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INTEGRATED MANAGEMENT OF SEED BORNE PATHOGENIC FUNGI OF DIFFERENT VARIETIES OF COTTON (*GOSSYPIUM HIRSUTUM* L.)

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Abstract

Single and combined doses of fungicides, plant extracts, and antagonists were used to control of nine cotton pathogens through a pot experiment. A total of 19 treatments, and controls with or without inocula of the pathogen were tested. Out of 19 treatments, T1 (Tilt) and T11 (Tilt + *Azadirachta indica* + *Trichoderma viride*) exhibited maximum seed germination and seedling vigor index against *Aspergillus flavus*, *A. niger*, *Curvularia lunata*, *Fusarium nivale*, *Mucor* sp. and *A. tamarii*, *Colletotrichum gloeosporioides*, *F. moniliforme*, *Rhizoctonia solani* respectively. T5 (*T. viride*), T10 (Tilt + *Psidium guajava* + *T. viride*) and T14 (Tilt + *A. indica*) showed promising germination percentage and seedling vigor index against *A. flavus*, *R. solani* and *A. tamarii*, *F. nivale* and *A. niger*, *C. gloeosporioides*, *C. lunata*, *F. moniliforme*, *Mucor* sp. respectively. Among all the treatments, the combined use of Tilt + *A. indica* + *T. viride* showed the best results for reducing the growth of the test pathogens and increasing the germination percentage of seeds.

Keywords: Integrated management, Pathogenic fungi, Cotton varieties, Bangladesh.

Introduction

Cotton is called the "The King of Fibers", the second important cash crop next to jute in Bangladesh. Seeds free from fungal infection are very much essential for good plant production. Seed-borne fungi affect the quality of seeds at all stages of production, from the cropping stages until post-harvest, processing, storage, and marketing (Machado *et al*., 2002). They are responsible for both pre and post-emergence death of grains, affect seedling vigor, reduction in germination, and variation in plant morphology (Van Du *et al*., 2001; Rajput *et al*., 2005; Niaz and Dawar, 2009).

Cotton production is being reduced every year for some injurious plant pathogens and most of which are fungi. *Alternaria*, *Colletotrichum*, *Fusarium*, *Macrophomina*, *Rhizopus*, *Rhizoctonia*, *Fusarium*, *Helminthosporium*, *Curvularia*, *Mucor*, *Penicillium*, *Aspergillus*, *Sclerotium*, *Cephalosporium*, *Myrithecium*, *Trichoderma* and *Xanthomonas* are some seed-borne pathogenic fungi which are most repeatedly identified from cotton

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seeds and seedlings (Khan and Kausar, 1967; Roy and Bourland, 1982; Minton and Garber, 1983; Seneewong *et al.*, 1991; Asran-Amal *et al*., 2005; Colyer and Vernon, 2005; Mikhail *et al.*, 2009; Fard and Mojeni, 2011). Numerous seed-borne fungal pathogens have been reported by different researchers that reduce the percentage of germination and seedling vigor of cotton seeds (Jeyalakshmi *et al.*, 1999; Eisa *et al*., 2007; Tomar *et al*., 2012).

Alternaria alternata, Aspergillus niger, Fusarium oxysporum, F. moniliforme, F. semitectum, F. acuminatum, F. solani, Pythium ultimum, Rhizopus arrhizus, Rhizoctonia solani and some other fungi were also found from cotton seeds and most of these fungi were pathogenic to cotton (Fulton and Bollenbacher, 1959; Mansoori and Hamdolahzadeh, 1995). Untill now, 20 types of symptoms and 52 species of fungi have been reported on cotton plants from various cotton-growing areas of the world (Wikipedia, 2022). A total of 14 cotton diseases were reported in Bangladesh, of which 12 are caused by fungal pathogens (BARI, 1990).

Controlling of seed-borne pathogens is the major step in any agricultural crop production and protection program. Proper seed treatment measures can substantially improve the quality of seeds and significantly increase the yield. Fungicides are the best defensive component to control cotton disease but it hazardous to human health and the environment. Biological control of plant diseases using antagonistic microorganisms is revealed as an alternative to hazardous and expensive chemical pesticides (Emmert and Handelsman, 1999).

Much researches has been done on cotton pathogens and their management. But information on combined or integrated management of cotton seed-borne pathogens is insufficient. Considering the facts mentioned above, an integrated or combined program was done to control the seed-borne pathogens of cotton. The present study was commenced to screen out the combined effect of some fungicides, plant extracts and antagonists on cotton pathogens and their impact on yield contributing factors.

Materials and Methods

Preparation of soil and treatments: An integrated approach was followed (Waris *et al*., 2018) with some modifications. The experiment was carried out in the earthen pot in the Botanical Garden, Department of Botany, University of Dhaka, to count the single and combined doses of fungicides, plant extracts, and antagonists for managing nine cotton pathogens. A total of 19 treatments and controls with or without inocula of the pathogens

were tested. The earthen pots (each 20 cm in diameter) were filled with 2 kg soil (mixing with sandy loam soil and decomposing organic fertilizer at 4:1) and treated with formalin.

The treatments and their combinations were : T1 = Tilt, T2 = Contaf, T3 = *Psidium guajava,* T4 = *Azadirachta indica,* T5 = *Trichoderma viride,* T6 = Contaf + Tilt, T7 = *Psidium guajava* + *Azadirachta indica,* T8 = Contaf + *P. guajava* + *T. viride,* T9 = Contaf + *A. indica* + *T. viride,* T10 = Tilt + *P. guajava* + *T. viride,* T11 = Tilt + *A. indica* + *T. viride,* T12 = Contaf + *A. indica,* T13 = Contaf + *P. guajava,* T14 = Tilt + *A. indica,* T15 = Tilt + *P. guajava,* T16 = Contaf + Tilt + *P. guajava* + *A. indica,* T17 = Contaf + Tilt + *P. guajava* + *A. indica*+ *T. viride,* T18 = Control (Inoculated without treatment), T19 = Control (Uninoculated healthy seeds).

