highest percent disease index (17.7%), which was significantly higher than that of the other treatment combinations. The second highest percent disease index (11.46%) was also recorded in T_3, which was statistically similar to T_5 (PR + ST-Carbendazim, 0.10%) and T_9. The lowest incidence (%) of stem canker (11.25%) and percent disease index (4.58%) were found in T_7 (Table 2 and Figure 1).

Table 2
Effect of integrated management options on the incidence of stem canker of potato

Treatment Combination	Incidence (%) of Stem Canker	Percent Disease Index (PDI)
T_1 = PM + ST-Azoxystrobin (0.05%)	16.25 cde (4.02)	7.49 ef
T_2 = PM + ST-Azoxystrobin (0.10%)	15.00 def (3.87)	6.24 fg
T_3 = PM + ST-Boric acid (3.0%)	22.5 b (4.74)	11.46 b
T_4 = PM + ST-Carboxin (0.20%)	17.50 cd (4.18)	8.54 cde
T_5 = PM + ST-Carbendazim (0.10%)	20.00 bc (4.46)	10.41 bc
T_6 = PM + SD-Azoxystrobin (0.05%)	13.33 efg (3.65)	5.61 g
T_7 = PM + SD- Azoxystrobin (0.10%)	11.25 g (3.33)	4.58 g
T_8 = PM + SD-Carboxin (0.20%)	16.66 cde (4.08)	7.91 def
T_9 = PM + SD-Carbendazim (0.10%)	21.66 b (4.64)	10.21 bcd
T_{10} = Untreated control	28.75 a (5.35)	17.71 a
CV %	7.39	8.75

Means followed by the same letter within a column did not differ significantly at the 5% level of DMRT.

Effect of Integrated Management on Tuber Quality

The data on the number of inflected tubers have different types of symptom. Russet, deformed and sclerotia-bearing tubers were varied significantly due to integrated management option (Table 3). The number of russet-bearing tubers ranged from 7.00 to 16.25, the highest number seen in the control and the lowest (7.00) in T_7. The maximum number of deformed tubers (15.00) was found in the control, followed by T_9 and T_1 (PR + ST with Azoxystrobin, 0.05%). The minimum number of deformed tubers was also noted in T_7. The sclerotia-bearing tubers were significantly varied among the treatments. It ranged from 2.75 to 52.00. The control showed the highest number of sclerotia-bearing tubers (52.00), which was significantly higher than in the other management options. T_3 showed the second highest number of sclerotia-bearing tubers (15.5), which was identical to T_5. The lowest number of sclerotia-bearing tubers (2.75) was found in T_7 (Table 3). Healthy tubers were significantly influenced by the integrated management option. The highest number of healthy tubers (297.1 tubers plot^{-1})

was found in T_7, which was statistically identical to T_6 but different from the rest of the treatments (Table 3 and Figure 2). The lowest number of healthy tubers (159.0 tubers plot^{-1}) was recorded in the control.

T_7: Integrated management with poultry T_{10}: Untreated control manure + soil drenching with Azoxystrobin

Figure 2. Effect of integrated management on the potato tubers

Table 3
Effect of integrated management options on the number of black scurf and healthy tubers

Treatment Combination	Number of Infected Tuber Plot^{-1}			
	Russet Tuber	Deformed Tuber	Sclerotia Bearing Tuber	Total Healthy Tuber
T_1 = PM + ST-Azoxystrobin (0.05%)	12.25^{b}	11.25^{ab}	5.25^{efg}	260.05 c
T_2 = PM + ST-Azoxystrobin (0.10%)	10.75^{bc}	9.05^{bc}	4.75^{efg}	275.05 b
T_3 = PM + ST-Boric acid (3.0%)	10.00^{bc}	9.25^{bc}	15.50^{b}	221.05 ef
T_4 = PM + ST-Carboxin (0.20%)	11.00^{bc}	11.75^{ab}	7.00^{cde}	241.00 d
T_5 = PM + ST-Carbendazim (0.10%)	10.25^{bc}	8.75^{bc}	13.25^{b}	217.03 f
T_6 = PM + SD- Azoxystrobin (0.05%)	8.75^{bc}	8.00^{bc}	4.00^{fg}	291.00 a
T_7 = PM + SD-Azoxystrobin (0.10%)	7.00^{c}	6.50^{c}	2.75^{g}	297.08 a
T_8 = PM + SD-Carboxin (0.20%)	11.50^{b}	11.00^{b}	6.50^{def}	272.10 b
T_9 = PM + SD-Carbendazim (0.10%)	10.25^{bc}	12.00^{ab}	7.75^{cd}	238.00 d
T_{10} = Untreated control	16.25^{a}	15.00^{a}	52.00^{a}	159.00 g
CV %	13.03	13.19	16.16	13.37

Means followed by the same letter within a column did not differ significantly at the 5% level of DMRT.

