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Epidemiological studies of black pepper anthracnose (*Colletotrichum gloeosporioides*)

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ABSTRACT

Black pepper (*Piper nigrum* L.) occupies a unique position in the spice industry. Anthracnose or fungal pollu incited by *Colletotrichum gloeosporioides* (Penz.) Penz. and Sacc. is a wide spread and economically important disease of black pepper. The influence of weather factors such as temperature, rainfall and number of rainy days was studied by correlating the disease incidence during different months vis-a-vis weather parameters. The results indicated that, maximum temperature has negative correlation, while minimum temperature, rainfall and number of rainy days have positive correlation with the disease incidence. Newly emerged leaves on the runner shoots, orthotrophs and plagiotrophs as well as young spikes were found to be more vulnerable to the disease.

Key words: Anthracnose, Black pepper, *Colletotrichum gloeosporioides*, Rainfall, Temperature, Weather

Black pepper (*Piper nigrum* L.) is the most important and widely used spice in the world. Black pepper originated in the moist evergreen forests of Western Ghats of South India, which is also considered as the centre of origin and diversity of several *Piper* sp. The black pepper of commerce is the dried, mature fruits commonly called as berries. Besides its homeland India, black pepper is also cultivated in about 26 countries, of which Indonesia, Vietnam, Brazil, Malaysia and Sri Lanka are the leading producers. In India, cultivation of black pepper is chiefly confined to Karnataka, Kerala and Tamil Nadu (Ravindran 2000). However, in the recent past India suffered a setback in black pepper production and eventually relegate to third rank behind its counterparts, Vietnam and Indonesia (Anonymous 2011). Factors such as losses due to pests and diseases, high cost of production and consequent neglect of the crop by the farming community are implicated to be the major contributing reasons for this setback. Among the major constraints in the production chain, diseases incited by various pathogenic organisms plays a significant role.

Black pepper suffers from a number of diseases, of which anthracnose/spike shedding/fungal pollu is an economically important disease, prevalent throughout the black pepper growing tracts of India. *Colletotrichum gloeosporioides* (Penz.) Penz. and Sacc., the incitant of anthracnose is also an important pathogen on other major spice crops (Nair *et al*. 1977, Karunakaran and Nair 1980, Govindaraju *et al*. 1998, Kumari and Rajagopalan 2000, Sankar and Kumari 2002). The fungus attacks all the aerial parts including foliage, stem, spikes and berries (Anandaraj and Sarma 1995). Anthracnose is a serious problem, particularly during the post-monsoon season in majority of the black pepper growing regions. Though the disease is sporadic in nature, it often attains epiphytotic proportions especially in the high elevation regions where, misty conditions prevail. Nair *et al.* (1987) reported that, the severity of disease varied from 28 to 34%, which amounted to a crop loss ranging from 1.9 to 9.5%.

In several host-pathogen systems, quantitative relationship between disease development and weather variables has been elucidated and employed for generating weather-based disease prediction models (Mc Cartney 1997). Epidemiological parameters responsible for the outbreak of diseases incited by different *Colletotrichum* species infecting economically important crops have been extensively investigated by various researchers (Eastburn and Gubler 1990, Kumar *et al*. 1999, Abang *et al*. 2003, Imtiaj *et al*. 2007). The relationship between disease progression and

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weather factors is of paramount importance in formulating reliable and effective disease management strategies. However, pertinent information on the role of various weather factors favouring the incidence and subsequent spread of black pepper anthracnose are inadequate. Therefore, the present study was carried out with objectives to investigate the role of weather variables in the development of black pepper anthracnose and also to identify vulnerable crop stages to the disease, under natural epiphytotic conditions.

MATERIALS AND METHODS

The study was undertaken at the experimental farm, Indian Institute of Spices Research, Cardamom Research Centre, Appangala (Karnataka) (12°26'N Latitude and 75°45'E Longitude). Thirty randomly selected black pepper vines (10 to 15 years old) belonging to the variety Panniyur I with inherent susceptible nature to the disease was used as the experimental material. Natural incidence of anthracnose was recorded by employing 0 - 8 disease rating scale (Table 1) during September 2009 to August 2011. Disease severity was recorded at monthly intervals and percent disease index (PDI) was calculated. Data on different weather variables such as maximum (T_{max}) and minimum temperature (T_{min}), rainfall and number of rainy days were also recorded daily. In order to establish the relationship between various weather parameters and disease incidence by correlation studies, monthly averages of these weather factors was used. Observations on initiation and progression of the disease were also recorded to identify crop stages, which are vulnerable to the disease.

