STUDY ON THE ETIOLOGY AND ECOLOGY OF "FUNGAL POLLU" IN PEPPER

By

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THESIS

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Introduction

INTRODUCTION

From the time immemorial, the coast of 'Malabar' has been a major attraction to foreign traders and tourists mainly because of the abundance of many important spices in this part of the country. Among the spices for which 'Malabar' was famous, pepper (Piper nigrum Linn.) enjoyed a unique position and had even won the name "King of spices". Though the plant is native to the moist ever green natural forests of Western Ghats and India had a monopoly in pepper production until 1948, our present contribution to world production of pepper is only 23 per cent.

In India, pepper is growing in an area of about 1.2 lakhs of hectares and our annual production of pepper is around 35,000 tonnes. The State of Kerala alone accounts for 96 per cent of the area and production in the country (Anonymous, 1981). But our average yield of pepper is surprisingly low (248 kg/ha) when compared to that of other pepper growing countries of the world like Malayasia (4067 kg/ha) and Brazil (3333 kg/ha). A number of reasons for this low productivity can be pointed out and among these, the incidence of pests and diseases plays a rather prominent role.

Though the most damaging and devastating disease of pepper is the quick wilt (caused by *Phytophthora palmivora* (Butler) Butler) and slow wilt (the etiology is not fully known), the "fungal pollu" (Anthracnose) disease of pepper caused by the pathogen *Colletotrichum gloeosporioides* (Penzig) Sacc, the imperfect stage of *Glomerella cingulata* (Stonem) spauld & Schrenk has also been found to cause considerable crop loss. Rao (1926) estimated the crop loss due to "fungal pollu" disease as 0.5 to 13 per cent. According to Krishna Menon (1949) the crop loss due to the "fungal pollu" alone was three to ten per cent. Recent studies on the "fungal pollu" disease at Pepper Research Station, Panniyur revealed greater variation in the extent of damage depending upon the agro-climatic factors, time and part of the plant where the infection took place (Anonymous, 1980).

Eventhough the "fungal pollu" disease is known to occur from 1921, there was not much work on symptomatology, disease incidence and control measures.

Attempts have been made to control the disease with different fungicides and among them one per cent Bordeaux mixture was found to be the best. But in most cases even the Bordeaux mixture failed to give the expected results. The reason for this may be due to improper timing in application of fungicide due to the lack of proper knowledge of the epidemiology of the disease. The fungicide will be effective only when its application synchronizes with the time of infection on different parts of the plant, especially on spikes and berries. It is with this background the present study was taken up with the following objectives.

1. To study the detailed sympstomatology of the "fungal pollu" disease on different parts of pepper vine.

2. To find out the influence of weather parameters on the occurrence and development of disease in the field.

3. To find out the peak period of infection on leaves, spikes and berries.

4. To study the effects of different fungicides *in vitro* and *in vivo* on the pathogen.

5. To find out the correct time of application of plant protection chemical to combat the disease; and

6. To estimate the percentage of crop loss due to this disease.

Review Of Literature

REVIEW OF LITERATURE

Pepper (*Piper nigrum* L.) an important spice crop of Kerala, is found attacked by several pathogens causing different diseases, of which fungal diseases are the most important. The three major diseases of pepper in Kerala and other pepper growing countries of the world are quick wilt (foot rot) caused by *Phytophthora palmivora*, slow wilt (yellowing) of unknown etiology and "fungal pollu" (Anthracnose) caused by *Colletotrichum gloeosporioides* (Penz) Sacc. the imperfect stage of *Glomerella cingulata* (Stonem) Spauld & Schrenk.

The extent of damage caused by "fungal pollu" disease had been variously estimated by different workers, Rao (1926) 0.5 to 13 per cent loss; Sundararaman (1932), 7.5 per cent; Thomas and Menon (1939) 4.0 to 13.0 per cent and Krishna Menon (1949) 3.0 to 10.0 per cent.

The detailed symptomatology of "fungal pollu" disease of pepper was first worked out by Thomas and Menon (1939). According to them the fungus produced circular or irregular grey spots on the upper surface of the leaves on which black acervuli appeared in concentric rings. Stem infection began at the tips and spread downwards gradually killing the young vines and tender runners from old ones. In old vines the attack started in the branching region and the fungus was found near the nodes of the dead branches.

The spikes were usually invaded at the site of their junction with stem, the leaf axils whence they emerge afforded favourable positions for the accumulation of water drops and spores washed down from the leaves. Once inside the spikes the fungus induced rotting of the tissues and shedding, especially in shaded and damp plots. The fungus also developed on the stalks of the spikes. On the berries a dirty brown discolouration of the rind commenced from the top and extended downwards sometimes accompanied by cracking. Vinukatananda and Celino (1940) gave detailed description of the anthracnose of pepper. During humid climatic conditions they observed dark grey yellow bordered lesions on the leaves. These spots progressively expanded and interrupted the normal functioning of the leaves. The disease started at the tip of the leaf and spread downwards and covered 1/2 to 1/3 of the leaf area. The infected leaves shed prematurely.

Based on a detailed survey, Krishna Menon (1949) reported an exhaustive symptomatology of 'pollu' disease. He found that the pathogen attacked the foliage and produced dead areas which interfered with the functions of leaves. In the early stage of the disease the lesions are small and have a distinct border. In the advanced stage the lesions enlarged and merged together forming large dead areas. He also observed premature shedding, shrinkage and drying up of individual berries and infection of the stalk of the spikes. Sometimes the fungus attacked the stem causing the death of young vines or fruiting branches.

The first record of the "fungal pollu" disease of pepper was made by Ayyar et al. (1921). Rao (1926) reported the casual agent of the 'pollu' disease as Colletotrichum necator Massee. Sundararaman (1931) noticed that the 'pollu' disease was caused by a combined attack of C. necator and the flea beetle Longitarsus nigripennis Motsch. Thomas and Menon (1939) however attributed three causes for the 'pollu' disease of pepper, namely physiological disturbance, fungal infection by C.necator and attack by flea beetle L. nigripennis.

The Malayalam word 'pollu' means a hollow thing. As applied to pepper it means hollow and light berries. In a wider sense the word is more often employed to denote the loss occasioned by the preference in varying quantities of the improperly developed, light and damaged berries of low commercial value.

Vinukatananda and Celino (1940) observed that in the Philippines 'pollu' (Anthracnose) was caused by an imperfect stage of Glomerella cingulata while according to Barat (1952) the disease was caused by unidentified species of Gloeosporium. Mei (1956) reported that in Sri Lanka 'pollu' disease was caused by Glomerella cingulata. Albuquerque (1964) recorded a species of Colletotrichum as the casual organism for leaf spot of pepper. Kueh (1976) on examination of berries and spikes of pepper found C. capsici on berries as black spot along with Cephaleuros virescens (Kunze) Kart. Association of G. gloeosporioides on hollow, light malformed berries of pepper was reported by Nambiar et al. (1978). Even though there is no report of Glomerella cingulata on pepper from India, Arx (1957) combined all straight spored Gleosporium and Colletotrichum spp. under one speices, C. gloeosporioides. Hence the correct name of pathogen causing 'pollu' disease is *C. gloeosporioides*, the imperfect stage of *Glomerella cingulata.*

Piper betle is a crop which resembles *Piper nigrum* in many ways. Except that in *Piper betle* spikes are not generally found, all other growth characters, etc. are the same. Both these plants have almost similar diseases also. Anthracnose disease of *Piper betle* was first reported by Hector (1925). He isolated *Colletotrichum* and *Gloeosporium* from anthracnose affected betel vines. Dastur (1935) reported that a destructive anthracnose disease of betel vine was caused by two unidentified species of *Colletotrichum* in Central Provinces. Su (1937) reported that black stem disease of betel vine was associated with a species of *Gloeosporium*. Uppal (1938) found that betel vine anthracnose prevalent in Daccan was caused by a species of *Gloeosporium.* Bertus (1942) reported that stem and leaf disease of *Piper betle* in Ceylon was caused by *Colletotrichum piperis* Petch. Chowdery (1945) found that leaf spot of *Piper betle* was caused by a species of *Gloeosporium*. Roy (1948) reported from Bengal that anthracnose of betel vine was caused by Colletotrichum dasturii Roy. Maiti and Sen (1977) identified that anthracnose of betel-vine was caused by C. capsici. Maiti et al. (1978) in their studies of fungal disease of betel vine, recorded four pathogens from India as causing leaf spot and stem anthracnose, C. piperis Petch (~~Dastur, 1935~~); C. dasturii Roy (~~Roy, 1948~~); C. capsici (Syd) Butler and Bisby (~~Singh and Shankar, 1971; Maiti and Sen, 1977~~) and the perethicial stage of Glomerella cingulata (Stonem) Spauld and Schrenk (Dastur, 1931).

Environmental factors have been found to influence the incidence of 'pollu' disease of pepper, as is the case with other diseases. Ayyar et al. (1921) described that sudden changes in the weather caused underdeveloped spikes to drop in numbers. This appeared to be the case during the month of September-October when the seasonal variations in some years were very marked. He also observed that a long spell of fine weather followed by heavy showers, vagaries of monsoons, strong winds and in fact every marked change in the weather appeared to affect the growing tender pepper spikes very appreciably. Vinukaiananda and Celino (1940) observed that 'pollu' disease appeared under humid climatic conditions. Krishna Menon (1949) noticed that rainy days favour the disease as it helped the germination of fungal spores and its penetration on young and tender leaves. He also noticed that sun scald and sun burned areas are more susceptible to the infection. Hence a severe summer may enhance the incidence of disease as it may cause sunscorching.

The time of occurrence of anthracnose on betel vine was studied in detail by Roy (1948). He working with anthracnose disease of betel vine in Bengal noticed that the disease appeared with the outbreak of rains and disappeared after the rainy season. During May to July it reached its optimum intensity. Thus high percentage of humidity accompanied by higher temperature favoured the spread and development of the disease.

Several other workers also noticed a relationship between the weather factors and anthracnose disease. Boning (1924) noticed that C. lindemuthianum (Sacc. & Magn.) Bri. & Cav. causing bean anthracnose germinated best at 22^{o}C and the development of the fungus on the plants was most rapid during damp and warm weather. Martinez-Salzar and Anderson (1957) also working with C. lindemuthianum on beans found that the optimum temperature for germination of the spore was 28°C and the fungus failed to cause infection below 10°C or above 32°C under artificial conditions.

Ocfemia and Agati (1925) noticed that cool moist and shady conditions were favourable for the development of infection of the fungus on young tender and succulent growth of avocado and mango. According to Monteita (1926) the two anthracnose disease of clover caused by Colletotrichum trifoli and Glomerella cingulata behaved differently, while C. trifoli was most important in warm weather. G. cingulata was more severe under cooler conditions. Ardt (1944) clearly recorded the effect of temperature and C. gloesporioides infection on cotton. Anthracnose lesion developed earliest at 29°C and 33°C, the per cent of the seedlings outgrowing the symptom at these two temperature were 10 and 40 respectively while at 22°C and 25°C the disease attained its maximum severity killing nearly all the infected plants before the 14th day and the per cent of survival was below 10 per cent. There was little infection by

C. gloeosporioides at 18°C and none at 36°C. Ling (1944) reported that humidity, when temperature is not extreme, determines to a large extent the reproduction and longivity of the inoculum, the initiation and intensity of infection and survival of the organism.

Nutman and Roberts (1960) observed that in Coffee, the range over which Colletotrichum coffeanum Noack. could cause infection ranged between 17°C and 28°C. Further they also noticed that presence of liquid water resulting from rain or heavy mist was necessary for infection under field conditions.

Singh and Prasad (1967) noticed that heavy and well distributed rain during July and October and low temperature favoured disease development by C. gloeosporioides in Dioscorea alata Linn. High temperature and sunlight favoured development of mycelium by which the fungus perennates under adverse seasons.

Chambers (1968) observed that in lima beans, C. gloeosporioides required at least two consecutive days of rain, cloudiness and high humidity for the development of disease symptoms. Further, in 1969 he noticed that the amount of rain was less important than prolonged wetness of the plants by continued intermittent rain. Only slight symptoms resulted when shorter periods of rain was observed. Fagan (1979) reported that Colletotrichum gloeosporioides was shown to be associated with the post bloom fruit drop disease of citrus. Susceptibility of flower buds to Colletotrichum gloeosporioides infection was shown to increase upto the time of opening, blossom infection occurred within 18 hours at 19°C to 30°C. Amin et al. (1979) reported that intermittent rain, cloudy days, day temperature of 26°C to 31°C and night temperature 18°C to 20°C were conducive for the development of Colletotrichum lagenarium (Pass) Ellis and Halsted causing anthracnose of watermelon. Omgupta and Nema (1979) reported that anthracnose disease of papaya (Colletotrichum papayae) was favoured by 30°C and 25°C and high per cent relative humidity, while lower or higher temperature reduced the disease development. Bleicher (1980) observed that the occurrence of bitter rot, Glomerella cingulata on apple was favoured by relative humidity more than 80 per cent and temperature 22°C - 25°C. Spore production is abundant at relative humidity 100 per cent. Denhan and Waller (1981) observed that fluctuations in the incidence and amount of post bloom fruit drop in citrus was caused by Colletotrichum gloeosporioides (Glomerella cingulata) in Belize prevent economic disease control. Large amount of disease developed when period of rain followed by prolonged wetness occur during peak blossoming periods.

