Original Research

Journal website : www.jeb.co.in ★ E-mail : editor@jeb.co.in

Journal of Environmental Biology

JEB™ p-ISSN: 0254-8704
e-ISSN: 2394-0379
CODEN: JEBIDP

DOI : http://doi.org/10.22438/jeb/42/4/MRN-1683

Response of cotton genotypes against the incidence of Alternaria leaf blight of cotton under field conditions

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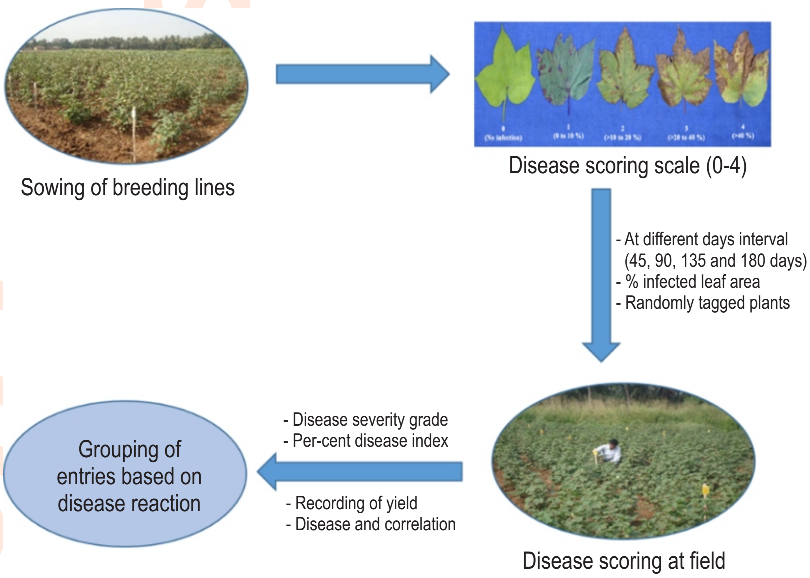
Received: 28.08.2020 *Revised*: 07.11.2020 *Accepted*: 20.02.2021

Abstract

Aim: To identify the resistant source present in the breeding materials against Alternaria leaf blight disease of cotton (*Gossypium* spp.).

Methodology: Breeding entries were sown in a randomized complete block design in the experimental site. Disease intensity on each genotype at 45, 90, 135 and 180 days after sowing (DAS) were recorded from leaves of lower, middle and upper parts of plants and graded. According to 0 - 4 disease scoring scale, per cent disease index (PDI) was calculated and genotypes were categorized into different categories based on disease reaction.

Results: Development of Alternaria disease was noticed at early days of crop growth in few genotypes and the disease increased upto 135 days after sowing. The maximum mean per cent disease index of 41.17 and 40.06 were recorded in Br.14a (ZT)1333 and Br.14a (ZT)1332 respectively. The least PDI of 0.58 was recorded in Br.03a (ZT)1303. Disease incidence of <11.00% of was reported in 37 entries at 45 days after sowing. None of the genotypes showed apparently immune reaction, twenty-one genotypes showed resistant reaction, eleven genotypes were moderately resistant and five showed moderately susceptible reaction.



Interpretation: Twenty-one breeding lines showed resistant reaction against Alternaria leaf blight disease under field conditions, however, further utilization of these lines may be carried out in breeding programmes for the development of resistant source against this disease.

Key words: Alternaria leaf blight, Cotton, Disease reaction, Genotypes

How to cite : Rajesha, G., S. Nakkeeran, T. Indumathi, P. Adhipathi and A. Chandrasekar: Response of cotton genotypes against the incidence of Alternaria leaf blight of cotton under field conditions. *J. Environ. Biol.*, **42**, 1002-1007 (2021).

