



***In vivo* Interaction between Alternaria and Corynespora Leaf Spot Pathogens in Cotton**

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Abstract : Cotton (*Gossypium* sp.) crop is affected by *Alternaria* sp. and *Corynespora cassiicola* causing significant yield reduction under congenial conditions. To understand the interaction between these two leaf spot pathogens, a field trial was conducted during *kharif* 2020-2021. Simultaneous inoculation of *A. alternata* and *C. cassiicola* expressed mutual synergistic effect of 8.83 PDI as against individually inoculated fields of *A. alternata* (2.42 PDI) and *C. cassiicola* (5.58 PDI) at 70 DAS. *C. cassiicola* (10.67 PDI) was antagonistic to *A. alternata* (3.92 PDI) at 80 DAS as against individually inoculated *C. cassiicola* (10.17PDI) and *A. alternata* (4.33PDI) and uninoculated with *A. alternata* (2.92 PDI) and *C. cassiicola* (8.25PDI). At 90 DAS, *C. cassiicola* inhibited the growth of *A. alternata* (8 and 9 PDI in combined and individual inoculations). Mutual antagonistic effect at 100 DAS was observed but at 110 DAS, *C. cassiicola* (33.25PDI) showed antagonistic effect on *A. alternata* (10.83 PDI) in combined inoculated fields and at 120 DAS (39.25 PDI for *C. cassiicola* and 8.25 PDI for *A. alternata*). *Corynespora* leaf spot dominated in hybrid (Jaadoo BG II, 37.83PDI) or variety (L 1060, 44.83 PDI) under inoculated (41.25 PDI) or uninoculated (41.33PDI) conditions, individual (41.25PDI) or in combined inoculations (39.25PDI).

Keywords: *Alternaria* leaf spot, *Corynespora* leaf spot, cotton, interaction, *in vivo*

Cotton (*Gossypium* sp.), the most important fibre crop in India, is affected by fungal, bacterial and viral diseases. In Andhra Pradesh, among fungal leaf spot diseases, *Alternaria* leaf spot (ALS) was predominant until 2016-2017. Under congenial conditions *Alternaria* blight causes severe defoliation, cracking and breaking of stems and reduction in boll formation. In recent years *Corynespora* leaf spot (CoLS) has surpassed *Alternaria* leaf spot and emerged as major cotton disease. *Corynespora* causes circular to oval or irregular concentric spots with tan to light brown centre develop with yellow halo around the margin. These spots enlarged and concentric zonations were formed resulting in target board symptom. Spots were initially found in the lower, interior canopy and spread upward and also observed on petioles, stems, squares with minute oval to irregular brick red coloured spots. On severe infection, these lesions coalesce causing chlorosis and necrosis followed by complete

senescence resulting in premature defoliation. To understand the field interaction between these two important leaf spot pathogens the present investigation was carried out at Regional Agricultural Research Station during *kharif* 2020-2021.

Pathogens obtained in pure culture were identified based on colony characteristics. Seeds of hybrid Jaadoo (BG II) and susceptible variety L 1060 were sown in the field on 27.07.2020 and maintained by spraying recommended insecticides against sucking pests and boll worms. Eight treatments *viz.*, T₁ – Inoculated *A. alternata*, T₂- Inoculated *Corynespora cassiicola*, T₃ - Inoculated *A. alternata* + *C. cassiicola* (for ALS), T₄ - Inoculated *A. alternata* + *C. cassiicola* (for CoLS), T₅ - Inoculated both (for ALS and CoLS), T₆- Uninoculated (for ALS), T₇ - Uninoculated (for CoLS) and T₈ - Uninoculated (for ALS + CoLS) and *Corynespora* were imposed in Factorial RBD and replicated thrice. At 60 DAS, using atomizer the plants were spray inoculated @ 5ml/plant with

15 days old cultures having spore load of 1×10^4 adjusted using haemocytometer and water spray served as control. High relative humidity was maintained by covering with polythene covers on the inoculated plants to create favorable conditions for better establishment and

development of pathogen inoculum. In each treatment 10 plants was selected randomly, leaving the border rows and another 10 plants at the centre were selected to score both leaf spot diseases by adopting standard 0-4 scale and Per cent Disease Index (PDI) was calculated.

$$\text{PDI} = \frac{\text{Sum of numerical ratings}}{\text{Total number of leaves scored} \times \text{maximum rating}} \times 100$$

Alternaria and *Corynespora* leaf spot diseases initiated one week after artificial inoculation. Care was taken to note individual and mixed infections.