RESULTS AND DISCUSSION

Disease incidence

Observations on disease incidence and weather variables were recorded during September 2009 to August 2011 (Table 2). It was noticed that, the disease progression followed a low-high-low pattern during a period of 12 months, i e from March 2010 to February 2011. Hence, observations recorded during this period were further considered for correlation studies. Though the disease was prevalent at lower levels during the months of February to May (7.5 to 14.7%), a rapid increase in the disease incidence was noticed in the month of June (22.08%) which subsequently registered a peak in the month of September (39.1%).

ROLE OF WEATHER FACTORS

Temperature

The average T_{max} profile during March 2010 and February 2011 varied between 23 and 32.9°C.While, average T_{min} ranged from 11.4 to 19.19°C. It is observed that, the disease incidence was also low (7.5 to 8.3%) during the months of March to April 2010 and February 2011 in which the T_{max} was in the range of 29.1 to 32.9°C and T_{min} from 11.4 to

Table 1 Disease rating scale for black pepper anthracnose (0 – 8 scale)

Scale	Infection on			
	Leaves	Runners	Laterals	Spikes
0	nil	nil	nil	nil
1	Isolated spots	Isolated spots	Isolated spots	Isolated spots
2	Sparse spots on young leaves	Sparse spots on young leaves	Sparse spots on young leaves	Less than 2% infection, no spike shedding
3	Coalescing spots on young leaves and isolated spots on old leaves	Coalescing spots on all runner shoots, no clear necrosis	Coalescing spots on few laterals	Spike shedding and spike infection less than 5%
4	Clear coalescing spots on young leaves and old leaves, defoliation of infected young leaves	Coalescing spots on all runner shoots	Infection on less than 10% of laterals	Spike shedding and spike infection less than 10%
5	Infection on all aerial parts, distinct crinkling of infected leaves, defoliation of young leaves	Infection on all runner shoots manifested as coalesced spots	Infection of 25% laterals	Spike shedding and spike infection less than 25%
6	Infection on all aerial parts, shedding of young leaves and deformity of old leaves	Necrosis of all runner shoots	Infection on 50% laterals	Spike shedding and spike infection more than 50%
7	Infection on all aerial parts, shedding of young leaves and deformity of old and young leaves	Extensive necrotic spots on all runner shoots	Extensive necrotic spots on all laterals	Infection on all spikes and extensive spike shedding
8	Infection on all aerial parts, deformity and defoliation of old as well as young leaves	Extensive necrosis of all runner shoots	Infection on laterals stunting and reduction of canopy	Infection on all spikes and total spike shedding

Table 2 Mean average data on weather factors and anthracnose incidence during 2009 - 2011

Period	Temperature		Rainfall		Percent disease
	Maximum (T_{max})	Minimum (T_{min})	Mean monthly rainfall (mm)	Number of rainy days	index (%)
September 2009	25.0	18.5	288.8	17	38.3
October 2009	26.5	17.3	206.8	7	33.7
November 2009	26.56	17.8	89.6	10	32.08
December 2009	26.4	16.9	39.2	2	30.4
January 2010	26.7	13.9	19.2	1	32.9
February 2010	29.32	15.3	0.0	0	10.4
March 2010	32.23	17.91	1.2	1	7.5
April 2010	32.9	19.19	53.6	5	7.5
May 2010	29.0	19.0	101.0	10	14.1
June 2010	25.4	18.7	333.4	18	22.08
July 2010	23.0	17.8	675.2	26	27.9
August 2010	23.7	17.6	584.7	31	37.9
September 2010	24.3	18.7	306.6	22	39.1
October 2010	24.8	18.2	280.6	15	33.3
November 2010	25.2	18.1	195.4	14	32.9
December 2010	25.3	15.6	18.2	1	31.6
January 2011	26.4	14.0	0.0	0	24.1
February 2011	29.1	11.4	13.8	1	8.3
March 2011	30.3	13.7	24.8	2	8.3
April 2011	31.6	15.4	117.2	8	9.5
May 2011	29.5	17.6	61.6	4	17.0
June 2011	25.1	18.2	644.8	25	23.3
July 2011	23.9	21.9	616.2	30	30.0
August 2011	23.91	16.08	625.4	30	36.2

19.19°C. On the contrast, the disease incidence was higher (37.9 and 39.1%) during the months of August and September 2010 during which the T_{max} ranged from 23.7 to 24.3°C and T_{min} from 17.6 to 18.7°C. It is also revealed from present study that, among the temperature variables T_{max} had a significant negative correlation and T_{min} had a positive correlation with the disease progression (Table 3).