The seeds were surface sterilized with 10% chlorox solution for 5 minutes. The seeds were then washed with sterile distilled water 4-5 times. Spore suspensions were prepared from 10 days old culture using sterile distilled water. 10^7- 10^8 cfu/ml spores were contained by each spore suspension. Then the seeds were inoculated with an equal volume of spore suspension of each test fungus separately and left in sterilized petri plates for two hours. Then the inoculated seeds were treated with various combinations of fungicides, plant extracts, and biocontrol agents. The fungicides were mixed with appropriate amount of water for their respective dose. Spore suspension of antagonistic fungus was made with sterile distilled water. Plant extracts were also prepared as described above and treated to the pre-inoculated seeds. The seeds were then sown in 12″ x 8″ size pots containing sterile soil. The experimental design was CRD and RBD having 3 replications. Observations and data were recorded after 7, 14, and 21 days of seed germination. Final data were recorded after 21 days of germination. The results of seed germination percentage, seedling mortality, shoot length, root length, and seedling vigor index were recorded carefully. The experiment was performed two times.

Analysis of data: The data were analyzed following computer package MSTAT-C, and the means were compared using the Duncans Multiple Range Test (DMRT). The data were collected and evaluated by analysis of variance (ANOVA) using STAR statistical program.

Results and Discussion

Different treatments affect on seed quality parameters of 14 cotton varieties against *Aspergillus flavus, A. niger, A. tamarii, Colletotrichum gloeosporioides, Curvularia lunata, Fusarium nivale, F. moniliforme, Mucor* sp., and *Rhizoctonia solani* are presented

in Table 1 and Figs. 1-4. This study revealed that all the treatments could significantly reduce seed-borne fungi and improve the quality of seeds. Different seed treatments were compared with the control set based on seed germination, seedling mortality, root length, shoot length, and seedling vigor index (Table 1).

Combined effect of plant extracts, fungicides, and antagonists on seed quality parameters of cotton against *Aspergillus flavus:*

Seed inoculated with *Aspergillus flavus* showed 39.44-88.23% germination. Out of 17 treatments, T1 showed the highest (88.23%) germination percentage, whereas the lowest (39.44%) was recorded by T12. Six treatments *viz.* T1, T5, T10, T14, T11, and T13 showed promising results compared to the control. The highest seedling vigor index (811.72) was observed in T1, and the lowest was found in T12 (410.17). Seedling mortality was also counted after 21 days of germination. The maximum seedling mortality (60%) was found in T17 and the minimum (20%) in T3 treatments. In this experiment, the maximum shoot length (7.2 cm) was recorded in T11 and minimum (5.6 cm) in T9, whereas the highest root length (3.6 cm) was noticed in T15 and the lowest (1.9 cm) in T9 (Table 1).

Combined effect of plant extracts, fungicides, and antagonists on seed quality parameters of cotton against *Aspergillus niger:*

Amongst 17 treatments, 5 treatments *viz.* T1, T5, T10, T14 and T11 exhibited best results compared to control. Among these treatments, T1 showed the highest (87.21%) germination percentage, whereas the lowest (43.67%) was recorded in T6. The highest seedling vigor index (898.26) was observed in T1 and lowest in T6 (384.23). The maximum seedling mortality (60.2%) was found in T17 and the minimum (21.20%) in T15 treatments after 21 days of germination. In the present investigation, the maximum shoot length (7.6 cm) was recorded by T11 and the minimum (5.6 cm) in T15, whereas, the highest root length (3.6 cm) was noticed in T10 and lowest (1.9 cm) in T9 (Table 1).

Joint effect of fungicides, plant extracts, and antagonists on seed quality parameters of cotton against *Aspergillus tamarii:*

Out of 17 treatments, 3 treatments *viz.* T5, T10 and T14 exhibited the best results compared to the control. Among these treatments, T11 showed the highest (86.34%) germination percentage, whereas the lowest (37.78%) was recorded in T12. The highest

Fig. 1. Combined effect of seed treatment with fungicides, leaf extracts and antagonists on seed quality parameters of cotton varieties. T1. Tilt, T2. Contaf, T3. *Psidium guajava,* T4. *Azadirachta indica* and T5. *Trichoderma viride*.