Interactions of pathogens and genotypes at 70 DAS

PDI of ALS in uninoculated plot (1.67) was significantly lower compared to that of inoculated (2.42). Similarly, *C. cassiicola* inoculated plot recorded 5.58PDI compared to uninoculated control (2.83). In simultaneous inoculation, PDI due to *A. alternata* (ALS, 2.50) was found *on par* with PDI of *A. alternata* inoculated individually (2.42); PDI of *C. cassiicola* (CoLS, 6.33) was *on par* with that of *C. cassiicola* in individually inoculated plot (5.58). However when PDI of both pathogens were considered it was found that combined inoculation of pathogens (8.83) was significantly superior in causing disease than uninoculated plots (4.50). Due to vigorous virulence of pathogens, synergistic effect was observed between *A. alternata* and *C. cassiicola* when inoculated together than individual inoculation resulting in enhanced disease severity (Table 1).

Variety L 1060 (4.92 PDI) recorded higher PDI due to *A. alternata* and *C. cassiicola* when compared to hybrid BG II (3.75 PDI) indicating its relative susceptibility as more, whether inoculated individually or combined in inoculated and uninoculated plots. There was no

significant variation observed between genotypes and pathogens in interaction (Table 1).

Interactions of pathogens and genotypes at 80 DAS:

PDI of *A. alternata* (ALS, 3.92) simultaneously inoculated with *C. cassiicola*, was found *on par* with that of individual inoculation (4.33PDI). Similar results were recorded with *C. cassiicola* (10.67 PDI) when inoculated together with *A. alternata* and was *on par* with *C. cassiicola* inoculated alone (10.17 PDI). In simultaneous inoculations, *C. cassiicola* (10.67 PDI) was found antagonistic to *A. alternata* (3.92 PDI) compared to individual inoculation of *A. alternata* (4.33 PDI). However PDI due to both *A. alternata* and *C. cassiicola* inoculated simultaneously (14.58 PDI) was found significantly superior against uninoculated control (11.17 PDI) (Table 1).

In uninoculated plots, PDI of *A. alternata* (ALS, 2.92) was significantly low when compared to individually inoculated (4.33PDI) and inoculated along with *C. cassiicola* (3.92 PDI). Similar trend was observed for *C. cassiicola* (8.25 PDI) in uninoculated field and significantly varied from *C. cassiicola* inoculated alone (10.17 PDI) or inoculated with *A. alternata* simultaneously (10.67 PDI). It shows in inoculated fields and uninoculated plots, *C. cassiicola* was superior in causing disease and *on par* with inoculated alone or along with *A. alternata* and limited the growth of

A. alternata. In case of *A. alternata* inoculated alone, it was significantly low and *on par* when combined with *C. cassiicola*, where *C. cassiicola* reduced the growth of *A. alternata* in inoculated and uninoculated plots. Variety L 1060 recorded significantly higher PDI (9.85PDI) and susceptibility to *A. alternata* and *C. cassiicola* compared to Jaadoo BG II (6.65 PDI) (Table 2).

Interaction between pathogen and genotype: Impact of interactions between *A. alternata* and *C. cassiicola* inoculated individually and/or together in cotton revealed PDI of *A. alternata* when inoculated alone in hybrid BG II was significantly low (3.00PDI) when compared to variety L 1060 (5.67PDI). In uninoculated plots also Jaadoo BG II recorded low PDI (ALS 2.50) compared to variety L 1060 (3.33PDI). When *A. alternata* (3.17PDI) and *C. cassiicola* (8.67PDI) were inoculated simultaneously, PDI of *A. alternata* was more in hybrid Jaadoo BG II compared to individually inoculated *A. alternata* (3.00) and *A. alternata* in uninoculated field (2.50 PDI), but in variety L 1060 simultaneous inoculation of both pathogens resulted in higher PDI of *A. alternata* (4.67) compared to PDI of *A. alternata* (3.33) in uninoculated field and when inoculated alone (5.67). Finally it was found that *A. alternata* disease severity was high in variety L 1060 compared to Jaadoo BG II in both inoculated and uninoculated plots (Table 1).