Introduction

Cotton (*Gossypium* spp.) known as the "king of fibers" is an important fiber and cash crop occupying nearly 33 million ha in 77 countries as a major source of natural fiber worldwide (Singh and Rathore, 2020). It is widely grown in India and is one of the important livelihood for an estimated 60 million Indian people, including 6 million farmers, mostly small and marginal. In addition to fiber production, it is also used for gossypol production due to its extensive range of biological properties including anti-cancer, antimicrobial, anti-HIV, anti-oxidative and male contraceptive activities (Vander *et al.,* 2000). It is being cultivated as a major crop in parts of the African Tropics, Australia, China, Egypt, India, New Mexico, Pakistan, Soviet Union, Sudan, United States and warmer regions of Central and South America (Leff *et al.,* 2004). India is the second world producer of cotton after China, but account for only 18% of total world cotton production against 23% of world cotton area. Cotton crop is continually exposed to threat of biotic stress and considered as a major biological challenge to exploit cotton productivity.About 80-90% of disease in cotton pertains to foliar diseases (Gulhane and Gurjar, 2011).

Among them, Alternaria leaf blight is one of the major foliar disease, prevalent in all cotton growing regions worldwide including Israel, India, China, Egypt, Russia, Zimbabwe, New South Wales, Australia and the United States (Newman, 2011). Average disease severity index ranged from 21.5 to 87.0% was reported in New Mexico (Zhu *et al.,* 2019). In India, this disease is one of the economic foliar disease of cotton (Bhattiprolu and Rao, 2013), which appears every year and has reduced the cotton production (Cui *et al.,* 2000). The yield loss of 37 per cent was reported in India by Padaganur *et al.* (1989) due to occurrence of this pathogen. In Tamil Nadu, the incidence of leaf blight disease increased to 54.62 PDI during the year 2013-2014 and caused severe yield loss of 32% (Saravanan *et al.,* 2015). The leaf blight symptom occurs due to two species of *Alternaria* (*A. macrospora* Zimm. and *A. alternata* (Fr.) Keissler) and are common in cotton crops grown around the world (Kaur and Aggarwal, 2015). The species *A. macrospora* causes sudden premature defoliation resulting in severe yield loss whereas *A. alternat* a infection is also prominent on cotton, but is usually less damaging (Hillocks, 1991; Rajesha *et al.,* 2020).

Several disease outbreaks have occurred mainly in cotton growing regions in the world and caused yield losses upto 25% in Israel (Rotem *et al.,* 1988).The yield reduction of 38.23% (Bashi *et al.,* 1983; Bhattiprolu and Rao, 2009) was reported due to increased incidence and severity, resulting in severe defoliation in the late cotton growing season (Zhu *et al.,* 2018), especially when it affects highly susceptible cultivars. Resistant crops provide an effective and inexpensive method for managing diseases in both high value as well as low value cropping systems. They are environmentally compatible, safe to use and do not require specialized applications, as faced in chemical application (Fitt *et al.,* 2002). The use of resistant cultivar has proved to be most desirable method of *Alternaria* leaf blight management. Although no commercial cotton cultivars grown are known to be immune to *Alternaria*, and no breeding program is known to develop *Alternaria* resistant cotton cultivars, different levels of Alternaria leaf blight resistance may exist in current commercial cotton cultivars and breeding lines (Zhu *et al.,* 2018). Bodhke *et al.* (2019) evaluated thirteen varieties against Alternaria leaf blight of cotton, only two varieties were found resistant reaction and remaining were susceptible to disease. Significant variation in disease severity index (DSI) ranged from 26.7% to 92% was recorded among the 160 genotypes of cotton in New Mexico (Zhu *et al.,* 2018). Thus, it is important to evaluate the disease reaction on available cultivars. In view of the above, this study was conducted to evaluate resistance source among genotypes of cotton for Alternaria leaf blight disease.

Materials and Methods

Experimental set up: A total of thirty-nine breeding entries were sown in a randomized complete block design for evaluation under field conditions at Department of Cotton, Tamil Nadu Agricultural University, Coimbatore, India. Land was prepared well and brought to good tilth condition suitable for sowing. The field was sown by breeding entries with plot size of 10 x 5 m (50 m^2) with 3 replications. The local recommended package of practices of cotton cultivation, Tamil Nadu were practiced without using any pesticides and fungicides application during experimentation.