The influence of environmental factors on disease development have been presented by Keitt and Jones (1926), Yarwood (1956), Yarwood (1959), Van der Plank (1960), Waggoner (1962), Waggoner (1965), John cohoun (1973), Van der Plank (1975) and Rotem (1978).

Bioassay

Bioassay of fungicides using several species of Colletotrichum has been conducted by various workers. Kothari and Bhatnagar (1966) reported inhibition of spore germination of C. capsici causing blight of guava with Dithane-Z-78 at 128 ppm, Ferbam 2 ppm, Ziram 32 ppm, Kirti copper 64 ppm and Fytolan 128 ppm. Chung (1970) reported that Difolatan was effective against Glomerella cingulata in the control of bitter rot of apple. Out of the eight fungicides tried at 5 ppm, 10 ppm, 20 ppm and 50 ppm by Narain and Ponigrahi (1971), Ziram at 5 ppm was found to be the most effective fungicide in checking the spore germination of C. capsici. Sajoo et al. (1970) reported that captan, Ziride, Fytolan, Dithane M-45, Dithane Z-78 and Duter were effective in inhibiting thespore germination of Colletotrichum sp. on avocado, the first two being superior to all other fungicide. Out of the 20 fungicides tested Pimentel et al. (1971) at six concentrations against C. gloeosporioides five fungicides, viz. Antracol, Brestan 60, Dithane M-45, Fuclasin ultra and Manzate D were the best ones. Singh et al. (1977) reported, out of seven fungicides tested in the lab against Colletotrichum sp. attacking chillies. Captan, Bordeaux mixture, Dithane Z-78 and Blitox-50 inhibited growth of the pathogen completely.

Field studies

Only very few workers had attempted to control the fungal disease of pepper by fungicidal spraying.

Rao (1926) observed that Bordeaux mixture one per cent was very effective in controlling the 'pollu' disease of pepper. Sundararaman (1928) made an attempt to find out a substitute for Bordeaux mixture and found that neither Burgundy mixture nor sulphur proved equal to Bordeaux mixture. Based on the same trials with Bordeaux mixture conducted by Thomas and Menon (1939), found that the disease have been found to control the fungus and insect 'pollu' and they also observed that May + October spraying gave better results than May spraying over control. Kueh (1976) reported that Benlate 0.02 per cent and 0.04 per cent ai topsin-M (0.02 per cent ai) and Cercobin (0.02 per cent ai) increased green berry yield, spike length and total number of berries per spike and reduced the number of black spots per berry.

Working on anthracnose disease of betel vine, Dastur (1935) reported good control of the disease by spraying Bordeaux mixture. Bertus (1942) reported that stem and leaf diseases of two Indian varieties of <u>Piper betle</u> caused by <u>C. piperis</u> could be controlled by spraying the vines with colloidal copper. Chowdery (1945) obtained good control of *Gloeosporium* leaf spot of betel vine by clean cultivation, destruction of dead refuse and by spraying the plants with 2-2-50 Bordeaux mixture or perenox. Maiti *et al*. (1978) in a field experiment found that application of Ziram or Carbendazim at 15 days intervals significantly reduced the intensity of betel vine leaf spot symptoms caused by *Colletotrichum* spp. Further studies by (Maiti *et al*., 1978) with eight fungicides on *Piper betle* showed that Bavistin (Carbendazim), Benlate (Benomyl), Cuman and Kitazin could effectively control *Colletotrichum capsici*.

There are several reports about the usefulness of fungicides against diseases caused by *Colletotrichum* spp. on other crops. Shear (1926) observed that good results were obtained in the control of bitter rot of green apples (*Glomerella cingulata*) by the application of Bordeaux mixture beginning a fortnight after the blossom. Simmonds (1933) reported that brown spot (*Colletotrichum gloeosporioides*) of Emperor mandarin may be controlled by spraying with Bordeaux mixture (3-2-40). ~~Anonymous (1940) reported that~~ Control of Papaw anthracnose (*Colletotrichum gloeosporioides*) was obtained by spraying the fruits at 14 day intervals beginning in November with Bordeaux mixture (4-4-50), Cuprocide 54 or Cuprocide 54Y (Anon. 1940).

Venkatakrishniah (1952) found that the spread of Glomerella psidii (Del.) Sheld. on apple, chilli, Citrus aurantifolia Swingle, mango, papaw, banana and tomato in the early stages of infection was controlled by three or four sprayings with Bordeaux mixture one per cent or lime sulphur (one in 25) at 15 day intervals. Singh and Prasad (1966) reported that organic fungicides were more efficient in the control of anthracnose of Dioscorea alata than inorganic fungicides. He observed that Zineb and Ferbam sprayed at 10 days intervals could control the disease upto 69 and 61 per cent respectively. Tandon and Singh (1968) found that mango anthracnose could be controlled by spraying the trees with Zineb or Bordeaux mixture 4:4:50. In a spraying experiments against stem anthracnose of lima bean, Chambers (1968) found that Manzate (Manganousethylene biz dithio-carbanate) Manzate D (Manzate + Zinc) Polysan (Zinc polyethylene thiuram disulphide complex) Difolatan (Cis-N-(1,2,2, tetrachloroethyl thio)-4 cyclohexene-1,2 Dicarboximide and

Dacnoil 2787 tetrachloroisophthalonitrile could gave excellent control and increased yields by more than 100 per cent of the control. Kim (1972) observed that best control of Glomerella cingulata in grape vine was given by Antracol applied every 10 days from late May to mid August followed by Benlate. Madaan and Grover (1980) reported best control of anthracnose of bottle gourd with Difolatan. Dithane M-45, Dithane Z-78 and Fytolan sprayed in combination with Ekalux and Rogor were not effective in controlling the disease (Anonymous, 1975). Karan et al. (1975) obtained effective control of C. gloeosporioides disease of Citrus sp. with Antracol.

Brooke (1977) found that spraying the apple trees with Captafol early in summer reduced the amount of fruit infection in apple that developed two months later and it was suggested that this was due to reduction of primary inoculum, the saprophytic phase of G. cingulata in the trees. Navarro and Puserto (1978) in their field studies with Dithane M-22, Daconil 2787, Benlate and Difolatan observed that control of anthracnose disease (C. lindemuthianum) of bean was obtained with Benlate and Difolatan.

Khanna and Chandra (1978) observed in lab tests with detached leaves of Rosa indica Linn. the best control of G. cingulata causing leaf spot of Rosa indica and Cinnamomum camphora (L) Nees & Eberm. was given by Difolatan 80 W (Captafol) and Benlate (Benomyl) which are recommended for use in the field. Sivaprakasam et al. (1978) found that best results against C. capsici on Capsicum were obtained with Dithane M-45 (Mancozeb) at 2 kg per ha. and Difolatan (Captafol) at one kg. applied four times at three weeks intervals from initial appearance of disease symptoms, yield was markedly increased.

Chung and Bae (1979) in their field studies against Gursery anthracnose (Colletotrichum panacicola) with inoculated plants, the best control of C.panacicola was given by Difolatan followed by Maneb, Zineb, Captan and Pholtan (Folpet). Schroeder and Fortes (1979) in their field trials against G.cingulata, (bitter rot of apple), captafol, dithanon, gave the best control of fruit rot. Raju et al. (1979) in their field trials over three years against chilly fruit rot reported that Captan and

Difolatan (Captafol) were the most effective fungicide in controlling _C. capsici_ on _Capsicum_ followed by Dithane M-45 (Mancozeb). Chauhan _et al._ (1980) in their field study on _Lagenaria siceraeia_ Ser. (bottle gourd) against _C. lagenarium_ best control was achieved with Difolatan (Captafol) followed by Bavistin and Benomyl. Madaan and Grover (1980) reported that leaf anthracnose of bottle gourd was controlled by field spraying with Difolatan (Captafol).

Materials and Methods

MATERIALS AND METHODS

Location of the experiment

The studies connected with this experiment were conducted at the Pepper Research Station, Vellanikkara, Trichur attached to the College of Horticulture.

Plants used

The entire work on the fungal 'pollu' disease of pepper was conducted on three year old pepper (Piper nigrum L) plants of variety Panniyoor-1. The plants were grown under uniform conditions of growth in the field as per the package of practice recommendations (Anonym, 1978).

Isolation and purification of fungus

The fungus causing the 'pollu' disease of pepper was isolated from the infected parts of the pepper vines using standard isolation techniques (Riker and Riker, 1936). Pure culture of the pathogen was maintained on the potato dextrose agar medium and used for in vitro studies.

Inoculation studies

Inoculation on leaves, vines, spikes were done.

Weather

Continuous recording of temperature and humidity was carried out using a self-recording thermohygrograph installed in the Pepper Research Station, Vellanikkara. The data on the total rainfall were recorded using a standard rain guage.

Epidemiological studies

The epidemiological studies were started during the first week of January, 1978 and continued upto the end of December, 1979. In order to study the time of infection and development of disease, fifty standards each having two vines, were randomly selected from a compact plot. All the observations for the study were taken from this fifty standards.

Leaf infection

On each vine the youngest physiologically active leaf (third fully developed leaf from the bud) was tagged. Along with this, all the infected leaves on a vine were also tagged. These leaves were observed at fortnightly intervals till the leaves were shed. The fallen leaves were brought to the laboratory and only the leaves infected with *Colletotrichum gloeosporioides* were taken into consideration. The observations were continued for a period of 24 months. All the leaves produced during this period were observed for new infections and development of leaf spots.

The intensity of leaf spot infection was graded using a score card having five grades from zero to five (Plate I). All the leaves of the selected plants were graded for the intensity of disease and the disease index was calculated using modified Mckinney's scale (Mc Kinney, 1923).

$$\text{Disease index} = \frac{\text{Grade x number of leaves}}{\text{Total number of leaves}} \times \frac{100}{\text{Maximum disease score}}$$

Spike infection

In order to determine the pedicel infection, the fallen spikes from each vine were collected from the ground at three days interval.

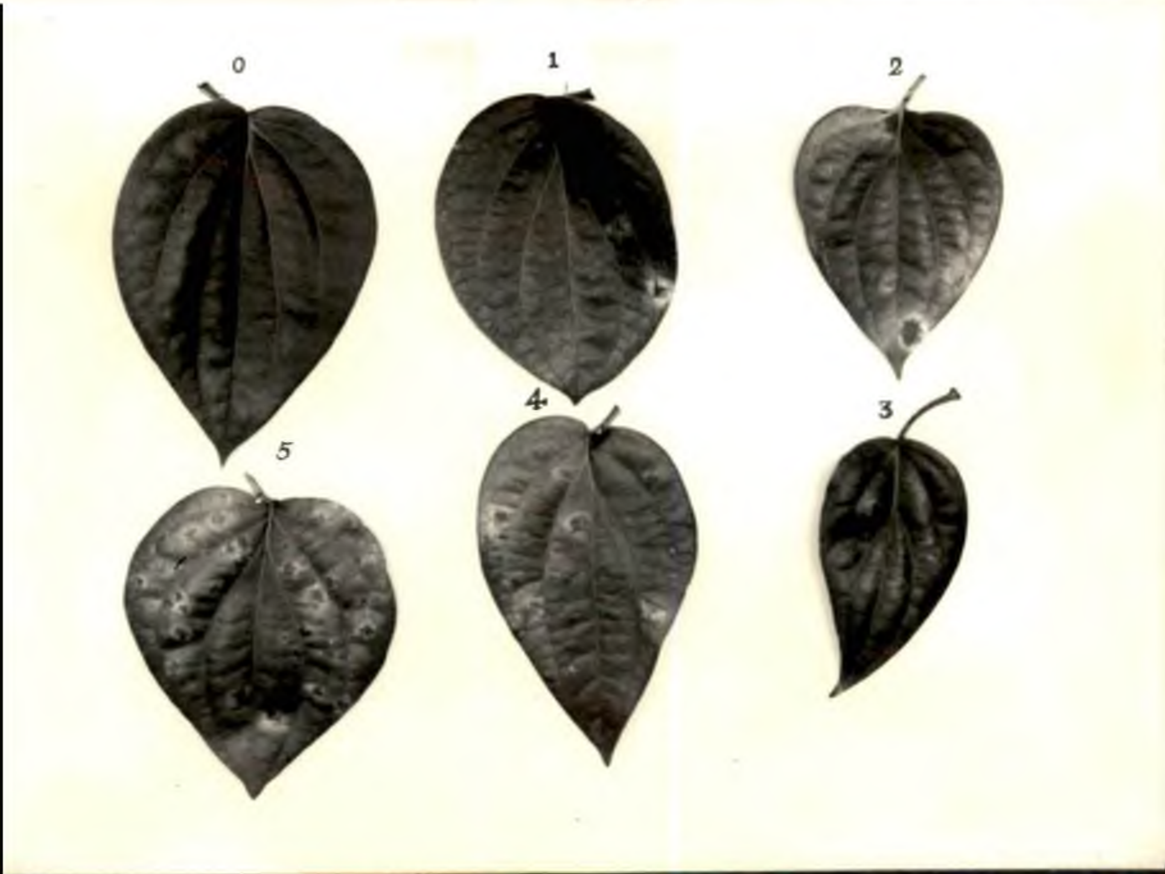


Plate 1. Score card for grading the intensity of leaf spot infection of "fungal pollu" disease of pepper.