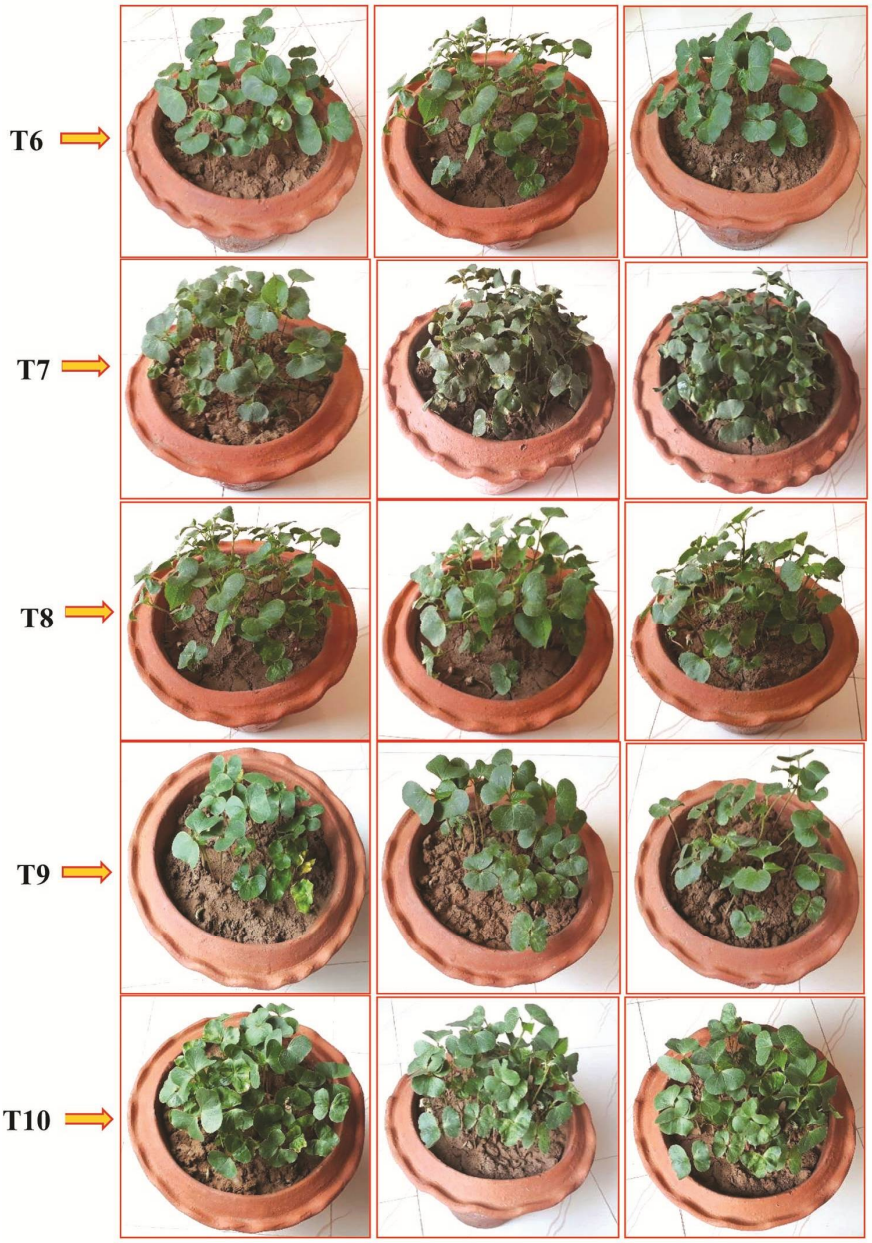

Fig. 2. Combined effect of seed treatment with fungicides, leaf extracts and antagonists on seed quality parameters of cotton varieties. T6. Contaf + Tilt, T7. *Psidium guajava* + *Azadirachta indica*, T8. Contaf + *P. guajava* + *Trichoderma viride*, T9. Contaf + *A. indica* + *T. viride* and T10. Tilt + *P. guajava* + *T. viride*.

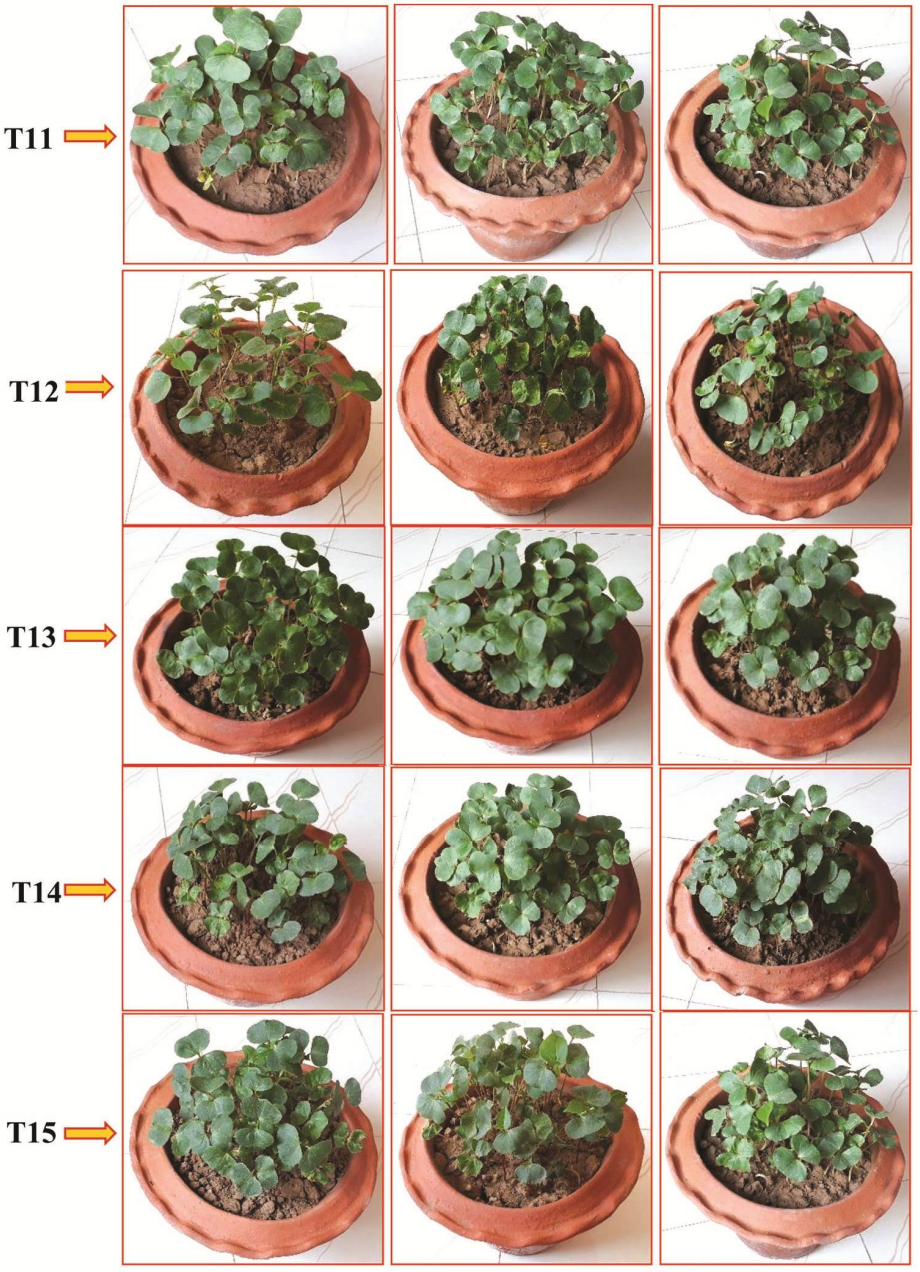

Fig. 3. Combined effect of seed treatment with fungicides, leaf extracts and antagonists on seed quality parameters of cotton varieties. T11. Tilt + *A. indica* + *T. viride*, T12. Contaf + *A. indica*, T13. Contaf + *Psidium guajava*, T14. Tilt + *Azadirachta indica* and T15. Tilt + *P. guajava*.