Field evaluation of cotton genotypes against Alternaria leaf blight of cotton: Evaluation of cotton breeding entries against Alternaria leaf blight disease was carried out to identify the source of resistance under field conditions. Thirty-nine breeding entries were screened by recording observations on the intensity of Alternaria leaf blight disease on each genotype at 45, 90, 135 and 180 days after sowing (DAS). Total of five leaves from lower, middle and upper parts from ten plants in each genotype were randomly selected and percent leaf area was calculated according to 0 - 4 disease scoring scale of following criteria: 0 - No infection, completely free from disease; 1- Few <2mm, scattered brown spots and 0.1 to 10% infected leaf area covered; 2 - Spots bigger, 3 mm, not coalescing, brown and 11-20% infected leaf area; 3 - Spots 3-5 mm, irregular in shape-coalescing, 21-40% infected leaf area; 4 - Spots coalescing to form bigger lesions, irregular >40 infected leaf area (Sheo Raj, 1988). Based on the PDI, genotypes were categorized into immune, highly resistant, moderately resistant, moderately susceptible and highly susceptible based on the disease reaction (Sheo Raj, 1988). In addition to disease incidence, an average seed cotton yield of all the selected 10 plants of each genotypes were recorded and expressed in gram per plant.

Statistical analysis: The data was analyzed independently. The treatment means were compared by Duncan's Multiple Range-Test (DMRT) (Gomez and Gomez, 1984). The package used for analysis was IRRISTAT version 92-1 developed by the International Rice Research Institute Biometrics unit, the Philippines.

Results and Discussion

Identification of disease resistant source is essential to use as donors for the resistant source in breeding programmes and recommendation for cultivation in high disease prone areas. The plants of durable disease resistance are effective to cultivate in larger area with out yield loss (Consortum, 2016). The resistance identified cultivars consistently resulted in less disease than non-resistant cultivator in high pathogen population (Wheeler *et al.,* 1999). Field evaluation is a useful and convenient method for identifying cotton genotypes with natural resistance to Alternaria leaf blight (Zhu *et al.,* 2018). In the present study, breeding materials were screened under field conditions and percent disease index (PDI) was recorded at 45, 90, 135 and 180 days after sowing (Table 1). The results revealed that development of disease was noticed at early days of crop growth in few genotypes and the increased PDI was observed upto 135 days after sowing (DAS) during flowering and boll

Table 1: Percent disease index (PDI) and seed cotton yield/plant due to Alternaria leaf blight after different days of sowing of cotton germplasm under field conditions