Inoculation of *C. cassiicola* alone in Jaadoo BG II recorded the lowest PDI (6.83) than variety L 1060 (13.50PDI). When both *A. alternata* (3.17PDI) and *C. cassiicola* (8.67PDI) were inoculated simultaneously in Jaadoo BG II, PDI of *C. cassiicola* was higher than individually inoculated (6.83) and uninoculated field (7.33). Whereas in variety L 1060 simultaneous inoculation of *A. alternata* (4.67PDI) and *C. cassiicola* (12.67 PDI) resulted in PDI of *C. cassiicola* higher than *C. cassiicola* in

uninoculated plots (9.17PDI) and lower than that of *C. cassiicola* inoculated alone (13.50PDI).

When both *A. alternata* and *C. cassiicola* were inoculated simultaneously in Jaadoo BG II (11.83PDI) and variety L 1060 (17.33 PDI), *C. cassiicola* was superior in causing disease than *A. alternata*. Similar trend was observed in uninoculated field for *A. alternata* and *C. cassiicola* in both Jaadoo BG II (9.83PDI) and variety L 1060 (12.50PDI). This shows that in simultaneous inoculations, *C. cassiicola* inhibited *A. alternata* in both inoculated and uninoculated fields and superior in causing infection. Disease severity was more in inoculated fields than uninoculated plots of both Jaadoo BG II hybrid and variety L 1060 (Table 1).

Interactions of pathogens and genotypes at 90 DAS

PDI of *A. alternata* inoculated alone (9) was significantly high compared to that of *A. alternata* in uninoculated field (7.42). When *A. alternata* (8.00PDI) and *C. cassiicola* (15.92 PDI) were inoculated simultaneously, *A. alternata* was *on par* with individually inoculated *A. alternata* (9.00PDI) but significantly high compared to *A. alternata* (7.42 PDI) in uninoculated field. PDI of the individually inoculated *C. cassiicola* (17.42) was significantly high compared to *C. cassiicola* in uninoculated plots (15.08). When *A. alternata* (8) and *C. cassiicola* (15.92) were inoculated simultaneously, *C. cassiicola* was *on par* with *C. cassiicola* in both inoculated (9 PDI) and uninoculated fields (15.08 PDI). When both *A. alternata* and *C. cassiicola* were inoculated in combination (23.92 PDI) they were found *on par* with uninoculated plots infected with both pathogens (22.50 PDI). At 90 DAS, there was no difference between simultaneously inoculated and uninoculated plots with respect to *A. alternata* and *C. cassiicola* infection. *C. cassiicola* was superior in causing severe disease and took over *A. alternata* when inoculated together and also in

uninoculated conditions. Environmental conditions also favoured development of *C. cassiicola* inoculum and to cause infection. Rainfall, rainy days, sun shine hours and wind speed significantly influenced the progress of *Corynespora* leaf spot during *kharif*, 2020 (Anonymous, 2021). In simultaneous inoculations *C. cassiicola* acted like an antagonist to *A. alternata* and limited the growth to minimum disease intensity (Table 2).

Variety L 1060 (16.96 PDI) showed significantly higher severity due to *A. alternata* and *C. cassiicola* compared to Jaadoo BG II hybrid (12.85 PDI) and more vulnerable to *A. alternata* and *C. cassiicola* infection (Table 2).

Interactions of pathogens and genotypes at 100 DAS

Interaction of *A. alternata* and *C. cassiicola* resulted in significant difference in PDI of Jaadoo BG II and variety L 1060 when inoculated alone and in combination. When *A. alternata* was inoculated individually (13.33PDI), it varied significantly higher than *A. alternata* in uninoculated field (11 PDI), but when both pathogens were inoculated in combination, *A. alternata* (11.58 PDI) was *on par* with *A. alternata* (11 DI) in uninoculated field. Similar results were also observed for *C. cassiicola* where PDI of individually inoculated *C. cassiicola* (23.42) was higher than PDI of *C. cassiicola* in uninoculated field (21.25) and inoculated simultaneously (21.50) with *A. alternata*. Whereas PDI of fields inoculated with both pathogens (33.08) was *on par* with uninoculated fields infected with both pathogens (32.25 PDI). It shows that *C. cassiicola* completely dominated *A. alternata* in individually inoculated fields, simultaneously inoculated fields and also in uninoculated fields. (Table 2).

