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An Updated Review of Alternaria Blight of Pigeonpea (*Cajanus cajan* (L.) Mill sp.)

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ABSTRACT

Pigeonpea (*Cajanus cajan* (L.) Mill sp.) is an important food legume grown in semi-arid tropical and sub-tropical farming systems under diverse agroecological environments. Alternaria blight (*Alternaria tenuissima* (Kunze ex Pers.) Wiltshire) is a minor disease when the pigeonpea is sown in June-July but becomes the most serious disease in crops that are sown in mid-September in North-Eastern India. Alternaria blight disease has been reported from 13.67 to 49.33% disease intensity in different climatic conditions. This disease is found on leaves, stems, and pods, and dark spots on the leaves and pods reduce the photosynthesis capacity and immature ripening, reducing the amount of quality seeds. The recurrence of the disease depends upon weather conditions, genotypes, age of plants, and virulence of the pathogen, and crop growing areas prioritized the research for developing an extensive range of Alternaria blight. Earlier workers on pathological, physiological, and biochemical characteristics of pathogen the nature of the infection process, and the genetic basis of the pathogen in variability could not clearly be reported. It is required to investigate Alternaria blight including signs, symptoms, biology, status, epidemiology, pathogenic, biochemical, and genetic variability, refinement of the resistance screening techniques, and develop integrated disease management technology of the pathogen to understand the change of disease scenario in the context of climate change. Available information on pathogen symptomatology, status, variability, source of resistance, different management options, and genetic basis of resistance have been updated and discussed with the identification of future research priorities.

Keywords Biochemical, Bio agent, Fungicides, Plant extract, Pathogenic.

INTRODUCTION

Pigeonpea (*Cajanus cajan* (L.) Mill sp.) is an important food legume grown in semi-arid tropical and sub-tropical farming systems under varied agro-ecological environments. Its cultivation is confined to developing countries, mostly in Africa, America, Asia, and the Caribbean islands. Globally the area and production of pigeonpea on 4.92 mha and 3.65 mt and productivity of 898 kg/ ha (ICRISAT 2019).

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India has the highest area and production under pigeonpea in the world. The shift of crop cultivation from the conventional *kharif* season to pre-*rabi* season (mid-September sowing) in North Bihar and Uttar Pradesh (India) has not only displayed an increased production possible of the crop but has also released generally a new prospect in the land use model of the rainfed areas of Bihar and adjoining states (India). Among the several factors responsible for the reduction of yield and quality deterioration of crops in India, in which diseases occupy a vital place. Alternaria blight was first time reported from Varanasi (India) by Pavgi and Singh (1971). The present review deals in brief with the pathogen causing, signs, symptoms, biology, status, epidemiology, pathogenic, biochemical, genetic variability, refinement of the resistance screening techniques, and develop integrated disease management technology of the pathogen to understand the change of disease scenario in the context of climate change.

Historical perspective of pathogen

The form genus Alternaria is a commonly encountered fungi of the Dictyosporae (Gr. Diction = net and spores = seed, spore). Taxonomically, Alternaria come under phylum; Ascomycota, subdivision; pezizomycotina, class, dothediomycetes, order: pleosporales. The conidia are large and multicellular with both horizontal and oblique septa. They are usually borne in chains. Conidia are also formed singly on the apex of the conidiophores. *Alternaria tenuissima* was first described as *Helminthosporium tenuissima* by Kunze (1818). Fries (1832), however, treated the species in the genus *Macrosporium*, it was Wiltshire (1933) agreed that Alternaria is stared that macrosporium in the original description was used to designate Alternaria type fungi having nonfiliform spores and one spore and one sore per conidiophore genus Alternaria in combination with *A. tenuissima* (Kunze ex pers.) Wiltshire. The Alternaria blight caused by *A. tenuissima* (Kunze ex Pers.) Wiltshire was described by Pavgi and Singh (1971).

Symptomatology of disease

Alternaria blight first appears in plants that are generally nine–weeks old in post-rainy season crops (Kannaiyan and Nene 1977). The old lower leaves of the plant are seen first of the disease, which later on spreads to the middle and upper leaves. The symptom is circular, chlorotic, dark-brown, minute spots with a yellow halo on the upper surface of leaflets, followed by the development of black spots that increase in size showing a purple margin around the black necrotic spots. The spots enlarged and as the infection progressed coalesce with each other forming big lesions. The dark brown spots increased in size having a yellow halo around them (Grewal 1984). Under severe infection, the infected leaves are defoliated. The whole upper portions stem and pods symptoms showing a withering and sickly stand of the crop. The flower buds do not open and finally drop down. The plants do not bear any fruit. The disease also occurs in the milked form on *kharif*- sown crop in June-July (Singh, 1996). The variation in shape, size color, and intensity of lesions are found on different host plants under different environmental conditions.