Rainfall

During the period of observation, total rainfall received in the months of March, April 2010 and February 2011 varied from 1.2 to 13.8 mm, during which the disease incidence was also found to be low (7.5 to 8.33%). Subsequently, an increase in the rainfall was observed from the month of May (101.0 mm), which reached a maximum of 675.2 mm in the month of July. It was also observed that, there was a proportionate increase in the disease incidence (22.08 to 39.1%) with an increase in the rainfall pattern as evidenced during the months of June to September.

Similarly, a steady increase in number of rainy days was also observed from 18 days (May) to 31 days (August), after which a decline in the precipitation was noticed (Table 2). The disease incidence also attained maximum during the months, which had more number of rainy days. It is inferred from present study that, both rainfall and number of rainy days have significant positive correlation with the disease progression (Table 3).

Progression of the disease

In the initial phase, i.e. during the months of February to April, the disease incidence was at lower levels and the infection was mainly confined to older leaves. On the older leaves, the symptoms were manifested as randomly distributed necrotic lesions surrounded by yellow halo. However, after the receipt of pre-monsoon showers, the disease was initiated

Table 3 Simple correlation between anthracnose disease incidence and weather variables

Weather parameters	Correlation coefficient
Maximum temperature (°C)	– 0.90*
Minimum temperature (°C)	0.20^{NS}
Monthly rainfall (mm)	0.58*
Number of rainy days	0.65*

*Significant at P = 0.05
NS - non significant

as small circular necrotic lesions on the young leaves of the runner shoots from which it advanced to the leaves of plagiotrophs (laterals), orthotrophs (climbing shoots) as well as to the spikes which resulted in subsequent shedding of leaves and young spikes.

Runner shoots

The symptoms initially manifested as small circular dark brown to black necrotic spots on the newly emerged leaves on the runner shoots. These spots subsequently enlarged and coalesced to form confluence of lesions, resulting in complete defoliation, even before the lesions spreads to the entire lamina. In the advanced stages, infection spreads to the runner shoots resulting in the formation of linear or oval brown to black necrotic lesions. Severely affected shoots exhibited a barren appearance due to complete defoliation. Further growth of the shoot was also arrested due to the necrosis of young emerging leaves and buds.

Plagiotrophs and spikes

On plagiotrophs (fruiting branches/laterals) the symptoms primarily appeared as brownish circular spots on the younger leaves with a yellow halo surrounding the spots. These isolated spots later turned necrotic with a dark brown center, which later withered off resulting in the formation of a shot hole. On the newly emerged foliage, the symptoms were similar to that noticed on the young leaves produced on the runners. These spots later coalesced together which resulted in the shriveling of leaves. On the spikes, the symptoms appeared as dull brown coloured lesions, which subsequently resulted in spike shedding.

Orthotrophs

Young leaves of orthotrophs were found to be more vulnerable to the disease. Symptoms observed on the leaves were similar to that noticed on the leaves of laterals. In the advanced stages of disease development, defoliation of leaves was noticed. Brown to black necrotic lesions were also observed on the shoots.

Among the various macro-meteorological parameters, temperature, rainfall and relative humidity play the predominant role and exert considerable influence on the disease cycle of pathogens (Mc Cartney 1997). In the present study, it was observed that, maximum temperature had a significant negative correlation with the disease development. In the case of bean anthracnose, Kumar *et al.* (1999) observed that, maximum spread and severity of bean anthracnose coincided with heavy and frequent rains with moderate temperature ranges. Abang *et al.* (2003) indicated that, the optimum temperature range for growth and sporulation of yam anthracnose pathogen, *C. gloeosporioides* ranges from 26 to 32°C. Conidial germination and development of appressoria of mango anthracnose pathogen were the maximum at 95 - 100% relative humidity and at 20 to 30°C (Dodd *et al*. 1991).

Imtiaj *et al*. (2007) observed that, the highest conidial germination and maximum mycelial growth of red rot pathogen of sugarcane were at 90 - 95% relative humidity and 25 to 30°C. Under field conditions, development of anthracnose disease of white beans was restricted at temperature above 25°C (Tu 1981).

It is evident from our results that, low disease incidence during the months of February - May is due to the existence of unfavourable temperature under field conditions. However, during the months of August to September, favourable temperature pattern favoured the disease development.