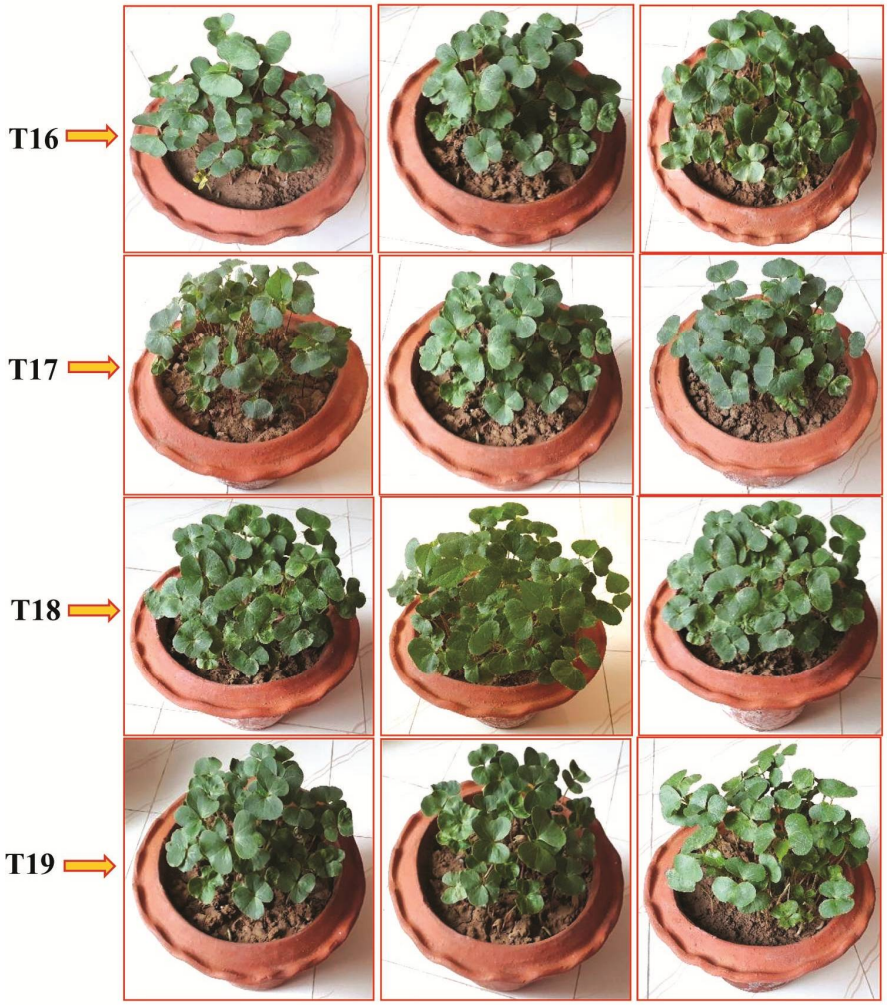

Fig. 4. Combined effect of seed treatment with fungicides, leaf extracts and antagonists on seed quality parameters of cotton varieties. T16. Contaf + Tilt + *P. guajava* + *A. indica*, T17. Contaf + Tilt + *P. guajava* + *A. indica* + *Trichoderma viride*, T18. Inoculated without treatment and T19. Control or Uninoculated healthy seeds.

seedling vigor index (923.84) was observed in T11, and the lowest was observed in T12 (374.02). The maximum seedling mortality (61.23%) was found in T17 and minimum (27.58%) in T3 treatments after 21 days of germination. In the present experiment, the maximum shoot length (7.3 cm) was recorded by T11 and the minimum (5.4 cm) in T16, whereas, the highest root length (3.8 cm) was noticed in T17 and the lowest (1.3 cm) in T9 (Table 1).

Table 1. Effect of different treatments with fungicides, leaf extracts and antagonists on seed quality parameters of cotton.