Jaadoo BG II (17.46 PDI) showed significantly lesser disease severity due to *A. alternata* and *C. cassicola* compared to variety L 1060 (24.40 PDI) and it shows that Jaadoo BG II was more resistant to *A. alternata* and *C. cassiicola* (Table 2).

Interactions of *A. alternata* and *C. cassiicola* in cotton hybrid, Jaadoo BG II and variety L 1060, inoculated alone and in combination, revealed that PDI of Jaadoo BG II was significantly low when inoculated with *A. alternata* alone (12.17) and compared to variety L 1060 (14.50). Similarly, uninoculated plots of Jaadoo BG II recorded low PDI (10.67) of *A. alternata* compared to variety L 1060 (11.33). When *A. alternata* (10.67 PDI) and *C. cassiicola* (17.17PDI) were inoculated simultaneously in Jaadoo BG II, PDI of *A. alternata* was less (10.67PDI) compared to individual inoculation of *A. alternata* (12.17) and *on par* with *A. alternata* in uninoculated control (10.67 PDI). In variety L 1060 simultaneous inoculation of both pathogens resulted in PDI of *A. alternata* (12.50) *on par* with *A. alternata* (11.33) in uninoculated plots and also plots inoculated with *A. alternata* alone (14.50). It was found that *A. alternata* disease severity was high in variety L 1060 compared to Jaadoo BG II in inoculated and uninoculated fields and also simultaneously inoculated Jaadoo BG II and variety L 1060. *C. cassiicola* acted like an antagonist against *A. alternata* and limited the disease severity to very low extent (Table 2).

Inoculation of *C. cassiicola* alone in Jaadoo BG II (18.50 PDI) recorded lower disease severity than variety L 1060 (28.33 PDI). When both *A. alternata* (10.67 PDI) and *C. cassiicola* (17.17PDI) were inoculated simultaneously in Jaadoo BG II, PDI of *C. cassiicola* was *on par* with individual inoculation (18.50) and uninoculated plots (16). Whereas in variety L 1060, simultaneous inoculation of both *A. alternata* (12.50PDI) and *C. cassiicola* (25.83 PDI) showed PDI of *C. cassiicola* *on par* with *C. cassiicola* in uninoculated plots (26.50 PDI) and individual inoculation of *C. cassiicola* alone (28.33 PDI). PDI of *C. cassiicola* was *on par* when inoculated alone or with *A. alternata* in Jaadoo BG II and variety L 1060, because there was no effect of *A. alternata* on *C. cassiicola* in inoculated and uninoculated

Table 1. PDI in cotton hybrid (Jaadoo BG II) and variety (L 1060) due to interaction between *Alternaria alternata* and *Corynespora cassicola*