Grade	Intensity of infection
0	Healthy (No infection)
1	1 - 2 leaf spots
2	3 - 4 " "
3	5 - 6 " "
4	7 - 8 " "
5	> 8 " "

The spike shedding in pepper is mainly due to two factors viz., pathological and physiological. The spike shed due to physiological reasons shows callus formation at the tip of the pedicel and the pedicels have pale green to yellowish colour. The basal end of the pedicel of the spike shed due to the attack of the Colletotrichum gloeosporioides never forms callus and there will be black rotten area on the pedicel, generally at the basal end. These characters were used for categorising the shedding into non-pathogenic and pathogenic.

This study was conducted for two years from January 1978 to December 1979. At the time of harvest, the total number of spikes per vine was estimated and the rachis infected spikes were separated. The percentage of pathogenic spike shedding was then calculated from the formula.

$$\text{Percentage of pathogenic spike shedding/rachis infection} = \frac{100 \times \text{Number of spike shed due to infection (pathogenic)}}{\text{Total number of spikes produced}}$$

Berry infection

In order to estimate the percentage of berry infection, the spikes showing berry infection were tagged during both the years viz., 1978 and 1979. The development of the berry infection was recorded at fortnightly intervals. After the harvest, the number of infected berries was counted.

Fifty spikes collected at random from each standard were thrasshed separately and the berries counted in order to work out the average number of berries per spike for each vine per harvest. To find out the percentage of berry infection the following formula was used.

$$\text{Percentage of berry infection} = \frac{100 \times \text{total number of berries infected}}{\text{Total number of spikes} \times \text{average number of berries per spike}}$$

Fungicidal studies

<u>Bioassay</u>

Bioassay studies were conducted using seven fungicides by poison food technique (Zentmayer, 1955) to find out the effectiveness of these fungicides against *C. gloeosporioides*. All fungicides except

Bordeaux mixture were tried at five concentrations, viz., 100, 250, 500, 1000 and 2000 ppm while Bordeaux mixture was tried only at one per cent concentration. The trade name and active ingredients of the fungicides used are given below:

1. Antracol	Zinc - propylene-bis-dithiocarbamate
2. Fycop A.	40% copper oxychloride
3. Bayleton	1-(4-Chloro-phenoxy) -3, 3-dimethyl-1-(1-H-1, 2, 4 - triazol-1-yl)-2-butanone
4. Difolatan	N-1, 1,2,2-tetrachloroethyl thio-cis-4 cyclohexene -1, 2-dicarboximide (Captafol)
5. Dithane-Z-78	75% ethylene bis-dithiocarbamate
6. Ziride	Zinc dimethyl dithiocarbamate
7. Bordeaux mixture	Basic copper sulphate

Field studies

The fungicides which showed more than sixty per cent inhibition of the fungus during in vitro studies viz., Antracol, Bayleton, Bordeaux mixture and Difolatan were selected for the field studies.

The pre-treatment observations were taken one day before the first spraying and subsequent observations were taken one month after each spray, i.e., one day prior to the subsequent sprayings.

The intensity of the disease on the leaf was recorded one day before spraying. The observation on the spike shedding due to infection could not be recorded before the treatment since only spikes shed during three or four days before the spraying were available for observation, and it will not give a clear picture of the disease intensity. The berry infection was observed only after the harvest in order to make the observation exhaustive.

The concentrations of the fungicides used in the field are as follows:

1. Antracol	0.1 per cent
2. Bayleton	0.01 per cent
3. Bordeaux mixture	1.0 per cent
4. Difolatan	0.2 per cent

Each treatment consisted of six standards (2 vines/standard). Each standard received one litre of spray fluid per application. The fungicides used were sprayed using a rocker sprayer. In the untreated check plots, water was sprayed instead of fungicide solution. Sufficient cadre was taken to avoid the drift of the spray fluid. All the plants received three fungicidal sprays at monthly intervals starting from the second week of July 1979.

Statistical analysis

The statistical analysis of the data on per cent inhibition of growth of Colletotrichum gloeosporioides by poison food technique with different concentrations of fungicides after eight days incubation was made from the result of the bioassay studies in solid medium according to the method suggested by Federer (1955).

The data were transformed to angles by using the inverse sine transformation given by $\theta = \sin^{-1}\sqrt{p}$ where θ is the angle corresponding to the per cent p. The variations between fungicides and between concentrations within fungicides were evaluated and tested for significance.

Data to determine the comparative efficacy of different fungicides in the control of 'pollu' disease of pepper during each observation were analysed by implying the analysis of variance technique of randomised block design.

The overall increase in disease index during the entire period of observation was calculated and the resulting observations were analysed statistically to measure the effects of different fungicides on the disease intensity. The average yield per plot was also recorded and subjected to statistical analysis.

The influence of weather parameters on the intensity of the disease was determined by working out the simple correlation coefficients.

Results

RESULTS

Symptomatology

The pathogen causing anthracnose disease of pepper (Fungal 'pollu') was found to infect all parts of the pepper vine, except roots and well matured stems and branches. The symptoms produced on leaves, tender shoots, pedicel of the spikes, threads of the spikes and immature and mature berries were different. Detailed observations on the symptomatology of the disease on different parts of the vine are given below:

Leaves

The pathogen usually attacked physiologically active and matured leaves and tender leaves were free from infection. On leaves, the initial symptom observed in the infection court was a chlorotic speck. This chlorotic speck turned dark brown in colour within two days (Plate II a). Under dry conditions this speck enlarged in an irregularly circular fashion with a definite dark brown margin (Plate II b). The well matured

Plate IIa   Dark brown spot on the leaf infected with the fungus

Plate IIb   Leaf spot showing definite dark brown margin spots under dry conditions were circular to irregularly circular in shape, measuring 0.2 mm to 20 mm in diameter. The holonecrotic area of the spots was slightly depressed and was ashy white to papery white in colour. The acervuli of the pathogen could be seen on both sides of the leaf. They were, however, more abundant on the upper surface. The holonecrotic area was surrounded by dark coloured plesionecrotic area which was encircled by a dark coloured raised margin. Development of the spots was very slow and no pronounced halo could be seen around the spots. Under this condition shedding of infected leaves usually did not take place (Plate 11c).

Under humid moist conditions the leaf spots enlarged quickly and attained 20-50 mm in diameter within a week. The holonecrotic area of the spots under humid moist conditions was not much depressed and was ashy white in colour. Fructifications of the pathogen were more under humid moist conditions. The holonecrotic area was surrounded by dark coloured plesionecrotic area without a definite margin which was in turn surrounded by a bright yellow halo (Plate 11d).

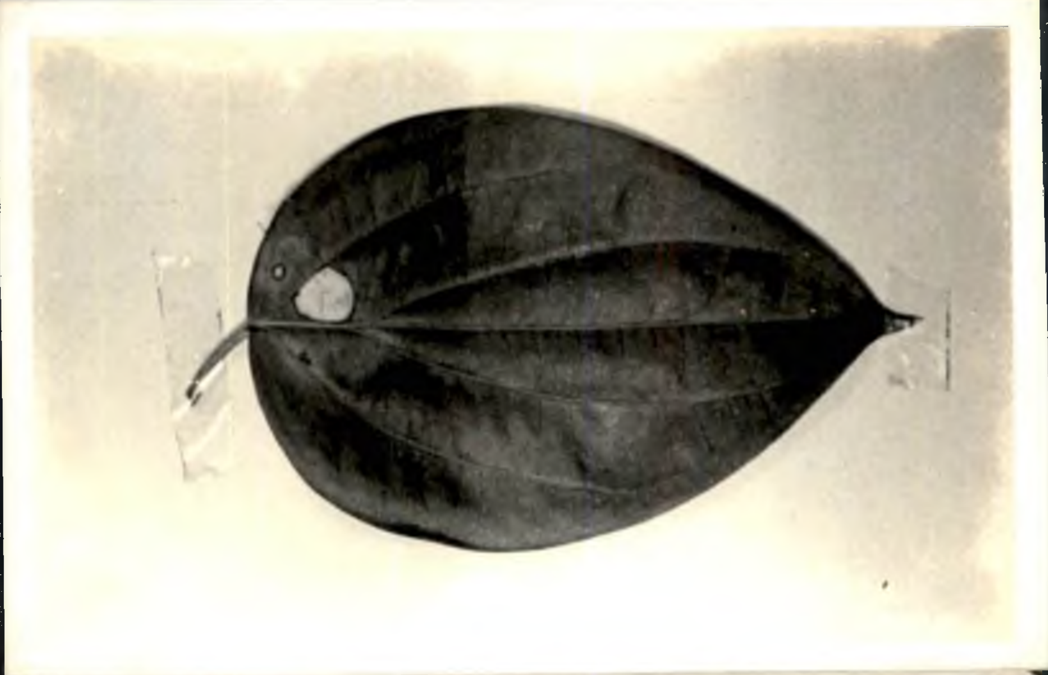


Plate IIc Leaf spot showing papery white holonecrotic area surrounded by dark coloured plesionecrotic area

Plate IId Leaf spot showing bright yellow halo

The infected leaves usually shed within 10-15 days, under moist conditions.

Tender shoots

The pathogen rarely attacked tender shoots. The initial symptom observed on tender shoot was the same as that on leaf. The chlorotic specks on tender shoots turned dark brown and enlarged longitudinally and measured upto 4-5 cm in length. Definite margin and halo were not observed around necrotic area (Plate III). When the infection spread all around, the young shoots got dried above the infected region.

Spikes

The pathogen infected different parts of the spike, namely, pedicel, rachis and immature and mature berries.

Pedicel

The pathogen attacked the pedicel of the young spike, which resulted in shedding of the spikes. The initial symptom observed on pedicel was similar to that observed on leaves and young shoots (Plate IV).

Plate III Infected tender shoot showing dark brown spot

Plate IV Spike showing pedicel infection

The spike shedding due to physiological and pathological reasons can easily be distinguished on the basis of callus formation at the base of the spike pedicel. In the case of spike shedding due to physiological reasons, callus formation at the base of the spike pedicel is the characteristics symptom whereas no such callus formation was observed in the case of spike shed due to fungus infection. The fungus infected portion was found to be rotten and dark in colour. Pedicel infection was not observed on mature spikes.

Rachis

Rachis infection usually occurred when the berries were half matured. The initial symptom of rachis infection was not observed in the field. As a result of infection, all the berries below the infected portion dried and became dark coloured. These dried and shrivelled berries were lighter than normal berries and did not fall off from the spike (Plate V).

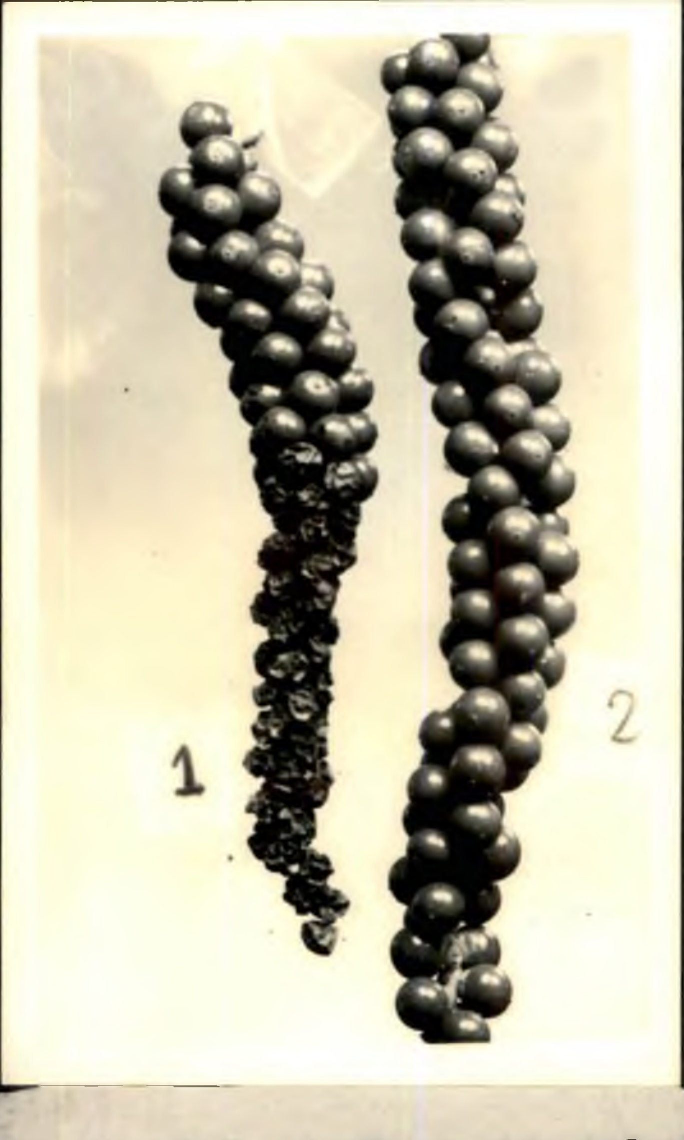


Plate V Spike showing rachis infection

1. Rachis infected spike
2. Healthy spike

Immature berries

The initial symptom on the berries was also in the form of chlorotic specks. These chlorotic specks in turn became dark brown within two days. These spots enlarged and the whole berry became dark brown in colour. Later, the berries became dried and shrivelled. But they were still attached to the spike. The infected berries were very light and less pungent (Plate VI).