Treat-ments	Seed quality parameters against test pathogens														
	Aspergillus flavus					*Aspergillus niger*					*Aspergillus tamarii*				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
T1	**88.23^{a}**	22.23^{j}	2.9^{bcd}	6.3^{abcd}	**811.72^{a}**	**87.21^{a}**	45.56^{j}	3.2^{bcd}	7.1^{abcd}	**898.26^{a}**	70.34^{f}	55.56^{abc}	2.3^{cde}	6.7^{ab}	633.06^{j}
T2	49.92^{bcdef}	40.23^{f}	2.9^{bcd}	5.9^{d}	439.23^{c}	68.45^{bcdef}	38.40^{f}	3.1^{bcd}	6.2^{d}	636.59^{c}	61.56^{l}	44.90^{cdef}	2.4^{bcde}	6.3^{bcde}	535.57^{m}
T3	58.78^{abcdef}	20.0^{j}	3.0^{a}	6.4^{abcd}	552.53^{k}	55.65^{abcdef}	25.05^{j}	2.7^{a}	6.3^{abcd}	500.85^{k}	51.67^{c}	27.58^{hi}	2.5^{bcde}	5.7^{def}	423.70^{p}
T4	70.60^{abcdef}	57.14^{b}	2.8^{bcd}	6.2^{abcd}	635.40^{h}	71.78^{abcdef}	35.8^{b}	2.8^{bcd}	6.4^{abcd}	660.38^{h}	68.45^{h}	56.89^{ab}	2.9^{abcd}	6.8^{abcd}	663.97^{f}
T5	84.12^{abc}	33.18^{h}	3.3^{ab}	6.3^{abcd}	807.55^{b}	80.23^{abcdef}	24.43^{h}	2.8^{ab}	6.0^{abcd}	706.12^{b}	77.44^{c}	38.45^{efgh}	3.0^{abcd}	6.1^{bcdef}	704.70^{d}
T6	40.23^{ef}	49.56^{c}	2.2^{cd}	5.9^{d}	325.86^{r}	43.67^{ef}	50.56^{c}	2.7^{cd}	6.1^{d}	384.23^{r}	41.78^{r}	53.77^{abcd}	3.1^{abcd}	6.8^{ab}	413.62^{q}
T7	67.45^{abcdef}	37.40^{g}	3.2^{abc}	6.5^{abcd}	654.27^{g}	69.90^{abcdef}	42.78^{g}	3.3^{abc}	6.7^{abcd}	699.0^{g}	63.88^{k}	47.56^{bcdef}	3.6^{ab}	6.6^{abc}	651.56^{h}
T8	47.16^{cdef}	38.55^{g}	2.7^{bcd}	5.7^{d}	396.14^{q}	53.67^{cdef}	36.17^{g}	2.9^{bcd}	5.6^{d}	461.56^{q}	46.48^{p}	35.55^{fghi}	2.2^{de}	5.8^{cdef}	611.84^{k}
T9	41.28^{def}	37.89^{g}	1.9^{d}	5.6^{d}	313.73^{s}	45.90^{def}	35.58^{g}	1.9^{d}	5.9^{d}	358.02^{s}	43.44^{q}	35.74^{i}	1.3^{e}	5.6^{ef}	299.74^{s}
T10	75.30^{abc}	45.0^{e}	3.5^{ab}	7.0^{abc}	791.18^{c}	78.55^{abc}	25.18^{e}	3.6^{ab}	6.5^{abc}	793.36^{c}	79.49^{b}	37.77^{efghi}	3.5^{abc}	6.8^{ab}	818.75^{b}
T11	73.35^{abcd}	33.12^{h}	2.8^{bcd}	7.2^{a}	733.50^{e}	76.78^{abcd}	25.78^{h}	3.4^{bcd}	7.6^{a}	844.58^{e}	**86.34^{a}**	39.90^{efh}	3.4^{abcd}	7.3^{a}	**923.84^{a}**
T12	39.44^{f}	29.74^{i}	3.3^{ab}	7.1^{ab}	410.17^{p}	49.90^{f}	58.23^{i}	3.0^{ab}	7.2^{ab}	508.98^{p}	37.78^{s}	30.45^{ghi}	3.2^{abcd}	6.7^{ab}	374.02^{r}
T13	75.23^{abc}	38.67^{g}	3.2^{abc}	6.5^{abcd}	729.73^{f}	74.80^{abc}	37.89^{g}	3.2^{abc}	6.7^{abcd}	740.52^{f}	66.89^{j}	38.09^{efgh}	3.0^{abcd}	6.8^{ab}	655.23^{g}
T14	80.0^{ab}	49.5^{c}	3.2^{abc}	6.4^{abcd}	768.0^{d}	84.0^{ab}	39.90^{c}	2.9^{abc}	5.9^{abcd}	739.2^{d}	74.56^{e}	48.56^{bcde}	3.0^{abcd}	6.7^{ab}	668.67^{e}
T15	52.2^{bcdef}	30.0^{i}	3.6^{ab}	5.9^{d}	495.90^{m}	56.67^{bcdef}	21.20^{i}	3.2^{ab}	5.6^{d}	498.70^{m}	53.44^{m}	32.33^{ghi}	3.1^{abcd}	6.1^{bcdef}	491.65^{n}
T16	50.1^{bcdef}	47.66^{d}	3.3^{ab}	6.0^{cd}	465.93^{n}	51.23^{bcdef}	48.09^{d}	3.0^{ab}	7.3^{cd}	527.67^{n}	52.39^{n}	46.44^{bcdef}	3.2^{abcd}	5.4^{f}	450.55^{c}
T17	65.3^{abcdef}	60.0^{a}	2.7^{bcd}	6.1^{bcd}	568.11^{j}	66.55^{abcdef}	60.2^{a}	2.4^{bcd}	7.5^{bcd}	658.85^{j}	67.34^{i}	61.23^{a}	3.6^{ab}	6.0^{bcdef}	646.46^{i}
T18	72.5^{abcd}	44.02^{e}	1.9^{d}	6.0^{cd}	572.75^{i}	80.34^{abcde}	32.09^{e}	2.8^{d}	7.1cd	795.37^{i}	76.45^{d}	45.67^{bcdef}	3.8^{a}	5.8^{cdef}	733.92^{c}
Control	66.0^{abcdef}	61.12^{a}	2.0^{d}	5.8^{d}	514.80^{l}	69.09^{abcdef}	36.88^{a}	2.3^{d}	5.9^{d}	566.54^{l}	68.89^{g}	42.45^{defg}	2.4^{bcde}	5.7^{def}	558.09^{l}
CV%	17.21	1.15	11.47	5.33	0.04	17.21	1.15	11.47	5.33	0.04	0.0151	9.34	13.95	4.29	49.0

Table 1 Contd.