Status of the alternaria blight

Successful plant protection depends upon the survey and surveillance of pathogens and early detection of the disease incidence followed by the timely adoption and application of preventive measures. Kannaiyan and Nene (1977) described the occurrence of Alternaria blight disease at ICRISAT, Hyderabad (India) as a minor disease. When the crop is sown in the *kharif* season but becomes a serious appearance in the crops that are sown in the post-rainy season (Mahmood *et al.* 1983). Alternaria blight disease intensity was diverse from 13.7 to 38.5% areas of UP (India) (Alka and Singh 2004 and Kushwaha *et al.* 2010a). Sharma *et al.* (2012) reported in 2009-11 in Andhra Pradesh (India) and the disease incidence was recorded at 20-80%. Balai *et al.* (2013a) reported in *rabi* seasons 2009-10 and 2010-11 in Eastern part of Uttar Pradesh (Azamgarh, Bhadohi, Ballia, Ghazipur, Chandauli, Jaunpur, Mau, Mirzapur, Sohanbhdra and Varanasi) and adjoining Bihar districts (Aurangabad, Arah, Buxar, Bhabhua, and Sivan). The disease intensity in distinctive areas ranged from 16.93 to 38.59% years. Rani *et al.* (2019) reported maximum disease incidence was found in Kanke (Karnataka) from (0-30 percent). Savitha *et al.* (2021) reported in Vijayapura (Andra Pradesh) the maximum disease severity with

a range of 38.67 to 49.33% and this might be due to distinctions in pathogenic character, congenial weather conditions like heavy rainfall, higher relative humidity, and moderate temperature and also disease severity ranged with genotypes denoting the source of resistance have supported in construction up of high disease pressure.

Varietal screening of pathogen

Host plant resistance is an economic, environmentally safe, and effective module in an integrated disease management tactic to retain Alternaria blight under the threshold level. The genes conferring adult plant resistance are the most durable worldwide and this type of resistance becomes operative after the plant enters its productive phase. Therefore, an attempt was made to identify sources of resistance that can be used in developing resistant cultivars or directly used as such with a view to mitigating. Balai *et al.* (2013b) screened eighty genotypes at Varanasi (India) and six resistant (IPA-7-2, MA 98, ICP- 7220, ICP-8869, ICP-9606, and ICP-8867), three moderately resistant (DA-11, ICP-13174, and BMSR-736) were found against the pathogen. Rathore *et al.* (2018a) one hundred six genotypes screened, and only seven genotypes (Path 402, Path 407, NDA14-15, NDA-14-16, NDA14-4, NDA-14-29, and NDA-14-36) were recorded resistant. Rajeswari *et al.* (2021) twenty-four genotypes screened, and only four genotypes viz., IPA 15F, BDN2, IPA 8F, and MA6 were found resistant against the pathogen.

Pathogenic variability of pathogens

Morphology of the pathogen

The taxonomy of Alternaria is based on mainly the morphology and development of the colony ashen-grey, and fluffy, producing greenish pigment on potato dextrose agar (PDA) medium. Hyphae sub-hyaline to olive buff, septate, 1-6 µm wide, conidiophores olive buff to dark olive buff, single or in groups, simple or branched, septate and cylindrical in shape, up to 90-160 µm long and 4.8 µm thick. Conidia formed singly or in the chain, dark olive buff to brown having 2-8 transverse and 1-5 oblique septa. Conidia are smooth or slightly constricted at septa, obclavate, elongate to oval in shape, and tapering gradually forming a beak or sometimes swelling terminally. The beak is usually shorter. Conidia are muriform and measure 14.0-86.00 × 12.00-16.00 mm in size (Singh 1996). While, Sharma *et al.* (2012) reported that the conidiophores were short, arising singly measuring 8.86 mm in length and were 2.97 mm thick. The conidia size ranges from 15.78 to 28.70 mm in length and 8.03 to 13.47 mm in width. The conidia are very small beaks (1.6 to 3.2 mm) or no beak was detected. Oblique and vertical septations of conidia range from 4 to 6 and 2 to 4 respectively. Rani *et al.* (2019) reported that mycelium was seen grey-brown to smooth occasionally with a cottony center, the conidia size was 38.02 × 7.12 µm with 2-4 transverse septa and 0-2 oblique septa. Savitha and Ajithkumar (2023) described the morphology of conidia diverse is were separated by one or two vertical septa and 2-8 oblique septa, and the maximum oblique septa is of 3-8 were exhibited. The maximum size of the conidia is revealed 226.52-394.60 mm × 75.40-105.40 mm. The maximum beak length of 44.40-190.70 mm is exhibited.

Time-dependent sporulation

Various media are used for culturing and maintenance of the fungus, Singh *et al*. (2003) reported that the maximum number of spores and size of conidia in a chain was produced on PDA and albumen + 0.9 % sodium citrate. Only one spore and the smallest conidia were seen in DW.