Mature berries

On the mature berries also the initial symptom was in the form of circular chlorotic specks. These spots enlarged gradually and the pericarp of the berries became rotten and pulpy. Usually the rind of infected berries cracked (Plate VII). However, even after infection, the seed did not get infected and but remained intact. Due to delayed infection, the weight and pungency of berries were not considerably reduced.

Inoculation studies

When the leaves, vines and spikes were inoculated with C. gloeosporioides, took infection and showed same symptom observed in the field.

Plate VI Infection on immature berries (Early infection)

Plate VII Infection on mature berries (Late infection)

WEATHER

The climate of Vellanikkara was typically monsoonic consisting of two monsoons, South West and North East. The average annual rainfall of this area for the last ten years (1970-1979) was 2865.5 mm, with an average of 1875 mm during South West monsoon period and 641.8 mm during North East monsoon period.

The number of rainy days ranged from 69 to 90 during South West monsoon and 33 to 62 during the North East monsoon. The annual maximum day temperature for the last ten years was 40.1°C, recorded during the month of March and the minimum was 18.4°C, recorded during the month of January. The maximum and minimum values of relative humidity recorded during these years were 100 and 57.4 per cent, respectively. The maximum relative humidity was observed during the peak period of South West monsoon, usually in June/July and the minimum relative humidity was observed during January. The climatic conditions during the period in which the study was conducted (1978-79) are given below:

Rainfall

The total rainfall and number of rainy days had profound influence on the growth and yield of pepper. Rainfall also influenced the build up and spread of inoculum of the pathogen.

The total rainfall recorded during 1978 was 3188 mm, received in 153 rainy days, while during 1979, 2995.3 mm was received in 140 days (Table 1).

In 1978, South West monsoon started during the second fortnight of May and resulted in 2530.8 mm of rain in 99 rainy days. In the same year during the North East monsoon period there was 382.4 mm of rainfall in 18 rainy days.

In 1979, South West monsoon started in June and 2115.1 mm of rain was recorded in 69 rainy days. During North East monsoon, 645 mm of rainfall was obtained in 51 days. The rest of the rainfall was received during the off season.

Temperature

Temperature is another important factor which governed the growth, development and distribution of the host as well as the pathogen. The lowest temperature generally occurred between December and January (20.4°C in 1978 and 21.4°C in

Table 1. Climatic data of Vellanikkara, 1978 and 1979 fortnightly recorded

Sl.No. of the fort-nights	Period			Rainfall		Temperature		Relative humidity %	
				No.of rainy days	Fall in mm	max.	min.	max.	min
1	2			3	4	5	6	7	8
1	1--1--78	to	14-1--78	-	-	31.7	21.4	79.8	60.2
2	15-1--78	to	28-1--78	-	-	32.0	20.4	76.5	61.0
3	29-1--78	to	11-2--78	-	-	33.6	22.4	80.2	60.1
4	12-2--78	to	25-2--78	2	40.3	34.6	22.1	90.0	68.2
5	26-2--78	to	11-3--78	-	-	35.4	25.2	79.0	66.3
6	12-3--78	to	25-3--78	1	0.4	35.4	25.7	90.0	67.7
7	26-3--78	to	8--4--78	2	14.8	35.7	26.6	92.5	74.0
8	9--4--78	to	22-4--78	2	6.7	35.4	26.3	92.0	70.0
9	23-4--78	to	6--5--78	4	26.4	35.5	26.4	89.0	78.7
10	7--5--78	to	20--5-78	6	66.4	33.5	25.1	93.0	80.1
11	21-5--78	to	3--6--78	11	366.2	30.2	24.1	98.0	90.0
12	4--6--78	to	17--6-78	14	397.1	28.1	22.2	99.5	93.1
13	18-6--78	to	1--7--78	13	307.4	28.8	22.8	98.5	91.7
14	2--7--78	to	15--7-78	13	438.6	28.0	22.7	99.5	91.0
15	16-7--78	to	29--7-78	14	298.7	28.7	23.1	98.5	89.7

(Continued)

Table 1. (Contd.)

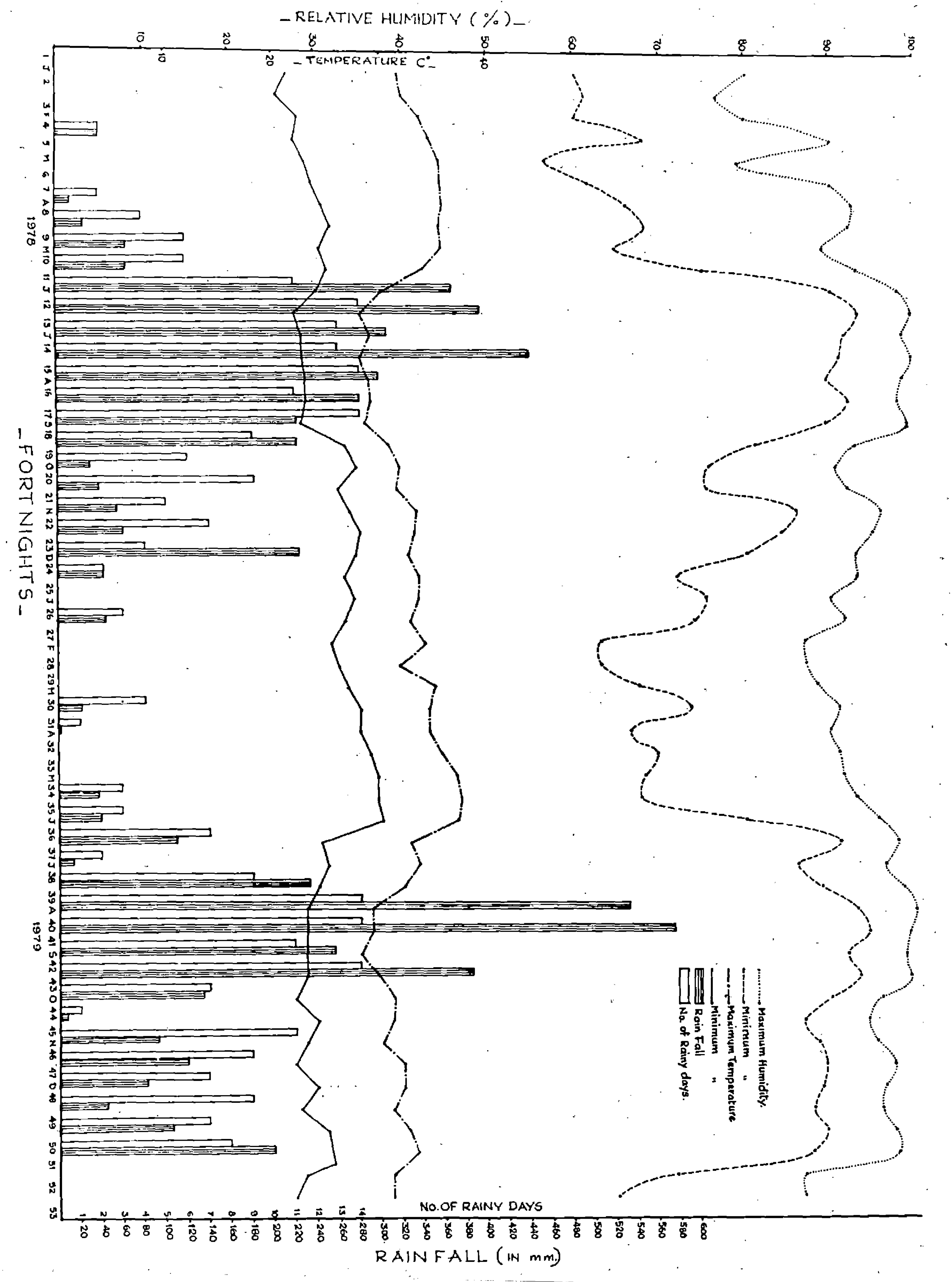
1	2	3	4	5	6	7	8
16	30-7--78 to 12-8--78	11	280.0	28.8	23.2	98.0	91.9
17	13-8--78 to 26-8--78	14	221.4	28.6	22.8	99.0	89.5
18	27-8--78 to 9--9--78	9	221.4	30.3	25.5	92.9	81.0
19	10-9--78 to 23-9--78	7	30.9	31.6	25.6	90.5	75.4
20	24-9--78 to 7-10--78	9	38.8	31.4	25.1	92.0	75.5
21	8-10--78 to 21-10-78	5	53.9	33.2	26.1	95.9	76.0
22	22-10-78 to 4-11--78	7	61.0	32.8	27.0	95.2	74.5
23	5-11--78 to 18-11-78	4	224.4	32.5	26.7	93.0	80.7
24	19-11-78 to 2--12-78	2	43.1	33.3	26.8	90.0	72.2
25	3-12--78 to 16-12-78	-	-	33.3	24.2	90.0	70.5
26	17-12-78 to 30-12-78	3	43.9	32.9	23.8	91.5	74.0
27	31-12-78 to 13-1--79	-	-	31.0	21.4	86.8	63.2
28	14-1--79 to 27-1--79	-	-	31.1	22.8	86.9	63.1
29	28-1--79 to 10-2--79	-	-	32.0	23.0	88.6	67.4
30	11-2--79 to 24-2--79	4	22.0	34.6	26.1	91.0	73.4
31	25-2--79 to 10-3--79	1	3.2	34.5	28.1	90.0	66.5
32	11-3--79 to 24-3--79	-	-	35.6	29.1	91.2	69.6
33	25-3--79 to 7--4--79	-	-	37.0	29.6	91.5	68.0
34	8--4--79 to 21-4--79	3	37.7	37.4	29.6	93.0	69.6
35	22-4--79 to 5--5--79	2	38.8	37.1	30.1	95.6	80.0

(Continued)

Table 1. (Contd.)

1	2	3	4	5	6	7	8
36	6--5--79 to 20-5--79	7	111.5	32.6	24.4	98.0	91.0
37	21-5--79 to 3--6--79	2	13.6	33.5	25.0	96.7	86.0
38	4--6--79 to 17-6--79	9	231.4	32.0	23.0	100.0	93.0
39	18-6--79 to 31-7--79	14	532.6	29.0	22.0	99.5	94.5
40	2--7--79 to 15-7--79	14	574.5	29.0	22.0	99.0	92.0
41	16-7--79 to 29-7--79	11	256.4	28.0	23.0	99.5	93.5
42	30-7--79 to 12-8--79	14	385.0	29.7	22.0	96.0	90.0
43	13-8--79 to 26-8--79	7	135.2	31.0	23.0	96.0	90.0
44	27-8--79 to 9--9--79	1	7.8	31.0	24.0	94.5	87.0
45	10-9--79 to 23-9--79	11	92.4	30.0	23.0	95.5	88.5
46	24-9--79 to 7-10--79	9	119.7	32.0	23.0	97.5	89.5
47	8--10-79 to 21-10-79	7	85.1	32.0	24.0	96.5	89.0
48	22-10-79 to 4-11--79	9	43.4	31.0	23.6	96.0	88.0
49	5-11-79 to 18-11-79	7	105.8	32.5	25.1	97.5	89.5
50	19-11-79 to 2--12-79	8	199.2	33.3	25.5	98.0	88.0
51	3-12--79 to 16-12-79	-	-	31.0	23.0	87.0	72.0
52	17-12-79 to 30-12-79	-	-	31.0	22.0	87.0	65.0

Fig.1 Climatic data of Vellanikkara 1978 and 1979



- RELATIVE HUMIDITY (%) -
- TEMPERATURE C° -
- FORTNIGHTS -
1978
1979
No. OF RAINY DAYS
RAINFALL (IN mm)
Maximum Humidity.
Minimum "
Maximum Temperature
Minimum "
Rain Fall
No. of Rainy days.