Treat-ments	Seed quality parameters against test pathogens														
	Colletotrichum gloeosporioides					*Curvularia lunata*					*Fusarium moniliforme*				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
T1	78.23^{c}	22.23^{fg}	1.9^{f}	5.3^{g}	563.26^{k}	**85.21^{a}**	45.56^{e}	3.5^{a}	8.1^{ab}	**979.92^{a}**	70.34^{h}	55.56^{b}	2.3^{de}	6.7^{cde}	633.06^{k}
T2	49.92^{gh}	40.23^{bcd}	2.9^{cde}	6.9^{abcd}	489.22^{c}	68.45^{h}	38.40^{h}	3.1^{a}	8.2^{a}	773.49^{h}	61.56^{k}	44.90^{h}	2.4^{de}	6.6^{de}	554.04^{n}
T3	58.78^{f}	20.0^{g}	3.0^{bcde}	6.4^{cdef}	552.53^{l}	57.68^{k}	25.05^{p}	2.8^{a}	7.5^{abcd}	605.64^{m}	59.34^{l}	21.49^{s}	2.3^{de}	6.8^{cde}	539.99^{o}
T4	70.70^{d}	57.14^{a}	2.8^{de}	6.6^{bcde}	678.72^{g}	67.78^{i}	35.8^{l}	3.1^{a}	7.8^{abc}	738.80^{i}	71.23^{g}	58.89^{a}	2.8^{bcde}	7.0^{bcde}	698.05^{i}
T5	84.12^{b}	33.18^{cdefg}	3.1^{abcde}	7.1^{abc}	858.02^{c}	78.90^{e}	24.43^{q}	3.4^{a}	8.0^{ab}	899.46^{b}	75.43^{f}	34.45^{p}	2.6^{cde}	7.3^{abcde}	746.76^{g}
T6	40.23^{ij}	49.56^{ab}	3.5^{abcd}	7.4^{a}	438.50^{q}	42.34^{c}	50.56^{c}	3.2^{a}	6.4^{d}	406.46^{r}	42.43^{q}	48.67^{d}	3.0^{abcde}	7.4^{abcde}	441.27^{r}
T7	67.45^{de}	37.40^{bcdef}	3.3^{abcde}	6.7^{abcd}	674.50^{h}	66.89^{j}	42.78^{f}	3.0^{a}	6.8^{bcd}	655.52^{l}	68.9^{i}	39.63^{l}	3.2^{abcd}	6.9^{cde}	695.89^{j}
T8	47.16^{h}	38.55^{bcdef}	3.8^{ab}	6.4^{cdef}	481.03^{p}	48.80^{n}	36.17^{k}	3.1^{a}	6.7^{cd}	353.47^{s}	50.67^{o}	37.44^{m}	3.5^{abc}	6.5^{e}	506.7^{p}
T9	41.28^{i}	37.89^{bcdef}	3. 5^{abcd}	6.3^{def}	404.54^{r}	42.34^{c}	35.58^{m}	2.9^{a}	7.1^{abcd}	423.40^{p}	49.29^{p}	39.82^{k}	2.0^{e}	7.4^{abcde}	463.33^{q}
T10	75.30^{c}	50.0^{ab}	3.1^{abcde}	7.1^{abc}	768.06^{d}	79.65^{d}	22.18^{r}	3.6^{a}	6.9^{bcd}	844.29^{c}	76.90^{e}	46.61^{g}	2.9^{abcde}	8.0^{ab}	838.21^{d}
T11	**93.35^{a}**	33.12^{cdefq}	3.2^{abcde}	7.3^{ab}	**980.18^{a}**	75.77^{g}	25.78^{c}	3.5^{a}	7.5^{abcd}	833.47^{e}	**88. 09^{a}**	31.37^{q}	2.8^{bcde}	8.1^{a}	**960.18^{a}**
T12	37.44^{j}	29.74^{defq}	3.9^{a}	6.9^{abcd}	400.61^{s}	38.90^{p}	58.23^{b}	3.5^{a}	7.0^{abcd}	408.45^{q}	40.87^{r}	48.52^{e}	3.1^{abcd}	7.6^{abcd}	437.31^{s}
T13	75.23^{c}	38.67^{bcde}	3.6^{abc}	5.9^{efg}	714.69^{f}	76.45^{f}	37.89^{i}	3.7^{a}	7.2^{abcd}	833.31^{f}	77.32^{d}	36.51^{n}	3.5^{abc}	7.7^{abc}	865.98^{c}
T14	85.0^{b}	49.5^{efg}	3.2^{abcde}	7.2^{ab}	884.0^{b}	81.87^{b}	39.90^{g}	3.0^{a}	7.3^{abcd}	843.26^{d}	79.45^{b}	42.28^{i}	3.7^{ab}	6.8^{cde}	834.23^{e}
T15	52.45^{g}	30.0^{defq}	3.5^{abcd}	7.0^{abcd}	550.73^{m}	51.45^{l}	21.20^{s}	3.2^{a}	6.9^{bcd}	519.65^{n}	55.34^{m}	27.44^{r}	3.6^{abc}	7.3^{abcde}	603.21^{l}
T16	50.67^{gh}	45.33^{abcd}	3.7^{ab}	6.8^{abcd}	532.04^{n}	50.89^{m}	48.09^{d}	3.3^{a}	6.7^{cd}	508.90^{c}	54.87^{n}	47.49^{f}	3.3^{abcd}	7.2a^{bcde}	576.14^{m}
T17	65.51^{e}	35.57^{bcdefq}	3.1^{abcde}	5.8^{fg}	583.05^{j}	66.45^{j}	60.2^{a}	3.4^{a}	6.9^{bcd}	684.44^{k}	67.38^{j}	5.48^{c}	3.5^{abc}	7.7^{abc}	754.66^{f}
T18	84.0^{b}	44.02^{abcd}	2.7^{e}	6.3^{def}	756.0^{e}	80.89^{c}	32.09^{n}	2.8^{a}	7.5^{abcd}	833.17^{g}	78.49^{c}	35.5^{o}	3.8^{ab}	7.4^{abcde}	879.09^{b}
Control	67.89^{d}	47.8^{abc}	2.8^{de}	6.8^{abcd}	665.32^{i}	68.78^{h}	36.88^{j}	2.7^{a}	7.4^{abcd}	694.68^{j}	70.37^{h}	40.45^{j}	3.9^{a}	6.6^{de}	745.92^{h}
CV%	1.91	14.15	7.78	3.72	0.05	0.22	0.125	10.50	5.70	0.0054	0.0322	0.0679	11.01	4.68	0.0037

Table 1 Contd.