Treatments	70 DAS (PDI)*			80 DAS (PDI)*			90 DAS (PDI)*		
	Hybrid (BG II)	Variety (L 1060)	Pathogen Means	Hybrid (BG II)	Variety (L 1060)	Pathogen Means	Hybrid (BG II)	Variety (L 1060)	Pathogen Means
T1 - Inoculated <i>Alternaria alternata</i>	1.83 (7.76)	3.00 (9.95)	2.42 (8.85)^d	3.00 (9.95) ^b	5.67 (13.75) ^g	4.33 (11.85)^d	7.67 (16.04)	10.33 (18.74)	9.00 (17.39)^d
T2 - Inoculated <i>Corynespora cassicola</i>	4.8 (12.69)	6.33 (14.54)	5.58 (13.62)^b	6.83 (15.13) ^{ef}	13.50 (21.54) ^b	10.17 (18.34)^b	14.83 (22.63)	20.00 (26.53)	17.42 (24.58)^b
T3 - Inoculated <i>A. alternata</i> + <i>C. cassicola</i> (for ALS)	2.17 (8.38)	2.83 (9.68)	2.50 (9.03)^d	3.17 (10.20) ^b	4.67 (12.40) ^g	3.92 (11.30)^d	7.33 (15.68)	8.67 (17.07)	8.00 (16.38)^{de}
T4 - Inoculated <i>A. alternata</i> + <i>C. cassicola</i> (for CoLS)	5.50 (13.85)	7.10 (15.49)	6.33 (14.52)^b	8.67 (17.10) ^{cd}	12.67 (20.82) ^b	10.67 (18.96)^b	13.67 (21.69)	18.17 (25.19)	15.92 (23.44)^{bc}
T5 - Inoculated Both (for ALS + CoLS)	7.67 (16.04)	10.00 (18.41)	8.83 (17.23)^a	11.83 (20.09) ^b	17.33 (24.57) ^a	14.58 (22.33)^a	21.00 (27.26)	26.83 (31.17)	23.92 (29.22)^a
T6 - Uninoculated (for ALS)	1.50 (6.97)	1.83 (7.65)	1.67 (7.31)^e	2.50 (9.06) ^b	3.33 (10.44) ^b	2.92 (9.75)^e	6.00 (14.76)	8.33 (16.76)	7.42 (15.76)^e
T7 - Uninoculated (for CoLS)	2.50 (9.06)	3.10 (10.22)	2.83 (9.64)^d	7.33 (15.68) ^{de}	9.17 (17.60) ^c	8.25 (16.64)^c	12.67 (20.80)	17.50 (24.70)	15.08 (22.75)^c
T8 - Uninoculated (for ALS + CoLS)	4.00 (11.53)	5.00 (12.89)	4.50 (12.21)^c	9.83 (18.26) ^c	12.50 (20.66) ^b	11.17 (19.46)^b	19.17 (25.92)	25.83 (30.52)	22.50 (28.22)^a
Genotype Means	3.75 (10.75)^b	4.92 (12.35)^a	-	6.65 (14.43)^b	9.85 (17.72)^a	-	12.85 (20.60)^b	16.96 (23.83)^a	-
SEM ±	0.19	0.39	G * P	0.20	0.40	G * P	0.23	0.47	G * P
CD (p=0.05)	0.56	1.13	NS	0.58	1.17	1.65	0.67	1.33	NS
CV (%)		8.24			6.17			5.13	

*Mean of three replications;

Treatment means with same alphabet do not differ significantly. Figures in the parenthesis are square root transformed values.

Table 2. PDI in cotton hybrid (Jaadoo BG II) and variety (L 1060) due to interaction between *Alternaria alternata* and *Corynespora cassiicola*

Pathogens and combinations (P) ↓	Genotypes (G) →	100 DAS (PDI)*			110 DAS (PDI)*			120 DAS (PDI)*		
		Hybrid	Variety	Pathogen	Hybrid	Variety	Pathogen	Hybrid	Variety	Pathogen
		(BG II)	(L 1060)	Means	(BG II)	(L 1060)	Means	(BG II)	(L 1060)	Means
T1 - Inoculated <i>A. alternata</i>		12.17 (20.39)g	14.50 (22.37)ef	13.33 (21.38)d	16.17 (23.69)f	19.50 (26.18)e	17.83 (24.94)c	19.17 (25.94)f	22.00 (27.96)f	20.58 (26.95)c
T2 - Inoculated <i>Corynespora cassiicola</i>		18.50 (28.80)b	28.33 (31.82)d	23.42 (36.05)c	27.83 (33.94)b	34.67 (36.95)e	31.25 (42.88)bc	36.15 (39.92)b	46.33 (25.46)c	41.25 (32.14)b
T3 - Inoculated <i>A. alternata</i> + <i>C. cassiicola</i> (for ALS)		10.67 (19.04)g	12.50 (20.65)g	11.58 (19.84)e	10.33 (18.74)g	11.33 (19.66)g	10.83 (19.20)d	8.00 (16.39)g	8.50 (16.91)g	8.25 (16.65)d
T4 - Inoculated <i>A. alternata</i> + <i>C. cassiicola</i> (for CoLS)		17.17 (24.46)cd	25.83 (30.51)b	21.50 (27.49)bc	29.33 (32.77)d	37.17 (37.54)bc	33.25 (35.15)b	36.33 (37.04)e	42.17 (40.48)cd	39.25 (38.76)b
T5 - Inoculated Both (for ALS + CoLS)		27.83 (31.82)b	38.33 (38.23)a	33.08 (35.03)a	39.67 (39.01)b	48.50 (44.12)a	44.08 (41.57)a	44.33 (41.72)c	50.67 (45.36)ab	47.50 (43.54)a
T6 - Uninoculated (for ALS)		10.67 (19.03)g	11.33 (19.61)g	11.00 (19.32)e	9.17 (17.60)g	11.00 (19.19)g	10.08 (18.39)d	9.00 (17.32)g	7.33 (15.48)g	8.17 (16.40)d
T7 - Uninoculated (for CoLS)		16.00 (23.55)de	26.50 (30.97)b	21.25 (27.26)c	29.00 (32.57)d	38.33 (38.24)bc	33.67 (35.40)b	37.83 (37.94)de	44.83 (42.02)c	41.33 (39.98)b
T8 - Uninoculated (for ALS + CoLS)		26.67 (31.06)b	37.83 (37.93)a	32.25 (34.49)a	38.17 (38.14)bc	49.33 (44.60)a	43.75 (41.37)a	46.83 (43.17)bc	52.17 (46.22)a	49.50 (44.70)a
Genotype Means		17.46 (24.35)b	24.40 (29.05)a	24.96 (29.29)b	24.96 (29.29)b	31.23 (33.20)a	29.71 (32.06)b	29.71 (32.06)b	34.25 (34.66)a	34.25 (34.66)a
SEM ±		G	P	G * P	G	P	G * P	G	P	G * P
CD (p=0.05)		0.23	0.46	0.65	0.27	0.54	0.76	0.36	0.71	1.01
CV (%)		0.66	1.32	1.88	0.78	1.53	2.20	1.03	2.00	2.91
		4.21	4.23	5.23						