1979) (Table 1). The maximum day temperature was recorded between March and April (35.7°C in 1978 and 37.4°C in 1979). The lowest day temperature was noticed during South West monsoon period (28°C in both the years under observation). In 1978, the minimum temperature was recorded in the first fortnight of July and in 1979 the same was in the second fortnight of July. Fortnightly averages of maximum and minimum temperatures for the years 1978 and 1979 have been presented in Table 1 and Fig.1.

Relative humidity

The relative humidity was very low (60.1 to 68.0 per cent) during December to April and high (90 to 100 per cent) during monsoon period. During South West and North East monsoon periods the fortnightly average minimum relative humidity was above 70 per cent (Table 1).

A detailed classification of the climate prevailing in Vellanikkara revealed that there are six well defined periods in a year, namely, warm dry period, premonsoon period, South West monsoon period, monsoon break period, North East monsoon period and cool dry period.

Warm dry period

This is the hottest period of the year and it extended from the middle of February to the first week of May in 1978. In 1979 this period started slightly early (in the first fortnight of February). The fortnightly averages of maximum temperature varied from 35.4°C to 35.7°C in 1978 and 34.5°C to 37.4°C in 1979. The fortnightly averages of minimum temperature ranged from 23.2°C to 26.6°C in 1978 and 26.1°C to 30.1°C in 1979.

The total numbers of rainy days during this period in 1978 and 1979 were nine and ten respectively. The total rainfall during this period in 1979 (131.7 mm) was more than double of that received in 1978 (48.3 mm). This variation in rainfall had its effect on the relative humidity also. The fortnightly averages of maximum relative humidity varied from 79 to 92.5 per cent in 1978 and 90 to 95.6 per cent in 1979. The same trend was also noticed in the fortnightly averages of minimum relative humidity (Table 2, Fig.2).

Pre-monsoon period

This period was characterised by intermittent rains, a gradual decrease in temperature and an

Table 2. Weather data of Vellanikkara during the warm dry periods of 1978 and 1979 (fortnightly averages)

Sl.No. of the fort-nights	Period	Rainfall		Temperature		Relative humidity %	
		No.of rainy days	Fall in mm	max.	min.	max.	min.
5	26-2--78 to 11-3-78	-	-	35.4	23.2	79.0	60.3
6	12-3--78 to 25-3--78	1	0.40	35.5	25.7	90.0	61.7
7	26-3--78 to 8--4--78	2	14.80	35.7	26.6	92.5	66.0
8	9--4--78 to 22-4--78	2	6.70	35.4	26.3	92.0	68.0
9	23-4--78 to 6--5--78	4	26.40	35.5	26.4	89.0	70.7
30	11-2--79 to 24-2--79	4	22.0	34.6	26.1	91.0	73.4
31	5--2--79 to 10-3--79	1	3.2	34.5	28.1	90.0	66.5
32	11-3--79 to 24-3-79	-	-	35.6	29.1	91.2	69.6
33	25-3--79 to 7--4--79	-	-	37.0	29.6	91.5	68.0
34	8--4--79 to 21-4--79	3	37.7	37.4	29.6	93.0	69.6
35	22-4--79 to 5--5--79	2	38.8	37.1	30.1	95.6	80.0

Warm dry periods in Vellanikkara - 1978 and 1979

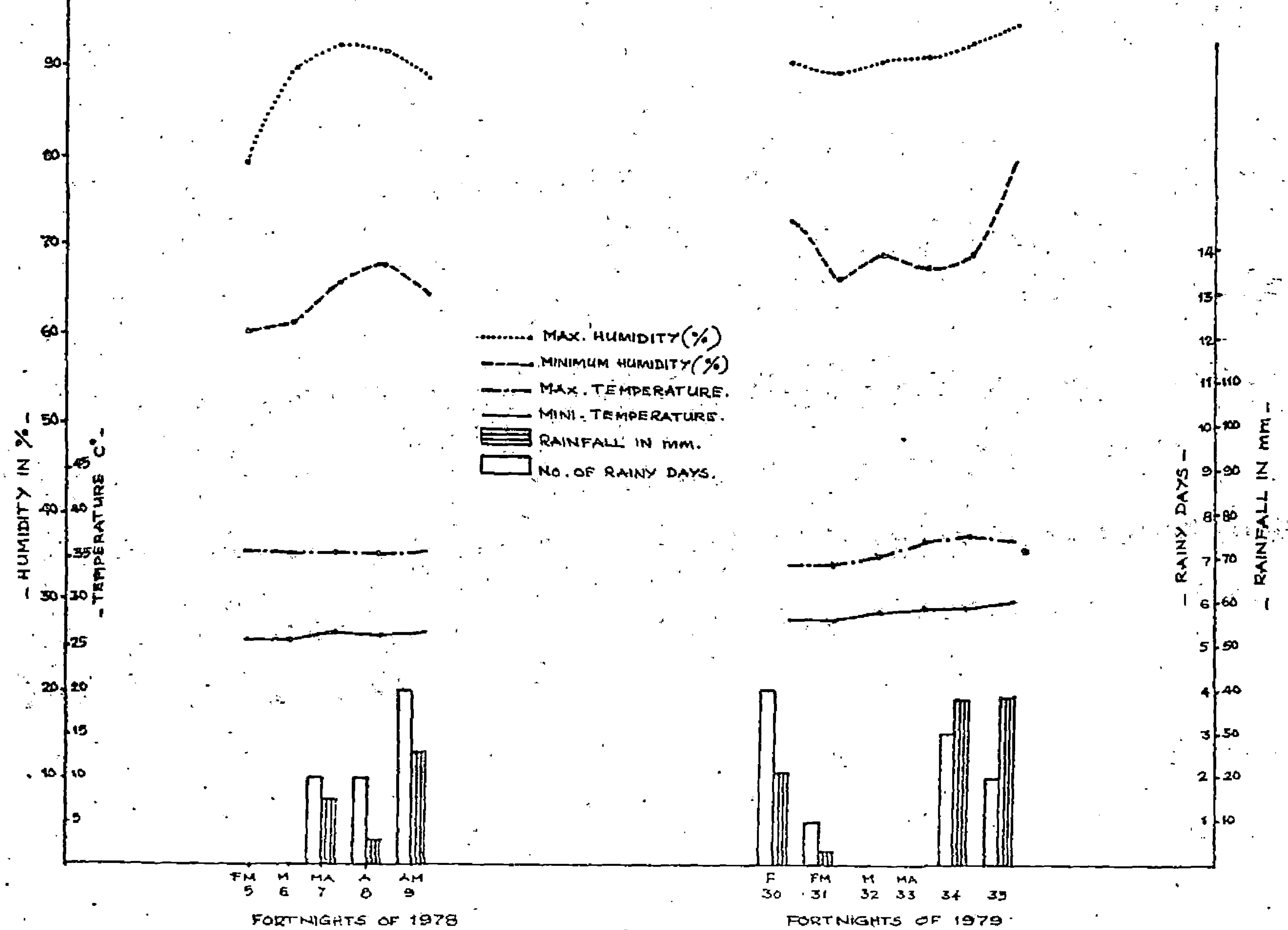


Fig. 2

increase in humidity. Among the six different periods, this constituted the shortest spell. Pre-monsoon period extended for a period of one fortnight from the first week of May in 1978 and two fortnights from the first week of May in 1979.

The maximum average temperature during pre-monsoon period of 1978 was 33.5°C and the minimum 25.1°C. The corresponding values for 1979 were 32.6°C to 33.5°C and 24.4°C to 25°C respectively. The relative humidity showed much variation during this period because of intermittent rainfall. In 1978, the maximum average relative humidity was 93 per cent and the minimum 75.1 per cent, while in 1979 the maximum ranged from 96.7 to 98 per cent and the minimum from 86 to 91 per cent. In 1978, 66.4 mm of rainfall was received in six days compared to 125.1 mm of rainfall received in nine days in 1979 (Table 3).

South West monsoon period

South West monsoon was characterised by heavy rainfall and near saturation values of relative humidity. The variation in average fortnightly

Table 3. Pre-monsoon period in Vellanikkara - 1978 and 1979 (fortnightly averages)

Sl.No. of the fort-nights	Period	Rainfall		Temperature		Relative humidity %	
		No.of rainy days	Fall in mm	max.	min.	max.	min.
10	7--5--78 to 20-5--78	6	66.4	33.5	25.1	93.0	75.1
36	6--5--78 to 20-5--78	7	111.5	32.6	24.4	98.0	91.0
37	21-5--79 to 3--6--79	2	13.6	33.5	25.0	96.7	86.0

values for maximum and minimum relative humidity was considerably narrow during this period. The South West monsoon started during the end of third week of May in 1978 while in 1979 it commenced in the first week of June. In 1978, the monsoon period extended for 110 days with 99 rainy days. In 1979, it was spread over 80 days with 69 rainy days. The variation in fortnightly maximum temperature was from 28.0°C to 30.3°C in 1978 and 28°C to 32°C in 1979. The minimum temperature varied from 22.2°C to 25.5°C and 22.0°C to 23.0°C in 1978 and 1979, respectively. The maximum fortnightly average relative humidity ranged from 92.9 to 99.5 per cent in 1978 and 96 to 100 per cent in 1979. The minimum relative humidity ranged from 81 to 93.1 per cent in 1978 and 90 to 94.5 per cent in 1979 (Table 4 and Fig. 3).

Monsoon break period

This period is characterised by sudden reduction in rainfall, slight increase in maximum and minimum temperature and reduction in maximum and minimum relative humidity in both the years under observation. In 1978, the monsoon break period

Table 4. South West monsoon period in Vellanikkara - 1978 and 1979 (fortnightly averages)

Sl.No. of the fort-nights	Period	Rainfall		Temperature		Relative humidity %	
		No.of rainy days	Fall in mm	max.	min.	max.	min.
11	21-5--78 to 3--6--78	11	366.2	30.2	24.1	98.0	90.0
12	4--6--78 to 17-6--78	14	397.1	28.1	22.2	99.5	93.1
13	18-6--78 to 1--7--78	13	307.4	28.8	22.8	98.5	91.7
14	2--7--78 to 15-7--78	13	438.6	28.0	22.7	99.5	91.0
15	16-7--78 to 29-7--78	14	298.7	28.7	23.1	98.5	89.7
16	30-7--78 to 12-8--78	11	280.0	28.8	23.2	98.0	91.9
17	13-8--78 to 26-8--78	14	221.4	28.6	22.8	99.0	89.5
18	27-8--78 to 9--9--78	9	221.4	30.3	25.5	92.9	81.0
38	4--6--79 to 17--6-79	9	231.4	32.0	23.0	100.0	93.0
39	18-6--79 to 1--7--79	14	532.6	29.0	22.0	99.5	94.5
40	2--7--79 to 15-7--79	14	574.5	29.0	22.0	99.0	92.0
41	16-7--79 to 29-7--79	11	256.4	28.0	23.0	99.5	93.5
42	30-7--79 to 12-8--79	14	385.0	29.7	22.0	96.0	90.0
43	13-8--79 to 26-8--79	7	135.2	31.0	23.0	96.0	90.0