Name of entries	Per cent Disease Index (PDI)*				Mean PDI	Seed cotton yield/plant (g)*
	45 DAS	90 DAS	135 DAS	180 DAS		
Br.03a (ZT)1301	0.00	2.32	3.75	2.25	2.08	184.00^{c-g}
Br.03a (ZT)1302	0.00	0.00	3.75	2.00	1.44	186.00^{c-f}
Br.03a (ZT)1303	0.00	3.00	4.57	5.00	3.14	191.00^{b-e}
Br.03a (ZT)1304	6.7	7.75	17.95	9.2	10.4	179.33^{c-i}
Br.03a (ZT)1305	6.75	10.50	16.25	7.50	10.25	171.67^{f-l}
Br.03a (ZT)1306	0.00	5.12	3.75	3.75	3.16	184.33^{c-g}
Br.03a (ZT)1307	0.00	0.00	1.12	1.59	0.68	206.00^{ab}
Br.03a (ZT)1308	0.00	2.32	0.00	0.00	0.58	208.67^{a}
Br.03a (ZT)1309	0.00	0.00	2.00	2.76	1.19	195.33^{a-d}
Br.04a (ZT)1311	3.75	11.43	17.50	9.79	10.62	170.67^{f-m}
Br.04a (ZT)1312	5.15	15.25	12.25	7.50	10.04	164.67^{h-o}
Br.04a (ZT)1313	3.76	8.72	3.75	5.25	5.37	179.33^{c-i}
Br.04a (ZT)1314	3.93	3.75	12.55	7.43	6.92	185.67^{c-f}
Br.04a (ZT)1315	0.00	8.30	3.75	3.75	3.95	181.67^{c-h}
Br.04a (ZT)1316	3.50	4.00	0.00	0.00	1.88	193.33^{a-e}
Br.04a (ZT)1317	3.75	8.50	3.75	5.70	5.43	170.67^{f-m}
Br.04a (ZT)1318	0.00	4.20	5.20	3.00	3.10	195.67^{abc}
Br.05a (ZT)1321	0.00	3.25	3.75	5.75	3.19	178.33^{d-j}
Br.05a (ZT)1322	0.00	9.75	12.85	20.20	10.70	168.33^{g-n}
Br.05a (ZT)1323	0.00	11.55	3.75	8.31	5.90	171.33^{f-l}
Br.05a (ZT)1324	0.00	0.00	3.50	3.00	1.63	195.33^{a-d}
Br.05a (ZT)1325	5.75	8.31	16.56	10.32	10.24	176.33^{e-k}
Br.05a (ZT)1326	0.00	5.00	5.00	9.12	4.78	186.67^{c-f}
Br.14a (ZT)1331	11.25	27.57	28.75	18.50	21.52	159.67^{k-q}
Br.14a (ZT)1332	32.72	38.50	46.25	42.75	40.06	145.67^{pq}
Br.14a (ZT)1333	37.28	41.72	47.55	38.12	41.17	143.67^{q}
Br.14a (ZT)1334	5.25	15.32	18.75	15.75	13.77	161.67^{j-p}
Br.14a (ZT)1335	8.37	16.70	21.75	18.30	16.28	158.33^{l-q}
Br.14a (ZT)1336	7.50	18.89	15.00	12.00	13.35	166.33^{h-o}
Br.14a (ZT)1337	9.08	22.75	27.20	24.05	20.77	159.67^{k-q}
Br.14a (ZT)1338	9.00	18.65	11.25	14.50	13.35	163.67^{i-o}
Br.14a (ZT)1339	9.75	24.75	29.75	19.85	21.03	153.33^{n-q}
Br.15a (ZT)1351	6.75	11.65	15.25	8.54	10.55	162.00^{j-p}
Br.15a (ZT)1352	0.00	5.55	3.75	2.75	3.01	170.00^{f-n}
Br.15a (ZT)1353	0.00	0.00	5.90	4.30	2.55	181.67^{c-h}
Br.15a (ZT)1354	0.00	0.00	4.20	5.70	2.48	194.67^{a-d}
Br.15a (ZT)1355	11.00	28.90	37.50	35.67	28.27	149.67^{opq}
Br.15a (ZT)1356	7.90	23.25	28.75	24.55	21.11	153.67^{m-q}
Br.15a (ZT)1357	0.00	0.00	2.70	4.60	1.83	189.33^{cde}
						r= -0.86

*Values are the mean of three replications

Table 2: Disease reaction, percent leaf area covered and number of entries of cotton germplasms against Alternaria leaf blight under field condition

Disease Severity Grade	Disease reaction	Per cent leaf area covered	Number of entries	Entries
0	Immune	0.00	-	-
1	Highly Resistant	Up to 10	21	Br.03a (ZT)1301, Br.03a (ZT)1302, Br.03a (ZT)1303, Br.03a (ZT)1306, Br.03a (ZT)1307, Br.03a (ZT)1308, Br.03a (ZT)1309, Br.04a (ZT)1313, Br.04a (ZT)1314, Br.04a (ZT)1317, Br.04a (ZT)1316, Br.04a (ZT)1318, Br.05a (ZT)1321, Br.05a (ZT)1323, Br.05a (ZT)1324, Br.05a (ZT)1326, Br.15a (ZT)1351, Br.15a (ZT)1352, Br.15a (ZT)1353, Br.15a (ZT)1354, Br.15a (ZT)1357
2	Moderately resistant	11-20	11	Br.03a (ZT)1304, Br.03a (ZT)1305, Br.04a (ZT)1311, Br.04a (ZT)1312, Br.04a (ZT)1315, Br.05a (ZT)1322, Br.05a (ZT)1325, Br.14a (ZT)1334, Br.14a (ZT)1335, Br.14a (ZT)1336, Br.14a (ZT)1338
3	Moderately susceptible	21-40	5	Br.14a (ZT)1331, Br.14a (ZT)1337, Br.14a (ZT)1339, Br.15a (ZT)1355, Br.15a (ZT)1356
4	Highly susceptible	>40	2	Br.14a (ZT)1332, Br.14a (ZT)1333