Effect of Integrated Management on the Weight of Infected and Healthy Tuber

The weight of russet, deformed and sclerotia-bearing tubers was significantly varied due to application of different integrated management options against canker disease of potato (Table 4). The maximum weight of russet tubers (1100 g plot^{-1}), deformed tubers (1330 g plot^{-1}) and sclerotia-bearing tubers (3530 g plot^{-1}) was found in the control (Table 4); the weight was significantly higher than that of the tubers in the other treatments. The minimum weight of russet tubers (480 g plot^{-1}), deformed tubers (450 g plot^{-1}) and selerotia-bearing tubers (150 g plot^{-1}) was observed in T_7. The weight of healthy tubers was also significantly influenced by the different treatments. T_7 showed the highest weight of healthy tubers (1900 g plot^{-1}); this was statistically similar to T_6 and T_8 (PR + SD-Carboxin, 0.20%). The lowest weight of healthy tubers (883 g plot^{-1}) was noted in the control (Table 4).

Table 4
Effect of integrated management options on the weight of black scurf infected tubers

Treatment Combination	Weight of Infected and Healthy Tubers Plot^{-1} (g)			
	Russet Tubers	Deformed Tubers	Sclerotia-Bearing Tubers	Weight of Healthy Tubers
T_1 = PM + ST-Azoxystrobin (0.05%)	800 ^{b}	780 ^{bc}	350 ^{def}	1500.68^{cd}
T_2 = PM + ST-Azoxystrobin (0.10%)	680 ^{bc}	650 ^{bcd}	300 ^{def}	1600.9^{bc}
T_3 = PM + ST-Boric acid (3.0%)	730 ^{bc}	630 ^{bcd}	1080 ^{b}	1400.35^{d}
T_4 = PM + ST-Carboxin (0.20%)	600 ^{bc}	800 ^{b}	500 ^{cd}	1500.27^{cd}
T_5 = PM + ST-Carbendazim (0.10%)	700 ^{bc}	600 ^{bcd}	950 ^{b}	1300.57^{d}
T_6 = PM + SD-Azoxystrobin (0.05%)	600 ^{b}	550 ^{cd}	280 ^{ef}	1800.0^{ab}
T_7 = PM + SD-Azoxystrobin (0.10%)	480 ^{c}	450 ^{d}	150 ^{f}	1900.05^{a}
T_8 = PM + SD-Carboxin (0.20%)	780 ^{b}	750 ^{bc}	450 ^{cde}	1800.8^{ab}
T_9 = PM + SD-Carbendazim (0.10%)	730 ^{bc}	800 ^{b}	600 ^{c}	1600.05^{bc}
T_{10} = Untreated control	1100 ^{a}	1330 ^{a}	3530 ^{a}	883^{e}
CV %	12.16	18.77	17.21	8.78

Means followed by the same letter in the same column did not differ significantly at the 5% level of DMRT.

Effect of Integrated Management on the Tuber Yield of Potato

The potato tuber yield was significantly influenced by the integrated management option of stem canker and black scurf disease. The potato yield ranged from 16.24 to 22.36 t ha^{-1}. The highest tuber yield (22.36 t ha^{-1}) was found in T_7, where soil was drenched with Azoxystrobin (0.10%) and poultry manure was used. T_6 showed the second highest yield (20.60 t ha^{-1}), followed by T2 (20.55 t ha^{-1}). The lowest tuber yield (16.24 t ha^{-1}) was recorded in the untreated control (Table 5).

Table 5
Effect of integrated management options of black scurf and stem canker on the tuber yield of potato

Treatment combination	Tuber yield (t ha^{-1})
T_1 = PM + ST-Azoxystrobin (0.05%)	19.55 [abc]
T_2 = PM + ST-Azoxystrobin (0.10%)	20.60 [ab]
T_3 = PM + ST-Boric acid (3.0%)	18.58 [bcd]
T_4 = PM + ST-Carboxin (0.20%)	19.02 [bcd]
T_5 = PM + ST-Carbendazim (0.10%)	17.52 [cd]
T_6 = PM + SD-Azoxystrobin (0.05%)	20.55 [ab]
T_7 = PM + SD-Azoxystrobin (0.10%)	22.36 [a]
T_8 = PM + SD-Carboxin (0.20%)	18.99 [bcd]
T_9 = PM + SD-Carbendazim (0.10%)	18.33 [bcd]
T_{10} = Untreated control	16.24 [d]
CV %	9.28

Means followed by the same letter within a column did not differ significantly at the 5% level of DMRT