South West monsoon period in Vellanikkara - 1978 and 1979

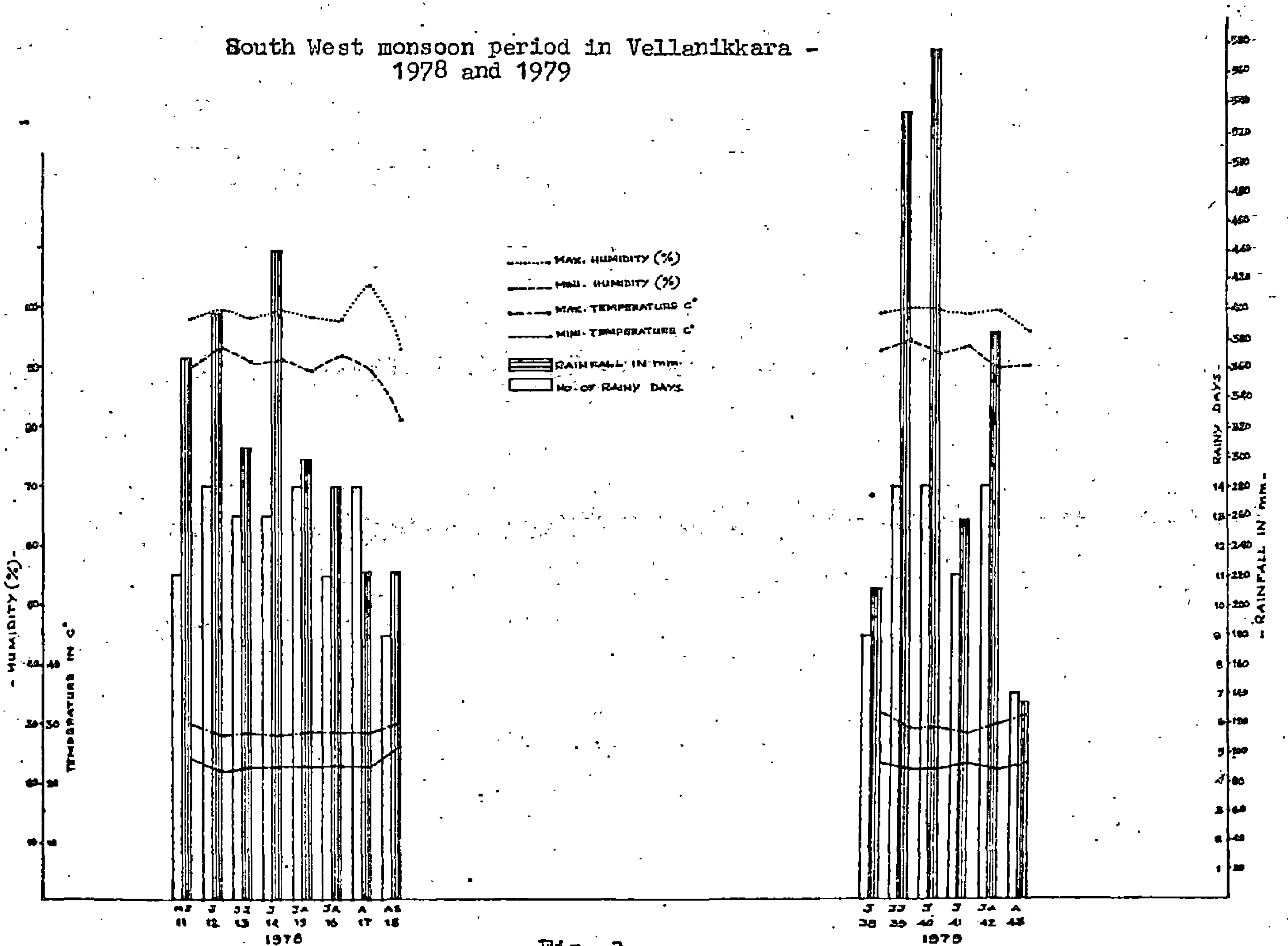


Fig. 3

lasted only for two fortnights with 16 rainy days and 69.7 mm rainfall. But in 1979, this period was only for one fortnight with a single rainy day of 7.8 mm rainfall. There was no marked variation in fortnightly average maximum and minimum temperatures in 1978 and 1979. The fortnightly maximum average humidity decreased and ranged from 90.5 to 92.0 per cent in 1978 while it was 94.5 per cent in the single fortnight of this period in 1979. Similarly, the minimum average relative humidity also decreased and ranged from 75.4 to 75.5 per cent in 1978. During 1979, the value recorded for this parameter was 87.0 per cent (Table 5).

North East monsoon period

The North East monsoon started during the second week of October and extended upto the first week of December in 1978. But, in 1979 the North East monsoon was observed even from the middle of second week of September and extended upto the first week of December. The maximum fortnightly average temperature ranged from 32.5°C to 33.3°C in 1978 and from 30.0°C to 33.3°C in 1979. The minimum average temperature ranged from 26.1°C to 27.0°C in 1978 and

Table 5. Monsoon break period in Vellanikkara - 1978 and 1979 (fortnightly averages)

Sl.No. of the fort-nights	Period	Rainfall		Temperature		Relative humidity %	
		No.of rainy days	Fall in mm	max.	min.	max.	min.
19	10-9--78 to 23-9--78	7	30.9	31.6	25.6	90.5	75.4
20	24-9--78 to 7--10-78	9	38.8	31.4	25.1	92.0	75.5
44	27--8--79 to 9-9-79	1	7.8	31.0	24.0	94.5	87.0

$23.0^{o}C$ to $25.5^{o}C$ in 1979. The fortnightly maximum average humidity in 1978 ranged from 90.0 to 95.9 per cent and in 1979 it ranged from 95.5 to 98.0 per cent. The fortnightly average minimum humidity varied from 72.2 to 80.7 per cent in 1978 and from 88.0 to 89.5 per cent in 1979. In 1978, there was 382.4 mm rainfall received in 18 days which was just half as compared to 1979 during which the rainfall was 645.6 mm received in 51 days (Table 6 and Fig.4).

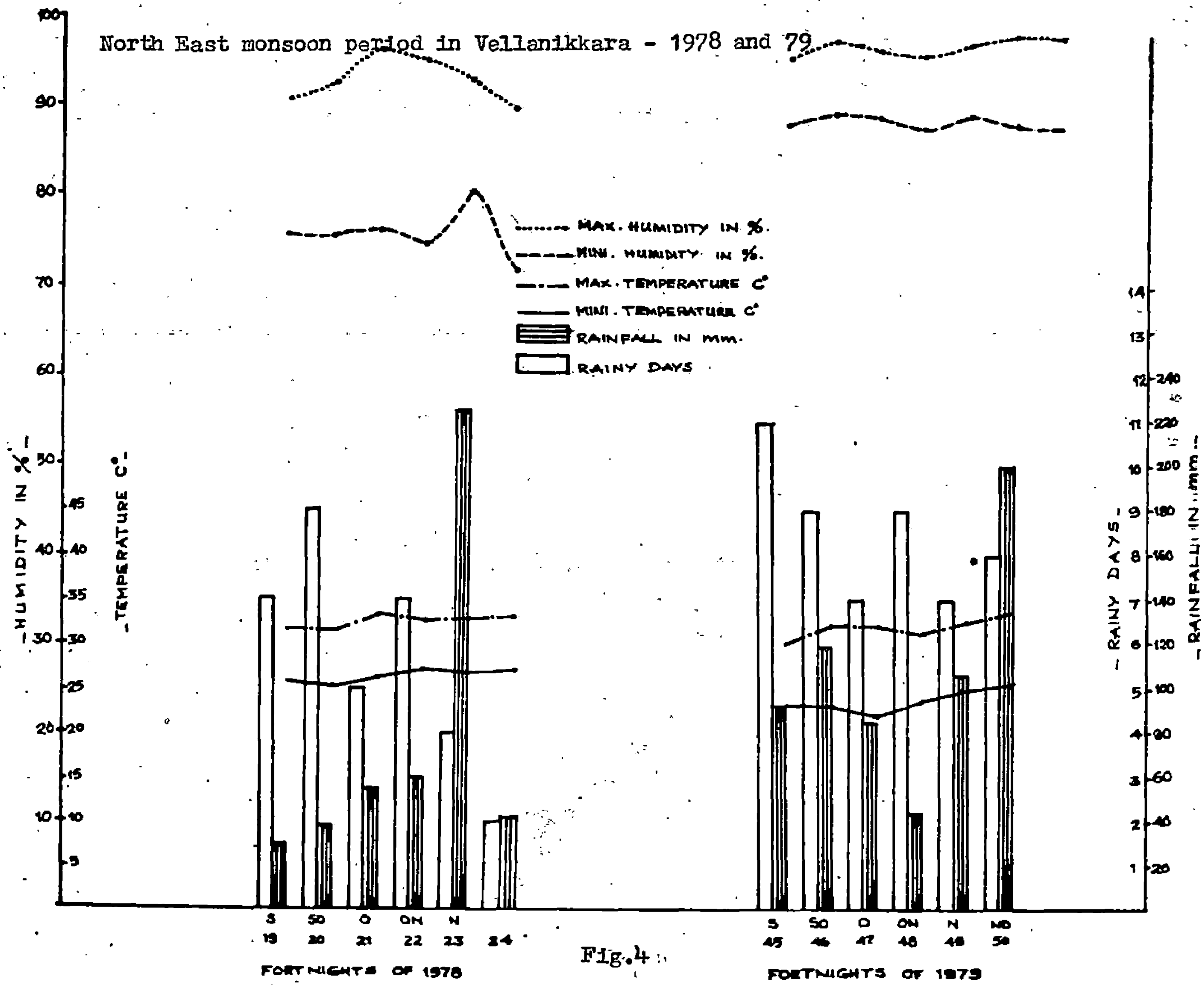
Cool dry period

This is the coolest period of the year. This is characterised by a reduction in relative humidity and temperature.

Cool dry period in 1978 started in first fortnight of December, 1977 and extended upto the second fortnight of February, 1978. Maximum relative humidity during this period ranged from 76.5 to 91.5 per cent. Maximum and minimum fortnightly temperatures ranged from $31.7^{o}C$ to $34.6^{o}C$ and $20.4^{o}C$ to $23.2^{o}C$, respectively. During this period, after January 1978 there were two rainy days in the month of February 1978 and a total of 40.3 mm rainfall was

Table 6. North East monsoon period in Vellanikkara - 1978 and 1979 (fortnightly averages)

Sl.No. of the fort-nights	Period	Rainfall		Temperature		Relative humidity %	
		No.of rainy days	Fall in mm	max.	min.	max.	min.
21	8-10--78 to 21-10-78	5	53.9	33.2	26.1	95.9	76.0
22	22-10-78 to 4-11--78	7	61.0	32.8	27.0	95.2	74.5
23	5-11--78 to 18-11-78	4	224.4	32.5	26.7	93.0	80.7
24	19-11-78 to 2--12-78	2	43.1	33.3	26.8	90.0	72.2
45	10-9--79 to 23-9--79	11	92.4	30.0	23.0	95.5	88.5
46	24-9--79 to 7-10--79	9	119.7	32.0	23.0	97.5	89.5
47	8-10--79 to 21-10-79	7	85.1	32.0	24.0	96.5	89.0
48	22-10--79 to 4-11-79	9	43.4	31.0	23.6	96.0	88.0
49	5--11--79 to 18-11-79	7	105.8	32.5	25.1	97.5	89.5
50	19-11-79 to 2--12-79	8	199.2	33.3	25.5	98.0	88.0



North East monsoon period in Vellanikkara - 1978 and 79
MAX. HUMIDITY IN %.
MINI. HUMIDITY IN %.
MAX. TEMPERATURE C°
MINI. TEMPERATURE C°
RAINFALL IN mm.
RAINY DAYS
- HUMIDITY IN % -
- TEMPERATURE C° -
- RAINY DAYS -
- RAINFALL IN mm -
S SO O ON N
19 20 21 22 23 24
FORTNIGHTS OF 1978
S SO O ON N NO
45 46 47 48 49 50
FORTNIGHTS OF 1979

Fig.4

received. Cool dry period in 1979 started in the first fortnight of December, 1978 and extended upto the first fortnight of February 1979. During this period the maximum fortnightly average temperature ranged from 31.0°C to 32.0°C and the minimum from 21.4°C to 23.0°C. Fortnightly average relative humidity in this period ranged from 86.8 to 88.6 per cent while the minimum relative humidity ranged from 63.1 to 74.0 per cent. The rainfall recorded during this period was 84.2 mm distributed in five rainy days (Table 7 and Fig.5).

EPIDEMIOLOGY OF DISEASE

The pattern of infection and the development of the disease on leaf, on the pedical of spikes and on the berries were observed at fortnightly intervals along with the climatic factors already described. The results of the observations are given in Tables 8 to 11 and presented in Fig.6. Infection on young growing tips was also observed in a few cases but the incidence was too low and sporadic and hence not accounted.