Treat-ments	Seed quality parameters against test pathogens														
	Fusarium nivale					*Mucor* sp.					*Rhizoctonia solani*				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
T1	**82. 23^{a}**	22.23^{k}	3.9^{ab}	7.3^{ab}	**920.97^{a}**	**85.21^{a}**	45.56^{e}	3.2^{abcd}	8.7^{a}	1013.99^{a}	75.34^{d}	55.56^{a}	2.3^{e}	6.7^{bcde}	678.06^{h}
T2	49.92^{k}	40.23^{f}	2.9^{bcd}	6.9^{abcde}	489.22^{m}	58.45^{j}	38.40^{h}	3.1^{abcd}	8.2^{ab}	660.49^{k}	61.56^{l}	44.90^{cd}	2.4^{e}	6.6^{bcde}	554.04^{o}
T3	58.78^{i}	20.0^{l}	3.0^{bcd}	6.4^{abcdefgh}	552.53^{l}	67.82^{g}	25.05^{p}	3.4^{abc}	7.6^{bcde}	746.02^{g}	60.55^{n}	30.0^{k}	3.0^{abcde}	6.8^{bcde}	593.39^{m}
T4	70.70^{f}	57.14^{a}	3.2^{bcd}	6.0^{defgh}	650.44^{h}	60.91^{h}	35.8^{l}	3.6^{ab}	7.4^{bcdef}	670.01^{j}	67.77^{j}	55.78^{a}	2.8^{cde}	6.2^{de}	609.93^{k}
T5	81.12^{ab}	33.18^{i}	3.5^{abc}	7.3^{ab}	876.10^{c}	80.06^{c}	24.43^{q}	3.7^{ab}	7.9^{abcd}	928.69^{c}	74.78^{e}	35.72^{h}	2.7^{de}	6.3^{de}	673.02^{i}
T6	40.23^{m}	49.56^{c}	2.0^{d}	5.9^{efgh}	317.82^{r}	48.61^{m}	50.56^{c}	2.8^{abcd}	7.2^{bcdefq}	480.61^{q}	68.76^{i}	35.55^{hi}	2.2^{e}	5.0^{fg}	495.07^{p}
T7	67.45^{g}	37.40^{h}	2.9^{bcd}	5.6^{gh}	580.07^{j}	67.52^{g}	42.78^{f}	2.5^{cd}	7.0^{cdefq}	641.44^{m}	60.88^{m}	39.3^{fg}	2.3^{e}	4.4^{g}	407.90^{r}
T8	47.16^{l}	38.55^{h}	3.1^{bcd}	5.8^{fgh}	419.72^{o}	53.62^{l}	36.17^{k}	3.0^{abcd}	6.9^{defq}	530.84^{o}	50.93^{q}	34.67^{i}	3.1^{abcde}	5.9^{ef}	458.37^{q}
T9	41.28^{m}	37.89^{h}	2.8^{bcd}	6.2^{cdefgh}	371.52^{p}	45.88^{n}	35.58^{m}	3.3^{abc}	6.7^{efq}	450.88^{r}	70.90^{h}	40.0^{f}	3.9^{ab}	6.4^{cde}	730.27^{f}
T10	75.30^{d}	50.0^{c}	3.9^{ab}	6.8^{abcdef}	805.71^{f}	79.51^{c}	22.18^{r}	3.5^{abc}	7.8^{abcd}	898.46^{d}	73.88^{g}	38.44^{g}	4.0^{a}	6.6^{bcde}	783.13^{d}
T11	73.35^{e}	33.12^{i}	4.9^{a}	7.4^{a}	902.21^{b}	75.34^{e}	25.78^{o}	2.9^{abcd}	8.6^{a}	873.94^{e}	**76. 66^{b}**	41.23^{e}	3.6^{abcd}	8.9^{a}	**958.25^{a}**
T12	37.44^{n}	29.74^{i}	2.3^{cd}	7.0^{abcd}	348.19^{q}	40.09^{o}	58.23^{b}	2.8^{abcd}	7.9^{abcd}	428.96^{s}	36.66^{r}	40.09^{f}	3.5^{abcd}	6.8^{bcde}	377.598^{s}
T13	75.90^{d}	38.67^{j}	3.8^{ab}	7.2^{abc}	834.9^{e}	77.76^{d}	37.89^{i}	3.7^{ab}	7.2^{bcdefq}	847.58^{f}	74.55^{f}	39.92^{f}	3.6^{abcd}	7.0^{bcd}	790.23^{c}
T14	80.0^{bc}	49.5^{gh}	4.0^{ab}	6.5^{abcdefgh}	840.0^{d}	83.61^{b}	39.90^{g}	3.8^{a}	8.0^{abc}	986.59^{b}	75.77^{c}	45.63^{c}	3.8^{abc}	7.5^{b}	856.20^{b}
T15	52.0^{j}	30.0^{c}	2.8^{bcd}	6.6^{abcdefg}	488.80^{m}	55.57^{k}	21.20^{s}	2.5^{cd}	7.1^{cdefq}	533.47^{n}	54.60^{o}	31.12^{j}	3.5^{abcd}	7.4^{bc}	595.14^{l}
T16	50.89^{jk}	47.9^{jd}	3.2^{bcd}	6.3^{bcdefgh}	483.45^{n}	59.53^{i}	48.09^{d}	2.2^{d}	6.4^{fq}	510.24^{p}	52.73^{p}	49.73^{b}	3.7^{abcd}	7.1^{bcd}	569.48^{n}
T17	65.09^{h}	40.0^{fg}	3.6^{abc}	5.9^{efgh}	624.86^{i}	69.0^{f}	60.2^{a}	2.7^{bcd}	6.6^{efq}	641.70^{l}	66.74^{k}	50.45^{b}	3.9^{ab}	6.9^{bcde}	720.79^{g}
T18	79.88^{c}	44.02^{e}	3.0^{bcd}	5.8^{fgh}	702.94^{g}	80.06^{c}	32.09^{n}	3.0^{abcd}	6.3^{q}	744.56^{h}	77.61^{a}	44.43^{d}	2.9^{bcde}	6.6^{bcde}	737.29^{e}
Control	66.0^{h}	55.56^{b}	3.2^{bcd}	5.5^{h}	574.20^{k}	68.54^{f}	36.88^{j}	3.1^{abcd}	6.9^{defq}	685.40^{i}	67.72^{j}	50.32^{b}	2.8^{dce}	6.7^{bcde}	643.34^{j}
CV%	0.6345	1.16	14.30	5.23	0.0375	0.3471	0.1285	10.91	4.55	0.0048	0.0428	0.7707	10.67	5.08	0.0044

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

T1: Tilt , T2: Contaf, T3: *Psidium guajava,* T4: *Azadirachta indica,* T5: *Trichoderma viride,* T6: Contaf + Tilt, T7: *P. guajava* + *A. indica,* T8: Contaf + *P. guajava* + *T. viride,* T9: Contaf + *A. indica* + *T. viride,* T10: Tilt + *P. guajava* + *T. viride,* T11: Tilt + *A. indica* + *T. viride,* T12: Contaf + *A. indica,* T13: Contaf + *P. guajava,* T14: Tilt + *A. indica,* T15: Tilt + *P. guajava,* T16: Contaf + Tilt + *P. guajava*+ *A. indica,* T17: Contaf + Tilt + *P. guajava*+ *A. indica*+ *T. viride,* T18: Inoculated without treatment, Control: Uninoculated healthy seeds. A: % germination, B: % mortality, C: Root length (cm), D: Shoot length (cm) and E: Seedling vigor index.

Combined effect of plant extracts, fungicides, and antagonists on seed quality parameters of cotton against *Colletotrichum gloeosporioides:*

Amongst 17 treatments, 4 treatments *viz.* T1, T5, T10, and T13 exhibited the best results compared to the control. Among these treatments, T11 showed the highest (93.35%) germination percentage whereas the lowest (37.44%) was recorded in T12. The highest seedling vigor index (980.18) was observed in T11, and the lowest was found in T12 (400.61). The maximum seedling mortality (57.14%) was found in T4, and the minimum (20.0%) in T3 treatments after 21 days of germination. In the present study, the maximum shoot length (7.4 cm) was recorded by T6, and the minimum (5.3 cm) was noticed in T1, whereas the highest root length (3.9 cm) was noticed in T12 and lowest (1.9 cm) in T1 (Table 1).