*Mean of three replications;

Treatment means with same alphabet do not differ significantly. Figures in the parenthesis are square root transformed value

plots (Table 2).

When both *A. alternata* and *C. cassiicola* were inoculated simultaneously in Jaadoo BG II (27.83 PDI) and L 1060 (38.33 PDI), *C. cassiicola* was superior in causing disease than *A. alternata*. Similar trend was also observed in uninoculated plots for *A. alternata* and *C. cassiicola* in both Jaadoo BG II (26.67 PDI) and L 1060 (37.83 PDI). This shows simultaneously inoculated plots of *A. alternata* and *C. cassiicola* were *on par* with uninoculated plots of Jaadoo BG II and L 1060. Mutual antagonistic affect was observed between *A. alternata* and *C. cassiicola* in Jaadoo BG II and L 1060 when inoculated simultaneously and uninoculated plots compared to their individual inoculations (Table 2).

Interactions of pathogens and genotypes at 110 DAS

PDI of *A. alternata* (17.83) was highest in individually inoculated field than *A. alternata* (10.08PDI) in uninoculated field and also from PDI of *A. alternata* (10.83) when inoculated with *C. cassiicola*, but in case of *C. cassiicola* lower PDI was noted when inoculated alone (31.25) than *C. cassiicola* (33.25PDI) in combination with *A. alternata* and also *C. cassiicola* (33.67 PDI) in uninoculated field. When pathogens were inoculated simultaneously *C. cassiicola* (33.25 PDI) acted like an antagonist to *A. alternata* (10.83PDI) when compared to the individually inoculated plots of *A. alternata* (17.83 PDI) and *C. cassiicola* (31.25 PDI). PDI of combination inoculated plots (44.08) was found *on par* with uninoculated plots infected with both pathogens (43.75). It shows that *A. alternata* was completely dominated by *C. cassiicola* in individually inoculated plots, simultaneously inoculated plots and also in uninoculated plots. (Table 2).

Variety L 1060 (31.23PDI) showed significantly higher disease severity due to *A. alternata* and *C. cassicola* compared to Jaadoo BG II (24.96 PDI) and more susceptible to *A. alternata* and *C. cassiicola* infection (Table 2).