Table 7. Cool dry period in Vellanikkara - 1978 and 1979 (fortnightly averages)

Sl.No. of the fort-nights	Period	Rainfall		Temperature		Relative humidity %	
		No.of rainy days	Fall in mm	max.	min.	max.	min.
1	1--1--78 to 14-1--78	-	-	31.7	21.4	79.8	60.2
2	15-1--78 to 28-1--78	-	-	32.0	20.4	76.5	61.0
3	29-1--78 to 11-2--78	-	-	33.6	22.4	80.2	60.1
4	12-2--78 to 25-2--78	2	40.3	34.6	22.1	90.0	68.2
25	3-12--78 to 16-12-78	-	-	33.3	23.2	90.0	70.5
26	17-12-78 to 30-12-78	3	43.9	32.9	23.0	91.5	74.0
27	31-12-78 to 13-1--79	-	-	31.0	21.4	86.8	63.2
28	14-1--79 to 27-1--79	-	-	31.0	21.8	86.9	63.1
29	28-1--79 to 10-2--79	-	-	32.0	23.0	88.6	67.4
51	3-12--79 to 16-12-79	-	-	31.0	23.0	87.0	72.0
52	19-12-79 to 29-12-79	-	-	31.0	22.0	87.0	65.0

Cool dry period in Vellanikkara - 1978 and 1979

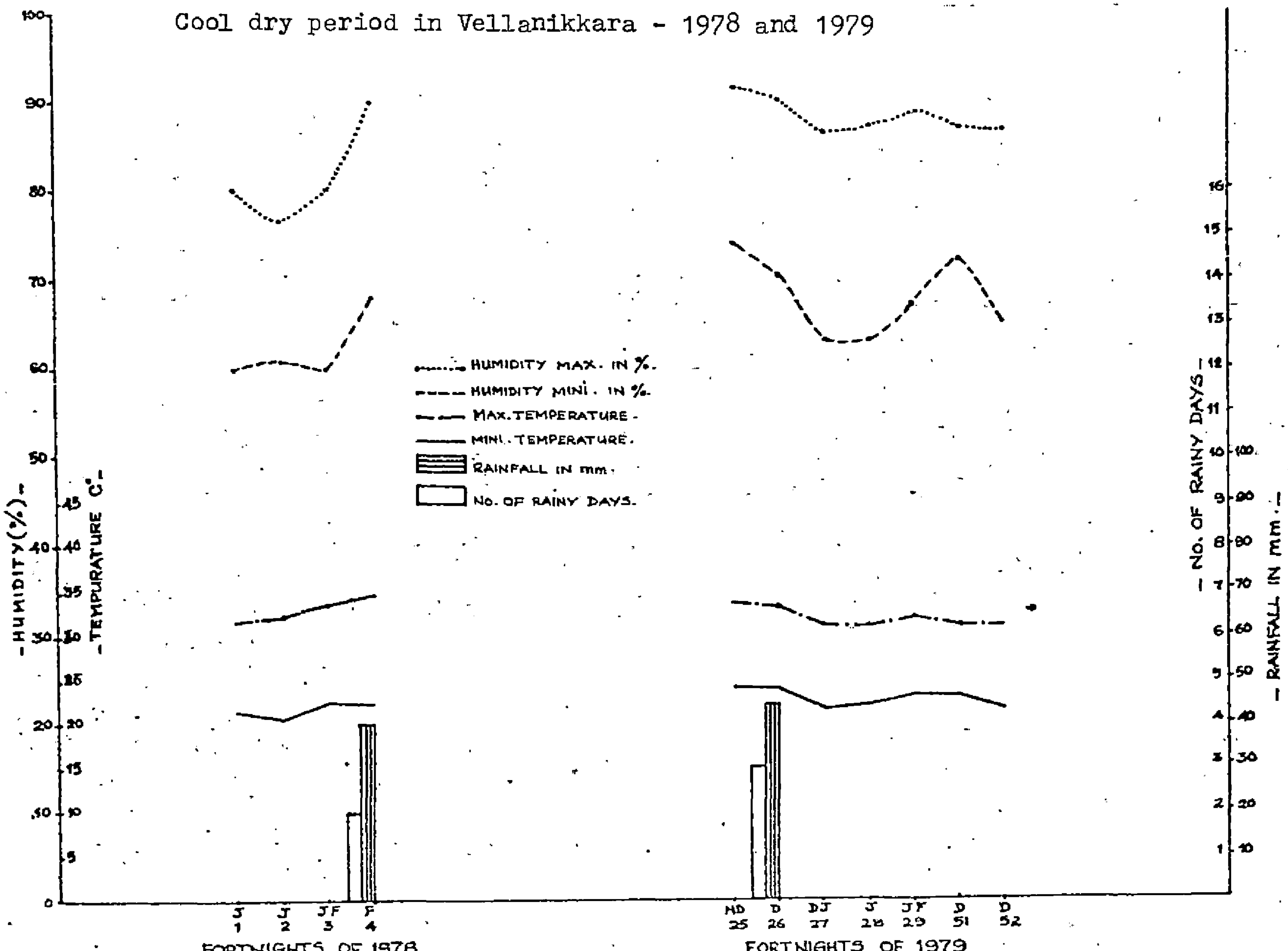


Fig. 5

Fresh infection on leaf

Eventhough the disease on the leaf was perennial in nature, fresh infection on leaf was first noticed only in the second week of May, after the warm dry period, in both 1978 and 1979. The infection period almost synchronized with the formation of new flushes on pepper during the premonsoon period. However, infection on leaves was noticed only on physiologically active leaves and never on tender leaves.

During 1978, the pre-monsoon period lasted only for one fortnight with six rainy days, 66.4 mm of rainfall, 33.5°C and 25.1°C average maximum and minimum temperatures and 93.0 and 75.1 per cent average maximum and minimum relative humidity. During this period an average of 12.76 new infection per standard was observed. In 1979, the pre-monsoon period was much different from that of the previous year. It extended for two fortnights with nine rainy days and a total of 125.1 mm rainfall. A slight decrease in the average maximum and minimum temperature and a considerable increase in maximum and minimum relative humidity were observed in 1979 compared to the previous year. This resulted in much higher infection on the leaves (120.7 per standard) during the pre-monsoon period.

An increase in the infection rate was observed during South West monsoon period. In the second fortnight of this period, the average number of infection was 150.2 per standard in 1978 and 169.9 per standard in 1979 indicating a slightly increased infection during the first fortnight of South West monsoon period in 1979. During both these years, the maximum infection was noticed during the peak period of South West monsoon which synchronised with a continuous heavy rain, consequent reduction in day and night temperature and considerable increase in maximum and minimum relative humidity (at the saturated level during most of the time). The number of fresh infections per standard during the South West monsoon period ranged between 50.98 and 180.73 during 1978 and from 105.40 to 189.50 in 1979.

The fresh infection rate reduced during the monsoon break period in both the years under observation. In 1978, the monsoon break period extended for two fortnights. During this period, the intensity of rain reduced considerably resulting in an increase in day and night temperature and a decrease in the maximum and minimum relative humidity. The number of fresh leaf infection during this fortnight decreased from 93.56 to 61.40 per standard. But in 1979, monsoon break period extended only for a fortnight and the climatic parameters during this period showed the same trend as that of the previous year and the infection was 96.4 per standard.

During the North East monsoon period there were only a few new flushes on pepper vines. In 1978, North East monsoon period prolonged for four fortnights while in 1979, it extended for six fortnights. During this period, in these two years, there was an increased intensity of rain, but average maximum and minimum temperatures had gone up and average maximum and minimum relative humidity decreased compared to the South West monsoon period. These factors resulted in a low rate of fresh infection during both the years under observation and it ranged from 22.00 to 60.54 per standard and 40.00 to 73.00 per standard in 1978 and 1979, respectively.

During the cool dry period, no new flush was produced on the pepper plant and almost all the leaves attained maturity. In the same period there was not much difference in the day temperature as compared to the previous period, while the night temperature was found to be at its lowest. The maximum and minimum relative humidity reduced considerably and reached the minimum of the year. As a result, no fresh infection on the leaves was noticed during this period in both the years under study. During the warm dry period also, no fresh infection was observed. The fresh leaf infection started only from the pre-monsoon period (Table 8 and Fig.6).

The data on fresh leaf infection and the climatic parameters were analysed statistically to find out the influence of the latter on the former.

The number of rainy days, total rainfall and the averages of maximum and minimum relative humidity were significantly and positively correlated with fresh leaf infection. The maximum positive

Table 8. Influence of weather parameters on the incidence of Pollu disease - fresh leaf infection - 1978 and 1979

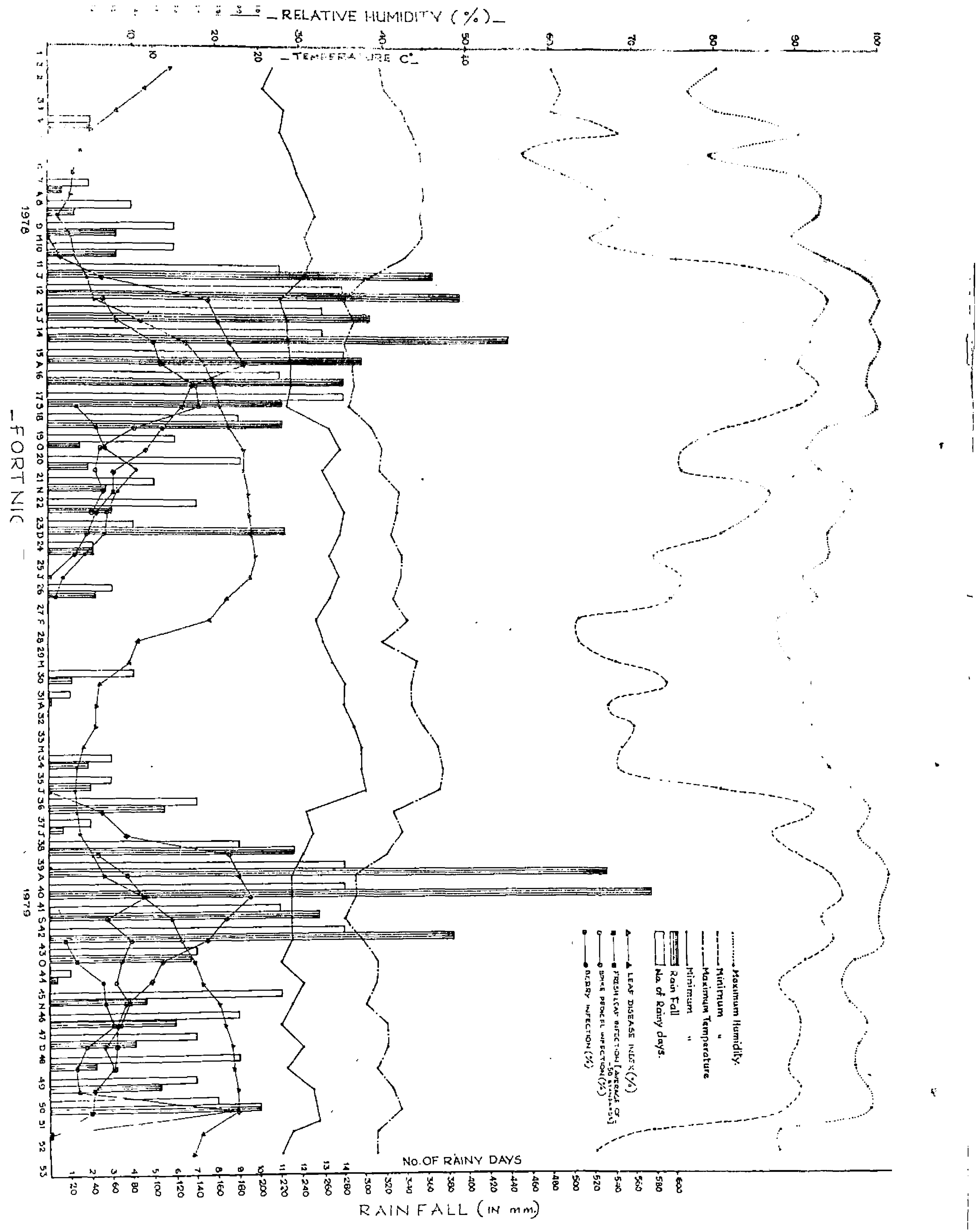
Sl.No. of the fort-nights	Rainfall		Temperature		Relative humidity %		Average No.of fresh infection on leaf per standard
	No.of rainy days	Fall in mm	max.	min.	max.	min.	
1	2	3	4	5	6	7	8
1	-	-	31.7	21.4	79.8	60.2	-
2	-	-	32.0	20.4	76.5	61.0	-
3	-	-	33.6	22.4	80.2	60.1	-
4	2	40.3	34.6	22.1	90.0	68.2	-
5	-	-	35.4	25.2	79.0	66.3	-
6	1	0.4	35.4	25.7	90.0	67.7	--
7	2	14.8	35.7	26.6	92.5	74.0	-
8	2	6.7	35.4	26.3	92.0	70.0	-
9	4	26.4	35.5	26.4	89.0	78.7	-
10	6	66.4	33.5	25.1	93.0	80.1	12.76
11	11	366.2	30.2	24.1	98.0	90.0	50.98
12	14	397.1	28.1	22.2	99.5	93.1	150.23
13	13	307.4	28.8	22.8	98.5	91.7	160.39
14	13	438.6	28.0	22.7	99.5	91.0	170.90
15	14	298.7	28.7	23.1	98.5	89.7	180.73
16	11	280.0	28.8	23.2	98.0	91.9	136.40
17	14	221.4	28.6	22.8	99.0	89.5	127.20
18	9	221.4	30.3	25.5	92.9	81.0	106.20
19	7	30.9	31.6	25.6	90.5	75.4	93.56
20	9	38.8	31.4	25.1	92.0	75.5	61.40
21	5	53.9	33.2	26.1	95.9	76.0	60.54
22	7	61.0	32.8	27.0	95.2	74.5	54.00