DISCUSSION

Stem canker and black scurf caused by *Rhizoctonia solani* is a very common and widespread disease of potato throughout Bangladesh (Ali & Dey, 1994). The management of this disease is not possible by a single control measure approach because of the nature of the soil and the very high degree of survivability of pathogens (Frank & Leach, 1980; Hide et al., 1973; Kumar, 1976). Therefore, the integration of chemical and organic substances is the best approach to control stem canker and black scurf disease of potato. It appeared from the results that incorporation of poultry manure (5 t ha^{-1}) at 25 days before planting, application of Azoxystrobin (0.1%) in furrows during sowing and soil drenching with Azoxystrobin (0.1%) at 45 days after sowing showed the better performance in controlling stem canker and black scurf disease of potato. Djelbali and Belhassen (2010) reported that the application of Pencycuron and Azoxystrobin on seed potato and/or in-furrow reduced the percentage of infection of Nicola progeny tubers by *R. solani* black scurf. The application of Azoxystrobin on seed potato and in-furrow proved to be of superior efficacy in reducing the percentage and level of infection of Nicola progeny tubers by *R. solani* black scurf in two years of experimentation. Integration of soil amendment by organic products and soil application of fungicide was reported by Sharma et al. (1995) as an effective management option against the disease. *Rhizoctonia* is not able to compete remarkably with other microbes in the soil. The growth rate of *Rhizoctonia* decreases with an increase in the decomposition rate of poultry manure. Poultry manure decomposition also releases carbon dioxide, which reduces the competitive ability of pathogens. *Rhizoctonia* is not an efficient cellulose decomposer, so soil populations are greatly reduced by competing microflora and less disease is observed (Phillip & Elisabeth, 2017). The possible mechanisms for pathogen suppression by poultry manure include inhibition of pathogen growth, pathogen survival and reduction of infection of the host (Hoitink & Grebus, 1994). First, beneficial microbial populations including poultry-manure-derived microorganisms compete for nutrients with plant pathogens in the rhizosphere zone (De Brito et al., 1995; Hoitink & Boehm, 1999). The second mechanism includes production of antibiotic compounds by beneficial microorganisms that are effective in controlling various plant pathogens (Hoitink et al., 1996). The third is parasitism and predation of soil-inhabiting pathogens by poultry-manure-inhabiting beneficial microorganisms (Hoitink & Boehm, 1999). Poultry manure caused a temporary initial increase in soil pH. This increase in pH was accompanied by an increase in ammonia levels and the release of this volatile toxic gas may have been involved in reducing the population levels of *S. scabies* (Conn & Lazarovits, 1999). Conn and Lazarovits also mentioned that application of fresh poultry manure was highly effective in reducing the incidence of Verticillium wilt, potato scab and the population of plant parasitic nematodes. The application of poultry manure to the soil not only reduced disease severity; it also increased the tuber yield of potato in this study. Organic manure may release some hormones or organic compounds that suppress stem canker disease. Organic amendments may exert stimulatory or inhibitory effects on microbial plant pathogen populations and disease development (Rahman et al., 2016). They may either prevent infection by activating soil microflora potentially competitive with or antagonistic to plant pathogens present in the soil or control plant pathogens by producing toxic compounds in the soil when they decompose in the soil (Narayanasamy, 2013; Swain et al., 2006).

Similar findings were also reported by many other researchers (Shaikh & Ghaffar, 2004; Hossain et al., 2007; Banyal et al., 2008) regarding the effects of soil amendment with poultry manure followed by soil drenching with a fungicide. This provides strong support for the results obtained from the integrated management options used in this study. These results were also supported by Naz (2006) and Mian (2007), who paved the way for black scurf disease management through integrated options. Similar observations for soil amendments with indifferent fungicides on other crops have been advocated by Banyal et al. (2008), Hossain et al. (2007), Hossain et al. (2009), Mian (2007), Naz (2006) and Sharma et al. (1975).

CONCLUSION

Integrated management significantly influenced disease incidence, yield attributes and yield of potato in this study. The lowest disease incidence (11.2%) and percent disease index (4.58) were found in T_7 (poultry manure at 5 t ha^{-1} before 25 days of planting, DAP + soil drenching with Azoxystrobin at 0.10% during sowing and 45 DAP) followed by T_6 (PM 5 t ha^{-1} + soil drenching with Azoxystrobin at 0.05%). The minimum weight of russet, deformed and sclerotia-infected tubers was also recorded in T_7. The highest number of healthy tubers and the highest tuber yield were found in the same treatment. Therefore, poultry manure 5 t ha^{-1} before 25 DAP + soil drenching with Azoxystrobin at 0.10% during sowing and 45 DAP can be recommended for producing healthy tubers and the maximum tuber yield of potato.

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