Cultural variation of the pathogen

Variations in cultural features of diverse isolates have been observed temperature and pH are known to affect the growth rate of fungi and these have been utilized to group fungi into species

Effect of temperature

Temperature is the most significant physical environmental aspect regulating the vegetative and reproductive activity of fungi. The highest germination (98%) radial growth, length of germ tubes, and number of germs conidium were observed at 25±2^{0}C. The conidia germinated range from 10-35±2^{0}C. The germination was not discernible at 40±2^{0}C or beyond.

The germination was reduced at 10±2^{0}C and 35±2^{0}C (Singh *et al.* 2001and Balai *et al.* 2016).

Effect of pH

Balai *et al.* (2016) described that the radial growth of seventeen isolates was superior at 7.0 pH followed by 6.5 pH at five different pH. The minimum radial growth was found at a pH of 8.0. The average growth rate after seven days was found to vary from 20.0 to 78.0 mm in different isolates.

Mycelial growth

The different isolates showed differences in their morphological variation and their growth characteristics. Balai (2013) described one hundred isolates grown on a PDA medium in mycelial growth. After eight days of incubation, fast-growing isolates covered the entire surface of Petri dishes. The range of growth rate of one hundred isolates varied substantially. The average growth rate for seven days varied from 20.00 mm to 78.00 mm. Variation in isolates was grouped on the basis of radial growth categories in four groups.

Aggressiveness of isolates

Balai *et al.* (2016) described ten isolates as diverse in their conidial size, morphology, length, beak length, width, and septal distance. The twelve genotypes evaluated against a pathogen, ICP-7220 were recorded to be HR to the pathogen next to IPA-7-2. The most susceptible genotype was MAL-24. The growing aggressiveness of diverse isolates of pathogens also ranged notably on different genotypes. Two isolates namely At 17 and At 45 were highly virulent, while Isolate At 71 was minimum aggressive on different genotypes.

Molecular identification

Molecular methods have been used not only in differentiating between species but also for assessing intra-specific variation. Sharma *et al.* (2013) described first-time molecular recognition of pathogen recognition temporarily on the morphological level and was characterized at the molecular level using rDNA-ITS region sequencing. ITS1 and ITS4-primer pairs were used for PCR amplification of the pathogen.

Biochemical variability

Chlorophyll and carotene

Singh and Singh (1999) described that chlorophyll 'b' increased in the upper and middle leaves of susceptible (S) and middle leaves of resistant (R) genotype, while chlorophyll 'a' and carotene were reduced in disease leaves. Balai *et al.* (2017) also described that chlorophyll 'a', chlorophyll 'b', total chlorophyll and carotene content have been recorded in higher amounts in R genotypes (IPA-7-2 and ICP-7220) next to moderately resistant (MR) (DA-11and ICP-13174) and moderately susceptible (MS) (ICP-11294 and ICP-4725), while low amount in S (ICP-7182 and BSMR-736) genotypes and highly susceptible (HS) genotypes (Bahar and MAL-24). The high content of chlorophyll and carotene was recorded in R genotypes at an initial stage of plants with minimum decline while the low content was recorded in S genotypes of old plants with the highest decline. It exhibited the same trend in a-virulent isolates in which the lowest decline in chlorophyll and carotenes content was found as compared to virulent isolates.

Total soluble protein

The changes in protein occur when the pathogen penetrates the host cells resulting in disturbances in protein and related metabolisms. Singh and Singh (1999) reported that total soluble protein in leaves of the S (Bahar) and R (MA 128) genotypes and found healthy leaves of the S genotype contained more soluble protein than the R genotype. Balai *et al.* (2020a) described soluble proteins content as found in higher amounts in the R genotype (ICP-7220 and IPA-7-2) next to MR (ICP-13174 and DA-11) and MS (ICP-11294 and ICP-4725), while minimum amount S (ICP-7182 and BSMR-736) genotype and HS genotype (Bahar and MAL-24). The high amount of soluble protein content was recorded in the R genotype at the initial stage of plants with the lowest decline while the low amount content was recorded in the S genotype old plants with the highest decline. It exhibited a similar trend in a-virulent isolate in which, the lowest decline in soluble protein content was recorded as compared to aggressive isolate.

Nitrate and nitrite reductase

Singh and Singh (1999) described that nitrate reductase (NR) and nitrite reductase (NiR) activities were S (Bahar) was much lower than R cultivar 'MA 128-2'. In both genotypes by a pathogen, it was found that drastic reduction in NR activity in diseased tissues than the healthy ones. The NR activity was increased found after infection. Munjal and Vasave (2011) reported on NR is an important biochemical parameter for nitrogen utilization, leaf NR potential, and the relation between leaf NiR in genotypes. Balai *et al.* (2020a) described that NR and NiR content have been found in maximum amounts in the R genotype (ICP-7220 and IPA-7-2) next MR (ICP-13174 and DA-11) and MS (ICP-11294 and ICP-4725), although lower amount S (BSMR-736 and ICP-7182) genotype and HS genotype (Bahar and MAL-24). The maximum soluble enzyme activity content was recorded in the R genotype at the initial stage of plants with minimum decline while the lowest content was recorded in the S genotype old plants with the highest decline. It exhibited a similar trend in the a-virulent isolate in which, the lowest decline enzyme activity content was recorded as compared to the aggressive isolate.