formation time, later decreased disease severity was noticed at maturity. The maximum mean per cent disease index of 41.17 was recorded in the entry Br.14a (ZT)1333 followed by mean per cent disease index of 40.06 in the entry Br.14a (ZT)1332. The least PDI of 0.58 was recorded in Br.03a (ZT)1303. Initially, higher disease incidence of 37.28% and 32.72% was recorded in Br.14a (ZT)1333 and Br.14a (ZT)1332, respectively, at 45 days after sowing whereas only <20.00% of disease reported in the remaining entries were moderately resistant.

The development of disease at early stage is less and starts increasing with increase of age because of susceptibility towards the disease. Several authors have reported different disease severity of Alternaria leaf spot during crop growth period of cotton. Zhu *et al.* (2019) reported incidence of 100% leaf blight symptoms at late growth stage of cotton. The increased disease severity at maturity period could be due to availability of suitable micro-climate for the disease occurrence and susceptibility of the lines for the disease. The prevailed micro climate within the lower canopy is more favorable for disease development and higher green boll loads are more susceptible to disease (Harde *et al.,* 2016). The favorable environmental condition plays a vital role in occurrence of leaf blight disease in cotton and their incidence increases year by year due to susceptibility of cultivars. Bhuiyan *et al.* (2007) reported that species of *A. macrospora* was most prevalent during early growth period and *A. alternata* species was more prevalent during the end of growing season responsible for defoliation and higher disease severity. Le and Gregson (2019) reported that, severe disease outbreaks were recorded in multiple cotton crops in south Wales (NSW) in the 2017/18 season.

The Manifestation of plant pathogens is most important cause of losses in several crop. The occurrence of foliar disease reduces the production and productivity in cotton (Bernardes *et al.,* 2013). In this study, the least seed cotton yield of 143.67 g per plant was obtained in Br.14a (ZT)1333 and higher seed cotton yield of 208.67 g per plant was reported in Br.03a (ZT) 1308 (Table1). The occurrence of disease in Br.14a (ZT)1333 reported maximum as compared to other breeding entries. The higher severity of disease was reported due to defoliation and reduced photosynthetic activities leads to reduced yield in cotton. Infection due to pathogenic *Alternaria* results in pre-mature defoliation in cotton (Rajesha *et al.,* 2012) and causes quick and severe defoliation responsible for yield losses (Zhao *et al.,* 2013). Saravanan *et al.* (2015) reported that incidence of leaf blight caused severe yield loss in cotton during the year of 2013-2014. The correlation between disease development and yield is most often summarized as a simple empirical model that describes average performances of the crop during the presence of virulent pathogen. Understanding the influence of weather factors on host stage and disease development is prerequisite to strategically manage these diseases (Bhattiprolu and Monga, 2018). In this study, correlation coefficient was determined between the yield and leaf blight disease severity among all the entries (Table 1).

The result revealed that the level of disease severity was negatively correlated to yield r= -0.86). It was summarized that every one per cent increase of disease incidence leads to reduction of 0.86 g of seed cotton yield. The higher incidence of disease recorded the least cotton yield in Br. 14a (ZT) 1333. The severity of disease and yield loss reported by Bhattiprolu (2018) revealed that the occurrence of 35% of Alternaria leaf blight disease was responsible for yield loss of 13.80%. Chattannavar *et al.* (2009a) reported that economic yield loss of 26% was reported due to Alternaria leaf blight in cotton. Higher severity of disease is directly correlated to yield loss in cotton. Bhattiprolu and Monga

(2018) reported that significant Alternaria disease correlation of r=0.984 was developed due to prevalence of weather factors in *kharif* 2017. In both 2016 and 2017, high rainfall than normal occurred in New Mexico in the fall, which caused high levels of Alternaria leaf blight incidence leads to severe foliar damage and yield loss (Zhu *et al.,* 2018). Utilization of developed resistant cultivars in farming is the simplest, effective and inexpensive method of disease management.