Combined effect of fungicides, plant extracts, and antagonists on seed quality parameters of cotton against *Curvularia lunata:*

Out of 17 treatments, 4 treatments *viz.* T5, T10, T1, and T14 exhibited best results compared to control. Among these treatments, T1 showed the highest (85.21%) germination percentage, whereas the lowest (42.34%) was recorded in T6. The highest seedling vigor index (979.92) was observed in T1 and the lowest in T12 (406.46). The highest seedling mortality (50.56%) was recorded in T6 and the lowest (21.20%) in T15 treatments after 21 days of germination. In the present investigation, the maximum shoot length (8.1 cm) was found in T1 and the minimum (6.4 cm) in T6, whereas the highest root length (3.7 cm) was noticed in T13 and the lowest (2.8 cm) in T3 (Table 1).

Joint effect of plant extracts, fungicides, and antagonists on seed quality parameters of cotton against *Fusarium nivale*:

Among the 17 treatments, 4 treatments *viz.* T5, T10, T13, and T14 exhibited the best results compared to the control. Among these treatments, T11 showed the highest (88.09%) germination percentage whereas the lowest (40.87%) was recorded in T12. The highest seedling vigor index (960.18) was observed in T11 and the lowest in T12 (437.31). The maximum seedling mortality (58.89%) was found in T4 and the minimum (21.49%) in T3 treatments after 21 days of germination. In the present experiment, the maximum shoot length (8.1 cm) was recorded by T11 and the minimum (6.6 cm) by T2, whereas the highest root length (3.7 cm) was noticed in T14 and the lowest (2.0 cm) in T9 (Table 1).

Combined effect of fungicides, plant extracts, and antagonists on seed quality parameters of cotton against *Fusarium moniliforme:*

Out of 17 treatments, 4 treatments *viz.* T5, T10, T13 and T14 exhibited the best results compared to the control. Among these treatments, T1 showed the highest (82.23%) germination percentage whereas the lowest (37.44%) was recorded in T12. The highest seedling vigor index (920.97) was observed in T1 and the lowest was in T12 (348.19). The highest seedling mortality (57.14%) was recorded in T4 and the lowest (20.0%) in T3 treatments after 21 days of germination. In the present study, the maximum shoot length (7.4 cm) was found in T11 and the minimum (5.6 cm) in T7, whereas the highest root length (4.9 cm) was noticed in T11 and the lowest (2.0 cm) in T6 (Table 1).

Joint effect of plant extracts, fungicides, and antagonists on seed quality parameters of cotton against *Mucor* sp.:

Among the 17 treatments, 4 treatments *viz.* T5, T10, T13 and T14 exhibited the best results compared to the control. Among these treatments, T1 showed the maximum (85.21%) germination whereas the minimum (40.09%) was recorded in T12. The highest seedling vigor index (1013.99) was observed in T1 and the lowest in T12 (428.96). The maximum seedling mortality (60.2%) was found in T17 and the minimum (21.20%) in T15 treatments after 21 days of germination. In the present investigation, the maximum shoot length (8.7 cm) was recorded by T1 and the minimum (6.4 cm) was recorded by T16, whereas the highest root length (3.8 cm) was noticed in T14, and the lowest (2.2 cm) in T16 (Table 1).

Combined effect of fungicides, plant extracts, and antagonists on seed quality parameters of cotton against *Rhizoctonia solani:*

Out of 17 treatments, 4 treatments *viz.* T5, T10, T13 and T14 exhibited the best results compared to the control. Among these treatments, T11 showed the highest (76.66%) germination percentage whereas the lowest (50.93%) was recorded in T8. Highest seedling vigor index (958.25) was observed in T11, and the lowest in T8 (458.37). The maximum seedling mortality (55.78%) was found in T4, and the minimum (30.0%) in T3 treatments after 21 days of germination. In the present experiment, maximum shoot length (7.5 cm) was recorded in T14 and minimum (4.4 cm) in T4, whereas the highest root length (3.7 cm) was noticed in T14, and the lowest (2.2 cm) in T6 (Table 1).

The findings of the present investigation are in agreement with the findings of Chowdhury *et al.* (2022), who reported that amongst 13 treatments, only T6 (*Azadirachta*

indica + Bavistin + *Trichoderma harzianum*) exhibited maximum percentage of seed germination and seedling vigor index of seeds inoculated with *Alternaria alternata, Aspergillus flavus, Curvularia lunata* and *Pestalotiopsis guepinii*. Treatment T10 (Bavistin + *Azadirachta indica* + Tall + *Citrus medica*) showed promising results against *Drechslera oryzae, Fusarium moniliforme, Microdochium oryzae,* and *Sarocladium oryzae.* Treatment T3 (*Azadirachta indica*) was responsible for the highest percentage of seed germination and seedling vigor index with *Fusarium solani* inoculated seeds. Out of all treatments, the combined use of Bavistin, *A. indica,* and *T. harzianum* exhibited the best results for reducing the growth of the test pathogens and increased the germination of seeds.

Similarly, Sultana (2021) observed that, in a field experiment out of twelve treatments T10 (Tilt + *Azadirachta indica* + *Trichoderma viride*), T3 (Bavistin + Tilt) and T7 (*Trichoderma viride*) were responsible for highest germination percentage and highest seedling vigor index against *Bipolaris oryzae, Curvularia lunata,* and *Fusarium fujikuroi*. On the other hand, T3 (Bavistin + Tilt), T7 (*Trichoderma viride*), and T1 (Bavistin) showed promising germination percentage and seedling vigor index. These are also in accordance with the results of the present research work.

Mahmood *et al.* (2015) observed that the integrated effect of Mancozeb and Cupravit 50 WP (0.4%) significantly reduced the mycelial growth of *Fusarium* spp, *Alternaria* spp, *Sclerotium* spp, *Aspergillus flavus,* and *A. niger*. The efficacy of Mancozeb and Cupravit against the mycelial growth of *Fusarium oxysporum* was also reported by Fravel *et al.* (2005), who observed that Mancozeb and Cupravit both reduced the colony growth of *Fusarium* spp. Jeyalakshmi *et al*. (1999) observed that applying bioagents and Bavistin increased seed germination percentage. Seed treatment with bioagents and fungicides also reduced root rot incidence, according to Patil *et al.* (2003). The present investigation also supports the results of above-mentioned researchers.

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