Total sugar, reducing sugar, and non-reducing sugar

Sugars are forerunners for the synthesis of phenolics, phytoalexins, lignin, and callose. Hence, they expression a significant part in the defense mechanism of plants against invading pathogens. In common, infection by some pathogens takes changes in the respiratory way and photosynthesis. Which are the vigors processes taking place inside the plant leading to wide variations in sugars. Kushwaha and Narain (2005) described the total and reducing sugars were significantly more in healthy leaves of the R (DA-2) genotype. The content was significant decline due to disease incidence. But the reduction percentage was more in the S (Bahar) genotype. Balai *et al.* (2020a) reported that total soluble sugar, soluble reducing sugar, and non-reducing sugar content have been found in maximum amounts in the R genotype (IPA-7-2 and ICP-7220) next to MR (DA-11 and ICP-13174) and MS (ICP-11294 and ICP-4725), although smaller amount S (BSMR-736 and ICP-7182) genotype and HS genotype (Bahar and MAL-24). The maximum soluble carbohydrate content was recorded in R genotypes at the initial stage of plants with minimum reduction while the lowermost content was recorded in S genotype old plants with the highest decline. It exhibited a similar trend in a-virulent isolate in which, the lowest decline in soluble carbohydrate content was recorded as compared to aggressive isolate.

Amino acids

Balai *et al.* (2020a) reported that soluble amino acids content has been found in higher amounts in the R genotype (IPA-7-2 and ICP-7220) next MR (DA-11 and ICP-13174) and MS (ICP-4725 and ICP-11294), however lesser amount S (BSMR-736 and ICP-7182) genotype and HS genotype (Bahar and MAL-24). The maximum soluble amino acid content was recorded in the R genotype at the initial stage of plants with minimum reduction however, the lowermost content was recorded in the S genotype of old plants with the highest reduction. It exhibited a similar trend in a-virulent isolate in which, the lowest decline in soluble amino acid content was recorded as compared to the virulent isolate.

Disease management strategies

Alternaria blight has a wide host range and multiplies at a very rapid rate resulting in large economic loss, it is required effective management of the pathogen and the adoption of integrated disease management tactics. Therefore, this review focuses on the different strategies which are the management of pathogens.

Assessment of yield loss

Accurate information regarding losses is also desirable by growers and plant protection experts to develop conclusion thresholds for determining when cost-effective control measures should be arranged. In this context, Alternaria blight caused yield losses reported by Kushwaha *et al.* (2010b) and Sharma *et al.* (2012). Balai and Singh (2013a) described that inoculated plots exhibited maximum disease intensity (44.19%) recorded in plots that did not receive any spray of Mancozeb. In plots with one, two three, and four sprays of Mancozeb, disease intensity was

recorded as 31.01, 20.57, 13.75, and 11.88% and the mean percent disease control was 29.88, 53.45, 68.88, and 73.09% respectively. An almost similar trend of disease intensity, crop yield, and hundred-grain seed weights was recorded in different treatments with Mancozeb.

Different dates of sowing and plant population

Modification of the date of sowing of the crop constantly plays a significant role in disease escape due to unfavorable weather circumstances for contamination and to be considered in the management of the disease. In this context, Sinha and Mahmood (1993) indicated that Alternaria blight appeared in the second week of November when the temperature, relative humidity, and rainfall were 24.08°C, 72.50 %, and 0.0 mm, respectively. Balai *et al.* (2013c) described that minimum disease intensity (4.96%) and maximum plant height (232.5 cm), biological yield (556.4 g/plant), and seed yield (121.7 g/plant) were recorded on 20th July date of sowing. While maximum disease intensity (47.5%) and minimum plant height (41.4 cm) biological yield (18.4 g/plant) and non-seed yield were recorded on the 05th November date of sowing. Plant population displayed that the maximum disease intensity (42.4%) and minimum plant height (121.0 cm), biological yield (85.9 g/plant), seed yield (13.8 g/plant), and test weight (6.6 g) were viewed in the field having maximum plant population (R×P=30×10). While, the field having minimum plant population (R×P=60×20) was seen with minimum disease intensity (19.5%) and maximum plant height (126.9 cm), biological yield (115.2 g/plant), seed yield (19.3 g/plant), and test weight (7.0 g) were recorded.