In addition to this, use of disease resistant cultivars conserves resources, other inputs and effectively minimizes the production cost, time and sources of energy when compared to other management practices of disease. In this study, thirty-nine genotypes were categorized into different groups based on disease reaction (Table 2). Among them, none of the genotypes showed apparently immune reaction to Alternaria leaf blight in cotton. However, twenty-one genotypes showed resistant reaction to leaf blight infection and eleven genotypes *viz.,* Br.03a (ZT)1304, Br.03a (ZT)1305, Br.04a (ZT) 1311, Br.04a (ZT)1312, Br.04a (ZT)1315, Br.05a (ZT)1322, Br.05a (ZT)1325, Br.14a (ZT)1334, Br.14a (ZT)1335, Br.14a (ZT)1336, Br.14a (ZT)1338 showed moderately resistant reaction. Further, five genotypes (Br.14a (ZT)1331, Br.14a (ZT)1337, Br.14a (ZT)1339, Br.15a (ZT)1355, Br.15a (ZT)1356) showed moderately susceptible reaction, however, two genotypes Br.14a (ZT)1332 and Br.14a (ZT)1333 showed of highly susceptible reaction to leaf blight. However, screening of cotton against *Alternaria* resistance can be easily incorporated into breeding program is an essential component, as was the case in this study.

In this study and also previous studies (Hosagoudar 2007; Anil 2013; Cia *et al.,* 2016), none of the cotton genotypes were identified as immune to Alternaria leaf blight whereas several Pima cotton cultivars were evaluated for resistance to Alternaria leaf blight, based on disease severity rating, lesion size and numbers and Pima was found to be more susceptible (Zhu *et al.,* 2018). Similarly, Chattannavar *et al.* (2009b) screened 196 cotton cultivars under field conditions for resistance to Alternaria blight during the kharif season of June 2007. Among them, nine cultivars *viz.,* DCH 32, RAMSHH 7, GSHB 895, CCHB 2628, CCCHB 07-2, DHB 0782, NSPL 414, Ajeet 999 and HAGHB 12 were found to be most resistant to disease. Zhu *et al.* (2018) evaluated 133 cotton genotypes for Alternaria leaf spot resistance and found that none cotton genotypes were immune to disease caused by *A. alternata*. Sandipan *et al.* (2017) reported that 21 of 38 entries were disease free from apparent Alternaria leaf blight in natural condition in India.

However, infection of *Alternaria* spp. (*A. macrospora* and *A. alternata*) is known to cotton and expression of typical symptom may be absent. Furthermore, the disease free conditions in some genotypes may be due to disease escape mechanism or field resistance, which is especially true when disease is not prevalent. Even-though, our study shows that breeding entries were resistant and moderately resistant to disease; and resistant entries may be good source of resistance in breeding programmes. The study revealed that 21 breeding entries were identified as resistant to leaf blight disease. The breeding lines Br.14a (ZT)1333 and Br.14a (ZT)1332 were highly susceptible to leaf blight disease. The present study clearly indicates that in spite of remarkable efforts required for breeding for disease resistance, availability of resistant genotypes to Alternaria leaf blight is more advantageous in event of epidemics of leaf blight of cotton.

Acknowledgments

The authors are thankful to the Department of Cotton, TNAU, Coimbatore, India for providing facilities to carry out field research work. Authors are also grateful to the Indian Council of Agricultural Research (ICAR), New Delhi for the research grant as Senior Research Fellowship.

Add-on Information

Authors' contribution: G. Rajesha: Methodology, investigation, Formal analysis, Writing-original draft preparation, Funding acquisition, **S. Nakkeeran:** Conceptualization and supervision, Funding acquisition, Resources, **T. Indumathi:** Methodology, investigation, Formal analysis, **P. Adhipathi: :** Methodology, Writing - original draft preparation, **A. Chandrasekar:** Resources, Conceptualization supervision.

Research content: The research content of manuscript is original and has not been published elsewhere.

Ethical approval: Not applicable

Conflict of interest: The authors declare that they have no conflict of interest.