Interactions of *A. alternata* and *C. cassiicola* inoculated alone and in combination revealed that PDI of Jaadoo BG II hybrid was significantly low when inoculated with *A. alternata* alone (16.17) and compared to variety L 1060 (19.50). Similarly, uninoculated plots of Jaadoo BG II hybrid recorded low PDI (10.67) of *A. alternata* compared to variety L 1060 (11.33). When *A. alternata* (10.33PDI) and *C. cassiicola* (29.33 PDI) were inoculated simultaneously in Jaadoo BG II hybrid, PDI of *A. alternata* was less (10.33 PDI) compared to individual inoculation of *A. alternata* (16.17) and *on par* with *A. alternata* in uninoculated control (11.00). In variety L 1060 simultaneous inoculation of both resulted in PDI of *A. alternata* (11.33) *on par* with *A. alternata* (11.00) in uninoculated plots. It was found that *A. alternata* disease severity was high (11.33 PDI) in variety L 1060 compared to Jaadoo BG II hybrid in both inoculated and uninoculated plots and also when inoculated along with *C. cassiicola* (39.67 PDI). *C. cassiicola* acted like an antagonist against *A. alternata* in inoculated and uninoculated plots in both Jaadoo BG II hybrid and variety L 1060 and limited the disease severity of *A. alternata* to very low extent (Table 2).

Inoculation of *C. cassiicola* alone in Jaadoo BG II hybrid (27.83 PDI) recorded lower disease severity than variety L 1060 (34.67 PDI). When both *A. alternata* (10.33 PDI) and *C. cassiicola* (29.33 PDI) were inoculated simultaneously in Jaadoo BG II hybrid, PDI of *C. cassiicola* was *on par* with individual inoculation (27.83) and uninoculated field (29). Whereas in variety L 1060, simultaneous inoculation of both *A. alternata* (11.33PDI) and *C. cassiicola* (37.17PDI) showed PDI of *C. cassiicola* *on par* with *C. cassiicola* in uninoculated plots (38.33) and inoculation of *C. cassiicola* alone (34.67). Thus PDI of *C. cassiicola* was *on par* when inoculated alone or with *A. alternata* in Jaadoo BG II hybrid and variety L 1060, because there was no effect of *A. alternata* on *C. cassiicola* in inoculated and uninoculated plots (Table 2).

When both *A. alternata* and *C. cassiicola* were inoculated simultaneously in Jaadoo BG II (39.67 PDI) and L 1060 (48.50 PDI), *C. cassiicola* was superior in causing disease than *A. alternata*. Similar trend was observed in uninoculated field for *A. alternata* and *C. cassiicola* in both Jaadoo BG II (38.17 PDI) and L 1060 (49.33 PDI). This shows simultaneously inoculated fields of *A. alternata* and *C. cassiicola* were *on par* with uninoculated fields of Jaadoo BG II and L 1060. *C. cassiicola* acted like an antagonist against *A. alternata* in Jaadoo BG II and L 1060 when inoculated simultaneously and in uninoculated plots compared to their individual inoculations (Table 2).

Interactions of pathogens and genotypes at 120 DAS

Interaction of *A. alternata* and *C. cassiicola* caused significant difference in PDI of Jaadoo BG II and L 1060 when inoculated alone and in combination. When *A. alternata* (8.25PDI) and *C. cassiicola* (39.25PDI) were inoculated simultaneously, *A. alternata* significantly varied with individually inoculation (20.58PDI), but was found *on par* with *A. alternata* (8.17PDI) in uninoculated plots. *C. cassiicola* (39.25PDI) inoculated simultaneously with *A. alternata* was found statistically *on par* with individually inoculated *C. cassiicola* (41.25PDI) and *C. cassiicola* (41.33PDI) in uninoculated plots. When pathogens were inoculated simultaneously, *C. cassiicola* (39.25PDI) acted like an antagonist to *A. alternata* (8.25PDI) when compared to individually inoculated plots of *A. alternata* (20.58PDI) and *C. cassiicola* (41.25PDI). Whereas PDI of *A. alternata* (8.17) and *C. cassiicola* (41.33) in uninoculated plots were found *on par* with PDI of *A. alternata* (8.25) and *C. cassiicola* (39.25) in simultaneously inoculated plots. It shows that *A. alternata* was completely dominated by *C. cassiicola* in individually inoculated plots, simultaneously inoculated plots and also in uninoculated plots. Environmental conditions

were more favourable for the development of *C. cassiicola* inoculum and infection (Table 2).

Variety L 1060 (34.25 PDI) expressed significantly high disease severity due to *A. alternata* and *C. cassiicola* compared to Jaadoo BG II (29.71 PDI) and more susceptible to *A. alternata* and *C. cassiicola* infection (Table 2).