Biological control

Biological control offers an economical and non-polluting release system for protective materials equated to other field application networks. Lal and Upadhyay (2002) described *Hypocrea rufa (=Trichoderma viride)* overgrew the colony of the pathogen, next to *Gliocladium virens* and *T. harzianum* of the pathogen in dual culture. Khare (2006) reported that biocontrol agents (i.e., *Aspergillus flavus, A. niger, T. harzianum, H. rufa*, and *G. virens*) significantly inhibited the mycelial growth of the pathogen. Rani *et al.* (2018) reported that the rate of mycoparasitism was faster in *H. rufa* providing 80.36% inhibition of the growth of *A. alternata*, while *H. rufa* provided 74.27% inhibition of the growth of *A. tenuissima.* The maximum percent growth inhibition of the pathogen was found against *H. rufa* which was next to *T. harzianum* and *T. fasciculatum. B. subtilis* was found least effective against pathogens in the dual culture plate method (Parmar and Pathak 2019 and Balai *et al.* 2020b).

In field conditions, Kumar *et al.* (2000) deduced that seed treatment with *H. rufa* completely eliminated seed-borne infection of pathogens. Lal and Upadhyay (2002) and Mishra (2011) described two sprays of *H. rufa* at 4 g/liter water gave 35.59 percent control next to *G. virens,* which exhibited 31.32% disease control. Balai *et al.* (2020b) described twenty-five treatments, and the grouping of Mancozeb with *H. rufa* was found furthermost real in decline the disease intensity and disease control next to Mancozeb with *T. harzianum* and Mancozeb alone, separately. While *T. harzianum* single was the minimum effective and maximum disease intensity recorded as equated to control next to *T. harzianum* with dual dose and *T. harzianum* and *H. rufa* combination treatment, separately. Both seed treatment and foliar spray of Mancozeb with *H. rufa* were recorded as most effective in declining the disease intensity and disease control next to the combination of Mancozeb with *T. harzianum* and Mancozeb alone, separately. While minimum effective and maximum disease intensity and disease control were detected in *T. harzianum* single as compared to control. Rajeswari and Balasupramani (2020) described that *Bacillus subtilis* exhibited the minimum mycelial growth of 2.8 cm with the highest growth inhibition of 68.90%. Rani *et al.* (2021) described that both seed treatment and foliar application with *T. harzianum* one were recorded as feasible, minimum disease intensity of 15.49 %was recorded in the sprayed plot. While Savitha and Ajithkumar (2023) described that *T. harzianum* was found most effective and statistically significant over other bio-control agents in inhibiting the mycelial growth (82.78%) of *A. alternata* followed by *H. rufa* (78.61%) in under dual culture. *H. rufa* may contain viridin-like antibiotics or maybe the presence of some

secondary metabolites or enzymes.

Botanicals

Rathore *et al.* (2018b) described neem extracts exhibited maximum inhibition against *A. tenuissima* at fifteen percent concentration after seven days of incubation *in vitro* next to eucalyptus and garlic. The lowest mycelial growth (21.00 mm) was recorded in garlic leaf extract at ten percent with the highest percent growth inhibition (74.28) (Parmar and Pathak, 2019 and Rajeswari and Balasupramani 2020). Rani *et al.* (2021) reported that garlic clove extract at ten percent was recorded as the most effective giving 84.31% inhibition against *A. alternata* under *in vitro* although 82.18% inhibition of mycelial growth was observed in *A. tenuissima* next to onion and neem. In the field, botanicals sprayed plotted the minimum disease intensity of 12.16% found in garlic extracts.

Fungicides

The use of fungicides is still the fastest and most efficacious way of controlling fungal diseases. This review emphasized the standing of the aspects involved in the successful use of fungicides. In order to achieve successful management, it is essential to use the correct active ingredient at the right concentration and applied at the correct time. Lal *et al.* (2000) reported that Iprodione at @ 2000 µg/ml recorded a hundred percent growth inhibition of the *A. tenuissima* colony *in vitro,* while 500 µg Carbendazim recorded the lowest growth inhibition (26.21%) of the pathogen. In the field, Iprodione at 2.6 kg/ ha recorded the lowest disease intensity (22.83%) and consequently the highest disease control (64.60%). Carbendazim recorded the lowest disease control (21.45%). The most effective was Mancozeb +Thiophanate-methyl recorded the lowest disease intensity by Kushwaha and Narain (2001). Khare and Kumar (2006) reported that seed treatment with Thiram, carboxin+thiram, and Carbendazim controlled the infection of most pathogens. Kushwaha *et al.* (2010b) Mancozeb to be found most effective in controlling the disease next to Difolatan and Chlorothalonil. Rani *et al.* (2018) reported that Tilt (Propiconazole) at all concentrations completely inhibited (100%) the mycelial growth and sporulation of the pathogen. Parmar and Pathak (2019) described that percent growth inhibition was observed in hexaconazole 4% + zineb 68%, propiconazole, and tebuconazole at 500 ppm and 1000 ppm in poisoned food technique. Balai *et al.* (2020b) described that mancozeb was found furthermost effective against pathogens next to Chlorothalonil and Iprodione. Propineb was the least effective against the pathogen. An increase in the concentration of fungicides was additionally effective in inhibiting the mycelial growth of the pathogen. Rajeswari and Balasupramani (2020) reported that Fluopyram SC 500 exhibited a hundred percent mycelial growth inhibition of the pathogen at 1000 ppm concentration *In vitro* condition. Rani *et al.* (2021) described that the seed treatment and two foliar applications of propiconazole (0.1%) recorded the least disease intensity (13.8%). Rajeswari *et al.* (2021) described carbendazim at twelve percent with mancozeb sixty-three percent @ one g / lit on forty-five DAS recorded the lowest incidence of 8.1 PDI (Percent Disease Index) with the highest disease reduction of 76.9% as against thirty-five PDI in the control plot.