Data from other sources: Not applicable

Consent to publish: All authors agree to publish the paper in *Journal of Environmental Biology*.

References

Bashi, E., J. Rotem, H. Pinnschmidt and J. Kranz: Influence of controlled environment and age on development of *Alternaria macrospora* and on shedding of leaves in cotton. *Phytopathology,* **73**, 1145-1147 (1983).

Bernardes, A.A., J.G.Rogeri, R.B. Oliveira, N. Marranghello and A.S. Pereira: Identification of foliar diseases in cotton crop. In: Topics in Medical Image Processing and Computational Vision. pp. 67–85 (2013).

Bhattiprolu, S.L. and M.P.P. Rao: Evaluation of cotton genotypes against Alternaria and Helminthosporium leaf spot diseases. *J. Cott. Res. Develop.*, **27**, 302-304 (2013).

Bhattiprolu, S.L. and D. Monga: Effect of weather parameters on the development of Alternaria leaf spot and grey mildew in cotton. *J. Agrometeorol.,* **20**, 315-318 (2018).

Bhattiprolu, S.L. and M.P.P. Rao: Estimation of crop losses due to Alternaria leaf spot in cotton. *J. Indian Soc. Cotton Impr.,* **14**, 151-154 (2009).

Bhattiprolu, S.L.: Evaluation of Pyraclostrobin 20% WG for the control of fungal diseases in cotton. *Int. J. Chem. Studi.,* **6**, 607-610 (2018).

Bhuiyan, A.S., M.C. Boyd, C. Martin and M. Hearnden: Development of Alternaria leaf blight on north Australian cotton (*Gossypium hirsutum*), species prevalence, and its control using mancozeb. *Aus. Pl. Pathol.,* **36**, 488-497 (2007).

Bodhke, V.S., C.U. Patil and S.B. Zade: Screening of different genotype of cotton for resistance against Alternaria leaf blight disease. *Int. J. Chemi. Studi.,* **7**, 1426-1428 (2019).

Chattannavar, S.N., G.N. Hosagoudar, R. Ammajamma and S.A. Ashtaputre: Survey for diseases of Bt cotton in north Karnataka. *J. Cotton Res. Dev.,* **23**, 156-158 (2009a).

Chattannavar, S.N., G.N. Hosagoudar, S.A. Ashtaputre and R. Ammajamma: Evaluation of cotton genotypes for grey mildew and Alternaria blight diseases. *J. Cotton Res. Dev.,* **23**, 159-162 (2009b).

Cia, E., M.G. Fuzatto, J.I. Kondo, L.H. Carvalho, M.F. Ito, F.L.F. Dias and P.B. Gallo: Response of cotton genotypes to theincidence of Alternaria leaf spot. *Summa Phytopathol.,* **42**, 357–359 (2016).

Consortium, R.E.X.: Combining selective pressures to enhance the durability of disease resistance genes. *Front. Plant Sci.,* **7**, 1916 (2016) doi: 10.3389/fpls.2016.01916

Cui, Y., A.A. Bell, O. Joost and C. Magill: Expression of potential defense response genes in cotton. *Physiol. Mol. Pl. Pathol.,* **56**, 25-31 (2000).

Fitt, G., C. Mares and G. Constable: Enhancing host plant resistance of Australian cotton varieties. *Austra. Cotton Grow.,* **23**, 20-26 (2002).

Gomez, K.A. and A.A. Gomez: Statistical Procedure for Agricultural Research. John Wiley and Sons, New York. (1984).

Gulhane, V.A. and A.A. Gurjar: Detection of diseases on cotton leaves and its possible diagnosis. *Int. J. Image Proc.*, **5**, 590-598 (2011).

Harde, S.N., L.V. Shinde and R.J. Chavan: Disease scenario on Bt cotton from Jalna district (MS), India. Proceeding of National Conference on Environment and Development, Lonavala, pp. 57-63 (2016).

Hillocks, R.J.: Alternaria leaf spot of cotton with special reference to Zimbabwe. *Tropical Pest Managem.,* **37**, 124-128 (1991).