Production of infective propagules in abundance and its subsequent dispersal by various disseminating agents are indispensable for completing disease cycle of pathogens. Among the various disseminating agents, rain plays a vital role, as it triggers the activation of quiescent structures, dissemination of inocula and pathogenesis. Rain promotes the release of many types of fungal spores and has been reported to play a major role in the spread of stem anthracnose of lima beans (Tu 1981). Rain splash is considered to be the most determining factor in the release of conidia of anthracnose pathogens since they are embedded in gelatinous substance in the acervulus (Tu 1981, Hirst and Steadman

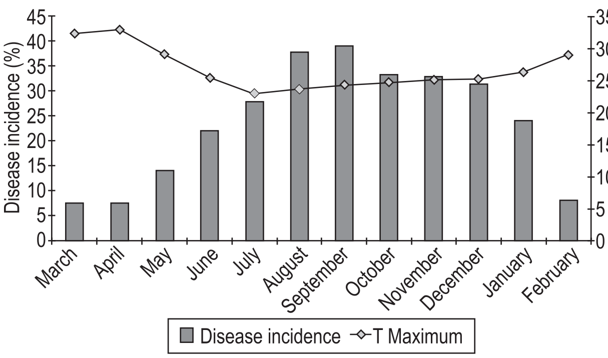

Fig 1 Effect of maximum temperature (Tmax) on the progression of anthracnose disease

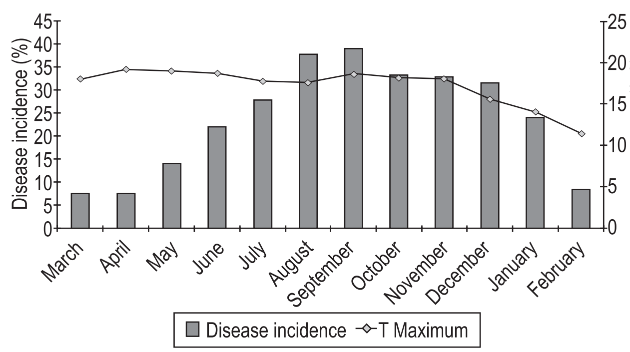

Fig 2 Effect of minimum temperature (Tmin) on the progression of anthracnose disease

1963).

Sainamole (2000) attributed high rainfall and number of rainy days as key determining factors in the outbreak of anthracnose of black pepper in the high ranges of Kerala. Manhandar *et al.* (1995) observed that during wet periods, appressoria produces secondary conidia, which facilitated secondary spread of anthracnose disease of bell pepper. Estrada *et al.* (1993) opined that, conidia of *C. gloeosporioides* often do not germinate *in situ* due to the presence of germination inhibitors present in the spore matrix. However, normal germination was restored after washing or by rain splash dissemination. It is inferred from the present study that, rainfall received during the months of June to August would have resulted in the disaggregation of conidia from the spore matrix and also had the washing effect by which the inhibitors were removed and subsequently resulted in the enhancement of conidial germination.

Observation on the period of maximum disease spread and severity index coincided with heavy and frequent rains with moderate temperature range is in confirmation with findings of Chambers (1969) and Tu (1981) who demonstrated period of heavy rain are responsible for the spread of *C. lindemuthianum* in the field.

Plant disease epidemics are the product of complex interactions between susceptible host, virulent pathogen, conducive weather conditions, incubation period (time) and human interventions. Identification of vulnerable crop stage is highly imperative in adopting appropriate prophylactic measures in order to manage plant diseases economically and effectively.

In the present study, it was observed that, young emerging leaves and young spikes were more vulnerable to the disease. Pre-monsoon showers coincided with the initiation of new foliage predisposed the plant to early initiation of the disease. Though the mature leaves were affected, the infection was confined to randomly distributed necrotic lesions. Observations on the disease progression indicated that, newly emerged leaves on the runners were infected initially from which, the disease spreads to other parts probably due to splash effect of rainfall and rain driven wind-borne inocula. Pre-monsoon showers aid the production of new leaves and also play a significant role in the activation of dormant resting structures, which subsequently provide primary inocula for disease initiation.

It was also observed that, early-emerged leaves and well-set spikes were less susceptible to anthracnose disease as it attained maturity before the conducive periods favouring disease development. While leaves and spikes emerged during later months were more susceptible to the disease. Ankegowda *et al.* (2011) stated that, tolerance to anthracnose or spike shedding in the susceptible variety Panniyur I could be imparted by providing pre-monsoon basin irrigation during the months of March to May. They attributed the mechanism of disease escape to the early initiation of leaves and spikes, which attained maturity well before the commencement of conducive periods for disease development. Implementing well-planned irrigation schedules during off seasons would modify physiology of the crop and subsequently promotes growth, improve yield levels and perhaps prevent disease development (Rush *et al*. 1997).

It is highly imperative to have a clear understanding about the vulnerable stages of the crop and weather factors that favour proliferation of diseases in the plantations in order to formulate as well as timely implementation of appropriate disease management strategies. As illustrated from the present study that the incidence of anthracnose disease is favoured by the prevalence of high and frequent rainfall with moderate temperature ranges. Therefore, timely adoption of prophylactic plant protection measures with appropriate fungicides during the months of May to June can lead to effective and economic management of the disease.

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