Integration disease management

In an integrated disease management approach is essential to combine more than one disease management practice. A combination of host plant resistance, modified date of sowing, crop rotation, bioagent, plant extracts and fungicides was found effective in minimizing Alternaria blight. Balai and Singh (2013b) and Balai *et al*. (2020b) reported that twenty-five treatment combinations in seed treatments, a combination of Mancozeb with *H. rufa* was found to be most effective in declining the disease intensity and disease control (6.15 and 71.08%) next to Mancozeb with *T. harzianum* (6.28 and 70.45%) and Mancozeb (6.35 and 70.14%) single, respectively in pot and field condition. In the case of foliar spray of Mancozeb with *H. rufa* was recorded as most effective in decline the disease intensity and disease control (11.92 and 71.29%) next to a combination of Mancozeb with *T. harzianum* (12.11 and 70.82%) and Mancozeb alone (12.25 and 70.48%) treatment, respectively. In case of together seed treatment and foliar spray of Mancozeb with *H. rufa* was recorded furthermost effective in reducing the disease intensity and disease control (11.37 and 72.69%) next to combination of Mancozeb

with *T. harzianum* (11.43 and 72.53%) and Mancozeb (11.49 and 72.40%) single, respectively. But minimum effective and maximum disease intensity and disease control were recorded for *T. harzianum* (33.85 and 18.67%) alone as compared to control. Rani *et al.* (2021) reported that IDM approach, the minimum disease intensity (11.16%) was recorded from a seed treatment with SAAF @ 2 g kg of seed in addition to two foliar sprays with propiconazole @ 0.1% significantly reduce disease. Savitha and Ajithkumar (2022) described two sprays of difenoconazole (0.1%) interspersed with *P. fluorescens* (0.5%) and recorded a minimum PDI of 25.75, which was effective with the application of two sprays of propiconazole (0.1%) interspersed with *P. fluorescens* (0.5%).

Production of a host-specific toxin by germinating spores

Nutsugah *et al.* (1994) described that necrotic lesions were observed when a toxin from spore-germination fluids was applied to separate young leaves. The R genotype Tanzania and nonhosts tolerated at least twenty thousand times higher concentrations of the toxin. The toxin perhaps plays a role as a disease estimate, as the toxin was released since developing spores as initial as three h of incubation and the amount separate within nine h was about six times the concentration desired for necrotic poisonousness.

Future prospects

Shift in the variable of climate changes, their unpredictable occurrences, and change in rainy frequency is creating ideal conditions for disease occurrence. Periodic surveys of pigeonpea fields should be made for detailed information in order to examine the correlation of any factor to disease appearance under natural conditions. Comprehensive research should be made on the physiological, pathological, and biochemical genetic aspects of pathogens. Regular monitoring of the native strains of pathogen should be made to develop durable resistant cultivars of pigeonpea for a particular location. Research on multiple factors governing aggressiveness in the pathogen isolates. The development of marker-assisted selection methods will enable rapid screening of different genotypes for disease resistance. A key integrated disease management package should be evolved in which poor farmers can incorporate the needed adjustments from time to time.

REFERENCES

Alka, Singh SP (2004) Survival of *Alternaria tenuissima* causing leaf spot of pigeonpea in diseased plant debris. *Ann Pl Prot Sci* 12 (1): 231-232.

Balai LP (2013) Pathogenic and biochemical variability of Alternaria blight in pathogen pigeonpea. PhD thesis. Mycology and Plant Pathology, Banaras Hindu University, Varanasi.

Balai LP, Singh RB (2013a) Losses caused due to Alternaria blight disease in the grain yield of pigeonpea. *Tren Biosci* 6 (1): 40-42.

Balai LP, Singh RB (2013b) Integration management of Alternaria blight of pigeonpea with some fungicides and antagonists in pot condition. *The Bioscan* 8(3): 881-886.

Balai LP, Singh RB, Sinha A, Yadav SM (2020a) Biochemical variability study in genotype and isolate of Alternaria blight in pigeonpea. *Chem Sci Rev Lett* 9 (33): 24-33.

Balai LP, Singh RB, Sinha A, Yadav SM (2020b) Evaluation of different fungicides and antagonists *In vitro* and *In vivo* condition against Alternaria blight of pigeonpea. *Leg Res-An Int J* 43 (2): 268-275.