Impact of interactions between *A. alternata* and *C. cassiicola* inoculated individually and together in inoculated and uninoculated plots of Jaadoo BG II and L 1060 revealed that PDI of Jaadoo BG II was significantly low when inoculated with *A. alternata* alone (19.17) compared to L 1060 (22.00), whereas in uninoculated plots of Jaadoo BG II *A. alternata* was recorded with low PDI (9) and *on par* with L 1060 (7.33). When *A. alternata* (8 PDI) and *C. cassiicola* (36.33 PDI) were inoculated simultaneously in Jaadoo BG II, PDI of *A. alternata* was less compared to individual inoculation of *A. alternata* (19.17) and *on par* with *A. alternata* in uninoculated control (9). In variety L 1060, simultaneous inoculation of both resulted in PDI of *A. alternata* (8.50) *on par* with *A. alternata* (7.33) in uninoculated plots. It was found that *A. alternata* disease severity was high in variety L 1060 compared to Jaadoo BG II hybrid in inoculated plots and low in uninoculated plots. When both *A. alternata* and *C. cassiicola* were inoculated simultaneously *C. cassiicola* acted like an antagonist against *A. alternata* in inoculated and uninoculated plots of both Jaadoo BG II hybrid and variety L 1060 and limited the disease severity of *A. alternata* to very low extent (Table 2).

Inoculation of *C. cassiicola* alone in Jaadoo BG II (36.15PDI) recorded the lowest disease severity as against variety L 1060 (46.33PDI). When both *A. alternata* (8 PDI) and *C. cassiicola* (36.33 PDI) were inoculated simultaneously in Jaadoo BG II hybrid, PDI of *C. cassiicola* was *on par* with individual inoculation (36.15) and uninoculated plots (37.83). Whereas in variety L 1060,

simultaneous inoculation of both *A. alternata* (8.50PDI) and *C. cassiicola* (42.17PDI) showed PDI of *C. cassiicola* on par with *C. cassiicola* in uninoculated plots (44.83) and individual inoculation of *C. cassiicola* alone (46.33). Thus PDI of *C. cassiicola* was on par when inoculated alone or with *A. alternata* in Jaadoo BG II hybrid and variety L 1060, because there was no effect of *A. alternata* on *C. cassiicola* in inoculated and uninoculated plots (Table 2).

When both *A. alternata* and *C. cassiicola* were inoculated simultaneously in Jaadoo BG II (44.33PDI) and L 1060 (50.67PDI), *C. cassiicola* was superior in causing disease than *A. alternata*. Similar trend was also observed in uninoculated plots for *A. alternata* and *C. cassiicola* in both Jaadoo BG II (46.83 PDI) and L 1060 (52.17 PDI). This shows simultaneously inoculated plots of *A. alternata* and *C. cassiicola* were on par with uninoculated plots of Jaadoo BG II and L 1060. *C. cassiicola* acted like an antagonist against *A. alternata* in Jaadoo and L 1060 when inoculated simultaneously and uninoculated plots compared to their individual inoculations (Table 2).

Almeida *et al.*, (2001) observed *C. cassiicola* as a necrotrophic fungus that destroys and utilize the nutrients from the host and remained as inoculum source in seeds and infected debris and 95 per cent RH favoured spore germination. Suryanarayanan *et al.*, (2002) reported *C. cassiicola* to grow as saprophyte or endophyte. Dutta *et al.*, (2020) reported that 20-30 °C temperature and relative humidity as major factors for mycelia growth, spore germination and production of *C. cassiicola*. Positive correlation was observed between conidial germination and relative humidity.

Jiahuai and Norton (2020) noticed that initial spots of *A. alternata* were small, brown necrotic lesions with purple halo. As the lesions grow they may coalesce and become irregular spots. Yi Zhu *et al.*, (2019) reported that *Alternaria* leaf spot pathogens were mainly

accompanied with late season development of cotton plants. MacKenzie *et al.*, (2018) observed *C. cassiicola* as a polycyclic disease with a short reproduction cycle, completing many generations in one cropping season. It reveals that late season development of *Alternaria* leaf spots was over taken by *Corynespora* leaf spot due to short reproduction cycle and completed many generations in a season.

It may be concluded that pathogen - pathogen interactions can be used to develop holistic disease management strategies in view of stage specific or overlapping progress of diseases in a crop.

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