Kaur, M. and N.K. Aggarwal: First report of *Alternaria* spp. causing leaf blight disease on *Parthenium weed* in India. *New Dis. Rep.,* **31**, 25 (2015).

Le, D.P. and A. Gregson: Alternaria leaf spot of cotton seedlings grown in New South Wales, Australia is predominantly associated with *Alternaria alternata*. *Australian Plant Pathol.,* **48**, 209–216 (2019).

Leff, B., N. Ramankutty and J.A. Foley: Geographic distribution of major crops across the world. *Global Biogeoche. Cycles,* **18**, 1-27 (2004). doi:10.1029/2003GB002108

Newman, M.A.: Cotton disease and nematode control. *Extn. Pl. Path. Info.,* **24**, 1-11 (2011).

Padaganur, G.M., R.V. Hiremath and M.K. Basavaraj: Estimation of yield loss due to Alternaria leaf spot and blight in cotton. *J. Cotton Res. Dev.,* **14**, 144 (1989).

Rajesha, G., S. Nakkeeran and A. Chandrasekaran: Genetic diversity of *Alternaria* isolates causing leaf blight of cotton and management of leaf blight with bacterial endophytes. *Natio. Acad. Biol. Sci. Newsletter*, **3**, 6 (2012).

Rajesha, G., S. Nakkeeran, T. Indumathi, P. Adhipathi and A. Chandrasekar: Evaluation of different fungicides against *Alternaria macrospora* Zimm. inciting leaf blight in cotton under *in vitro*. *Int. J. Curr. Microbiol. App. Sci.,* **9**, 1051-1058 (2020).

Rotem, J., J. Eidt, U. Wendt and J. Kranz: Relative effects of *Alternaria alternata* and *A. macrospora* on cotton crops in Israel. *Plant Pathol.,* **37**, 16-20 (1988).

Sandipan, P.B., G.R. Bhanderi, R.D. Patel, D.M. Patel and B.G. Solanki: Screening of varieties/ breeding materials for resistance to different diseases in natural condition under south Gujarat region. *Int. J. Curr. Microbiol. App. Sci.,* **6**, 1355-1361 (2017).

Saravanan, P., S. Divya, P. Venkatesan, R. Tanwar, A. Birah, C. Chattopadhyay, P. Jeyakumar and A. Barik: Trend analysis of pests and diseases complex in Bt cotton. *J. Crop Prot.,* **4**, 431-439 (2015).

Sheo, R.: Grading for cotton disease, Nagpur, *CICR, Tech Bull.,* pp. 1-7 (1988).

Singh, K. and P. Rathore: Planting geometry and nutrient levels affecting seed cotton yield, productivity indices and economic parameters of Bt cotton (*Gossypium hirsutum* L.). *J. Environ. Biol.,* **41**, 1550-1559 (2020).

Vander, J.D.L., L.M. Deck and R.E. Royer: Gossypol prototype of inhibitors targeted to dinucleotide folds. *Curr. Medicinal Chem.,* **7**, 478-498 (2000).

Wheeler, T.A., J.R. Gannaway and K. Keatin: Identification of resistance to *Thielaviopsis basicola* in diploid cotton. *Plant Dis.,* **83**, 831-833 (1999).

Zhao, J., F. Zhao, G. Jian, Y. Ye, W. Zhang, J. Li and F. Qi: Intensified Alternaria spot disease under potassium deficiency conditions results in acceleration of cotton (*Gossypium hirsutum* L.) leaf senescence. *Aust. J. Crop Sci.,* **7**, 241(2013).

Zhu, Y., P. Lujan, S. Dura, R. Steiner, J. Zhang and S. Sanogo: Etiology of Alternaria leaf spot of cotton in southern New Mexico. *Plant Dis.,* **103**, 1595-1604 (2019).

Zhu, Y., P. Lujan, S. Dura, R. Steiner, T. Wedegaertner, J. Zhang and S. Sanogo: Evaluation of commercial upland (*Gossypium hirsutum*) and Pima (*G. barbadense*) cotton cultivars, advanced breeding lines and glandless cotton for resistance to Alternaria leaf spot (*Alternaria alternata*) under field conditions. *Euphytica,* **214**, 147(2018).