Balai LP, Singh RB, Yadav SM (2013a) Survey for the disease status intensity of Alternaria blight of pigeonpea in Eastern part of UP. and adjoining districts of Western Bihar. *The Bioscan* 8 (1): 63-66.

Balai LP, Singh RB, Yadav SM (2013b) Varietal screening and agronomical performance of pigeonpea genotypes/cultivars against Alternaria blight. *J Food Leg* 26 (1 and 2): 54-56.

Balai LP, Singh RB, Yadav SM (2013c) Sowing time and plant population on the disease intensity of Alternaria blight of pigeonpea. *Ind J Pl Prot* 41(4): 326- 331.

Balai LP, Sinha A, Singh RB, Yadav SM (2016) Cultural, morpho logical and pathogenic variability of *Alternaria tenuissima* causing blight in pigeonpea of Eastern Uttar Pradesh. *Ind Phytopath* 69 (1): 32-37.

Balai LP, Sinha A, Singh RB, Yadav SM (2017) Biochemical constituents of Alternaria blight of pathogens in pigeonpea. *Asian J Biol* 12(1):1-7.

Fries EM (1832) Systema mycologicum. Vol. 3. Gryphiswaldiae, pp 524.

Grewal JS (1984) Major disease of pulse crops and their management. Pulse production constants and opportunities. Oxford and IBH New Delhi, pp 273-284.

ICRISAT (2019) International Crops Research Institute for the Semi-Arid Tropics. Pigeonpea crop. Accessed from http:// http://www.icrisat.org/croppigeonpea.htm.

Kannaiyan J, Nene YL (1977) Alternaria leaf spot of pigeonpea. *Trop Gra Leg Bull* 9: 34.

Khare A (2006) Comparative efficacy of bio-agents against *Alternaria tenuissima* causing leaf blight of pigeonpea *in vitro*. *Farm Sci J* 15 (1): 62.

Khare A, Kumar K (2006) Effect of fungicidal seed treatment on the germination, seedling vigor and associated pathogens in pigeonpea. *Farm Sci J* 15 (1): 90-91.

Kumar K, Khare A, Srivastava M (2000) Seed borne fungal disease of pigeonpea. Diagnosis and management. In : Advances in plant disease management (Narian V, Kumar K, Srivastava M (eds). New Delhi India, Advance publishing concept pp 1-33.

Kunze (1818) *Helminthosporium tenuissimuma* in Nees von Esenbeck and Nees von Esenbeck *Nova Acta Phys-Med. Acad Caes Leop-Carol Nat* 9: 242.

Kushwaha A, Srivastava A, Nigam R, Srivastava A (2010a) Occurrence and severity of Alternaria blight of pigeonpea in central UP. *Int J Pl Prot* 3(2): 361-362.

Kushwaha A, Srivastava A, Nigam R, Srivastava N (2010b) Management of Alternaria blight of pigeonpea crop through chemicals. *Int J Pl Prot* 3(2): 313-315.

Kushwaha KPS, Narain U (2001) Evaluation of fungicides against Alternaria leaf blight of pigeonpea. *Ann Pl Prot Sci* 9 (2): 330-332.

Kushwaha KPS, Narain U (2005) Biochemical changes in pigeonpea leaves infested with *Alternaria tenuissima. Ann Pl Prot Sci* 13 (2): 415-417.

Lal HC, Upadhyay JP, Ojha KL (2000) Evaluation of certain fungicides for the control of Alternaria leaf blight of pigeonpea. *Madras Agric J* 87: 153-155.

Lal HC, Upadhyay JP (2002) Biological control of leaf blight caused by *Alternaria tenuissima* (Kunze ex. Pers.) Wiltshire in pigeonpea. *J Bio Cont* 16 (2): 141-144.

Mahmood M, Sinha BK, Kumar S, Chowdhury SK, Singh CP, Murtaza M (1983) Fungicidal control of leaf blight of pigeonpea caused by *Alternaria tenuissima. Rajendra Agric Univ J Res* 4: 89-90.

Mishra RS (2011) Effect of *Trichoderma viride* as foliar spray against Alternaria leaf spot of pigeonpea. *J Pl Dis Sci* 6 (1): 63-64.

Munjal M, Vasave G (2011) Correlation of pigeonpea grain protein and leaf nitrate reductase: Grain biochemical parameters and leaf nitrate reductase in pigeonpea. Lap Lambert Academic, pp 124.

Nutsugah SK, Kohmoto K, Otani H, Kodoma M, Sunkeswari RR (1994) Production of a host-specific toxin by germinating spores of *Alternaria tenuissima* causing leaf spot of pigeonpea. *J Phytopath* 140 (1):19-30. https://doi.org/10.1111/j.1439-0434.1994.tb00172.x.

Parmar KA, Pathak DM (2019) *In vitro* evaluation of bioagents against *Alternaria tenuissima*-an incitant of pigeonpea (*Cajanus cajan* (L.) Mill sp.) leaf blight. *Asi J Biol Sci* 14 (1 and 2): 5-7. https://doi.org/10.15740/has/ajbs/14.1and2/5-7.

Parmar KA, Pathak DM (2019) *In vitro* evaluation of fungicides and phytoextracts against *Alternaria tenuissima*-An incitant of pigeonpea (*Cajanus cajan* (L.) Millsp.) leaf blight. *Int J Pl Prot* 12(2): 94-97.

Pavgi MS, Singh RA (1971) Parasitic fungi from North India, VIII. *Mycopatho Et Mycolo Appl* 43: 117-125.

Rajeswari E, Akiladevi P, Jayamani P (2021) Management of Alternaria leaf blight in pigeonpea through host plant resistance and micronutrient application. *Leg Res-An Inter J* DOI: 10.18805/LR-4470.

Rajeswari E, Balasupramani P (2020) *In vitro* evaluation of plant extracts, biocontrol agents and fungicides against leaf blight in pigeonpea. *J Pharma Phytoche* 9 (3): 1784-1788.

Rani N, Lal HC, Kumar P (2019) Survey and morphological characterization of Alternaria spp. causing Alternaria blight of pigeonpea. *Int J Curr Micro Appl Sci* 9: 437-440.

Rani N, Lal HC, Kumar P, Ekka S, Kumar B, Kumar N (2021) Management of Alternaria blight of pigeonpea caused by Alternaria spp. using chemicals, botanicals, biological control and its integration. *J Myco Pl Pathol* 51(1): 36-47.

Rani N, Lal HC, Kumar P, Ekka S, Kumar N (2018) *In-vitro* evaluation of fungicides, bioagents and plant extracts against Alternaria sp. infecting pigeonpea. *Int J Curr Micro Appl Sci* 7(S): 5112-5118.

Rathore US, Singh SK, Kumar S (2018a) Identification of resistant sources for Alternaria blight of pigeonpea (*Cajanus cajan* L. Millsp). *Int J Curr Micro Appl Sci* 7(4): 3380-3393.

Rathore US, Singh SK, Kumar S, Rishi S (2018b) Application of botanicals for effective management of Alternaria blight of pigeonpea. *J Pharm Phytoche* SP2: 328-338.

Savitha AS, Ajithkumar K (2022) Integrated management of Alternaria blight disease of pigeonpea. *J Eco-fri Agric* 17(1):150-153.

Savitha AS, Ajithkumar K (2023) Morphological characterization and *in vitro* efficacy of bioagents against *Alternaria alternata* blight of pigeonpea. *J Eco-fri Agric* 18 (1): 1-7.

Savitha AS, Ajithkumar K, Yenjerappa ST (2021) Investigation on the severity of Alternaria blight of pigeonpea and its characterization in Northern Karnataka. *Ind J Agric Res* 10.18805/IJARe.A-5804.

Sharma M, Ghosh R, Mangla N, Saxena KB, Pande S (2012) *Alternaria tenuissima* causing Alternaria blight on Pigeonpea (*Cajanus cajan* (L.) Millsp.) in India. *Pl Dis* 96(6): 907.2 - 907.2.

Sharma M, Ghosh R, Pande S (2013) Occurrence of *Alternaria alternata* causing Alternaria blight in pigeonpea in India. *Adv Biosci Biotec* 4: 702-705.

Singh SK (1996) Epidemiology and control of Alternaria blight of pigeonpea (*Cajanus cajan* (L.) Millsp.) caused by *Alternaria tenuissima* (Kunze ex Pers.) Wiltshire. PhD thesis . BHU, Varanasi, India.

Singh SK, Singh UP (1999) Effect of *Alternaria tenuissima* (Kunze ex. Pers.) Wiltshire on some biochemical changes in pigeonpea (*Cajanus cajan* (L.) Millsp. leaves. *Ind J Pl Pathol* 17(1/2): 36-42.

Singh SK, Tuli L, Singh UP, Prithiviraj B (2001) Effect of temperature, light/darkness and relative humidity on germination and sporulation of *Alternaria tenuissima. Ind Phytopath* 54(1): 128-130.

Singh UP, Singh SK, Sarma BK (2003) Time-dependent sporulation, conidial size and germ tube formation in *Alternaria tenuissima* (Kunze ex pers.) Wiltshire on different media. *J Phytopath* 148 (7-8): 413-416.

Sinha BK, Mahmood M (1993) Epidemiology of Alternaria leaf blight of pre-*rabi* pigeonpea in Bihar caused by *Alternaria tenuissima* (Kunze ex. Pers.) Wiltshire. *J Appl Biol* 3(1/2): 52-55.

Wiltshire SP (1933) The foundation species of Alternaria and Macrosporium. *Trans Bri Myco Soc* 18: 135-160.