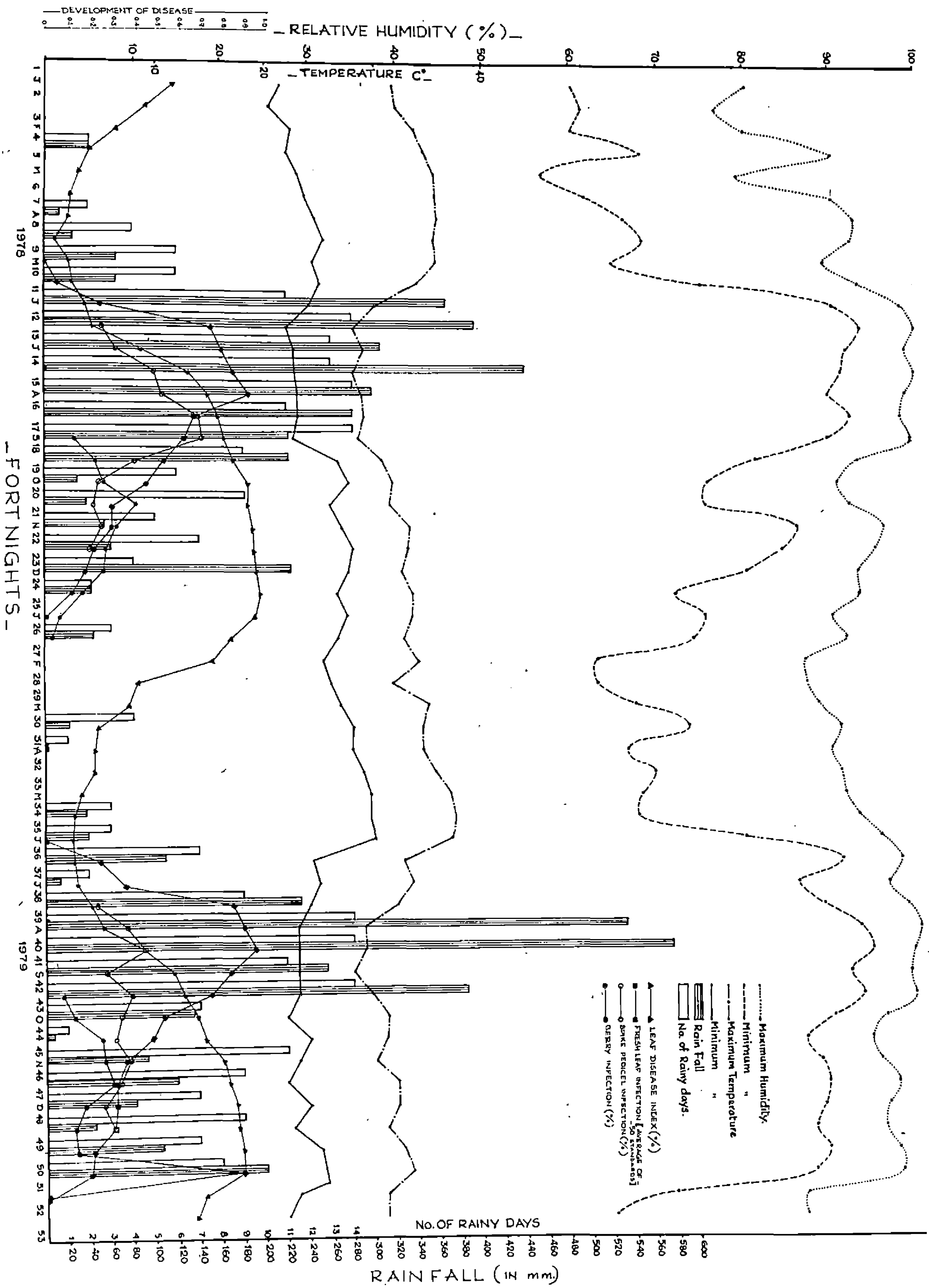
(Continued)

Table 8. (Contd.)

1	2	3	4	5	6	7	8
23	4	224.4	32.5	26.7	93.0	80.7	36.50
24	2	43.1	33.3	26.8	90.0	72.2	22.00
25	-	-	33.3	24.2	90.0	70.5	-
26	3	43.9	32.9	23.8	91.5	74.0	-
27	-	-	31.0	21.4	86.8	63.2	-
28	-	-	31.1	22.8	86.9	63.1	-
29	-	-	32.0	23.0	88.6	67.4	-
30	4	22.0	34.6	26.1	91.0	73.4	-
31	1	3.2	34.5	28.1	90.0	66.5	-
32	-	-	35.6	29.1	91.2	69.6	-
33	-	-	37.0	29.6	91.5	68.0	-
34	3	37.7	37.4	29.6	93.0	69.6	-
35	2	38.8	37.1	30.1	95.6	80.0	-
36	7	111.5	32.6	24.4	98.0	91.0	48.90
37	2	13.6	33.5	25.0	96.7	86.0	71.80
38	9	231.4	32.0	23.0	100.0	93.0	169.90
39	14	532.6	29.0	22.0	99.5	94.5	178.90
40	14	574.5	29.0	22.0	99.0	92.0	189.50
41	11	256.4	28.0	23.0	99.5	93.5	167.20
42	14	385.0	29.7	22.0	96.0	90.0	149.20
43	7	135.2	31.0	23.0	96.0	90.0	105.40
44	1	7.8	31.0	24.0	94.5	87.0	96.40
45	11	92.4	30.0	23.0	95.5	88.5	73.00
46	9	119.7	32.0	23.0	97.5	89.5	65.00
47	7	85.1	32.0	24.0	96.5	89.0	63.00
48	9	43.4	31.0	23.6	96.0	88.0	61.50
49	7	105.8	32.5	25.1	97.5	89.5	41.10
50	8	199.2	33.3	25.5	98.0	88.0	40.00
51	-	-	31.0	23.0	87.0	72.0	-
52	-	-	31.0	22.0	87.0	65.0	-

Fig. 6 Influence of weather paramaters on the incidence of pollu disease - 1978 and 1979.


RELATIVE HUMIDITY (%)
TEMPERATURE C°
No. OF RAINY DAYS
RAINFALL (IN mm)
FORTNIC
1978
1979
Maximum Humidity
Minimum "
Maximum Temperature
Minimum "
Rain Fall
No. of Rainy days.
LEAF DISEASE INDEX (%)
BERRY INFECTION (%)



DEVELOPMENT OF DISEASE
RELATIVE HUMIDITY (%)
TEMPERATURE C°
FORTNIGHTS
1978
1979
No. OF RAINY DAYS
RAIN FALL (IN mm)
Maximum Humidity.
Minimum "
Maximum Temperature
Minimum "
Rain Fall
No. of Rainy days.
LEAF DISEASE INDEX (%)
FRESH LEAF INFECTION [AVERAGE OF 50 STANDARDS]
SPIKE PEDICEL INFECTION (%)
BERRY INFECTION (%)

correlation was found in the case of number of rainy days (0.876) followed by total rainfall (0.844), the averages of maximum relative humidity (0.707) of the fortnight. The averages of maximum and minimum temperature of the fortnight showed significant negative correlation with the fresh leaf infection. Among the temperature parameters, the average of maximum temperature exhibited the maximum negative correlation (-0.776) with fresh leaf infection (Table 9).

Leaf disease index

The disease index of the pepper vine in the field was calculated as described under the materials and methods. The observations were taken from the first fortnight of January 1978 to the end of December, 1979.

In the first fortnight of January 1978, the disease index was 0.580 per cent. During the cool dry period the disease intensity reduced and it was only 0.203 per cent. During this period no fresh infection was noticed. Further, defoliation of infected leaves also occurred. The decrease in

Table 9. Coefficients of simple linear correlation (r) between weather parameters and intensity of fresh leaf infection

	Fresh leaf infection (y_1)	Rainy days (x_1)	Rainfall (x_2)	Maximum temperature (x_3)	Minimum temperature (x_4)	Maximum RH (x_5)	Minimum RH (x_6)
Fresh leaf infection (y_1)	1	0.876*	0.844*	-0.776*	-0.402*	0.707*	0.802*
Rainy days (x_1)		1	0.857*	-0.715*	-0.320*	0.768*	0.831*
Rainfall (x_2)			1	-0.685*	-0.360*	0.651*	0.718*
Maximum temperature (x_3)				1	0.741*	-0.405*	-0.592*
Minimum temperature (x_4)					1	0.050^{NS}	-0.144^{NS}
Maximum RH (x_5)						1	0.915*
Minimum RH (x_6)							1

Weather parameters are recorded as fortnightly averages except for rainy days and rainfall which are the total of the fortnight.

NS = Non significant *Significant at 5 per cent level disease index continued till the end of the warm dry period and it was 0.108 per cent during the first fortnight of May, and no fresh infection was noticed.

The disease index slightly increased during the pre-monsoon period (from 0.108 to 0.125 per cent) due to fresh infection on the new flush.

In the beginning of the South West monsoon season, the disease index was only 0.125 per cent and it reached 0.868 per cent by the end of the South West monsoon period (Table 10). A total of 99 rainy days with 2530.8 mm of rainfall was observed during this period. As a result, a reduction in maximum and minimum temperature and an increase in maximum and minimum relative humidity were recorded.

During the South West monsoon period, pepper vine in the field was in actively growing stage and large number of fresh leaves emerged out. The maximum fresh infection on leaves occurred during this period. The leaf spots enlarged very rapidly. As a result of the above factors, the disease index percentage increased to the maximum (0.868 per cent) during this period.

Table 10. Influence of weather parameters on the progress of disease on leaf indices during 1978 and 1979

Sl.No. of the fort-nights	Rainfall		Temperature		Relative humidity %		Average disease index
	No.of rainy days	Fall in mm	max.	min.	max.	min.	
1	2	3	4	5	6	7	8.
1	-	-	31.7	21.4	79.8	60.2	0.580
2	-	-	32.0	20.4	76.5	61.0	0.462
3	-	-	33.6	22.4	80.2	60.1	0.323
4	2	40.3	34.6	22.1	90.0	68.2	0.203
5	-	-	35.4	25.2	79.0	66.3	0.160
6	1	0.4	35.4	25.7	90.0	67.7	0.123
7	2	14.8	35.7	26.6	92.5	74.0	0.112
8	2	6.7	35.4	26.3	92.0	70.0	0.104
9	4	26.4	35.5	26.4	89.0	78.7	0.108
10	6	66.4	33.5	25.1	93.0	80.1	0.125
11	11	366.2	30.2	24.1	98.0	90.0	0.189
12	14	397.1	28.1	22.2	99.5	93.1	0.219
13	13	307.4	28.8	22.8	98.5	91.7	0.422
14	13	438.6	28.0	22.7	99.5	91.0	0.628
15	14	298.7	28.7	23.1	98.5	89.7	0.738
16	11	280.0	28.8	23.2	98.0	91.9	0.786
17	14	221.4	28.6	22.8	99.0	89.5	0.807
18	9	221.4	30.3	25.5	92.9	81.0	0.868
19	7	30.9	31.6	25.6	90.5	75.4	0.921
20	9	38.8	31.4	25.1	92.0	75.5	0.922
21	5	53.9	33.2	26.1	95.9	76.0	0.943
22	7	61.0	32.8	27.0	95.2	74.5	0.951

(Continued)

Table 10. (Contd.)

1	2	3	4	5	6	7	8
23	4	224.4	32.5	26.7	93.0	80.7	0.962
24	2	43.1	33.3	26.8	90.0	72.2	0.979
25	-	-	33.3	24.2	90.0	70.5	0.945
26	3	43.9	32.9	23.8	91.5	74.0	0.840
27	-	-	31.0	21.4	86.8	63.2	0.762
28	-	-	31.1	22.8	86.9	63.1	0.423
29	-	-	32.0	23.0	88.6	67.4	0.382
30	4	22.0	34.6	26.1	91.0	73.4	0.242
31	1	3.2	34.5	28.1	90.0	66.5	0.223
32	-	-	35.6	29.1	91.2	69.6	0.215
33	-	-	37.0	29.6	91.5	68.0	0.162
34	3	37.7	37.4	29.6	93.0	69.6	0.132
35	2	38.8	37.1	30.1	95.6	80.0	0.120
36	7	111.5	32.6	24.4	98.0	91.0	0.132
37	2	13.6	33.5	25.0	96.7	86.0	0.144
38	9	231.4	32.0	23.0	100.0	93.0	0.204
39	14	532.6	29.0	22.0	99.5	94.5	0.256
40	14	574.5	29.0	22.0	99.0	92.0	0.453
41	11	256.4	28.0	23.0	99.5	93.5	0.578
42	14	385.0	29.7	22.0	96.0	90.0	0.618
43	7	135.2	31.0	23.0	96.0	90.0	0.687
44	1	7.8	31.0	24.0	94.5	87.0	0.724
45	11	92.4	30.0	23.0	95.5	88.5	0.805
46	9	119.7	32.0	23.0	97.5	89.5	0.825
47	7	85.1	32.0	24.0	96.5	89.0	0.857
48	9	43.4	31.0	23.6	96.0	88.0	0.870
49	7	105.8	32.5	25.1	97.5	89.5	0.890
50	8	199.2	33.3	25.5	98.0	88.0	0.892
51	-	-	31.0	23.0	87.0	72.0	0.726
52	-	-	31.0	22.0	87.0	65.0	0.680

This trend of increase in the disease index was also observed during the monsoon break period when the index attained a value of 0.922 from 0.868 recorded during the end of South West monsoon period.

The increase in the disease index during the North East monsoon period was only 0.057 per cent (from 0.922 to 0.979) from the South West monsoon break period. During this period, 18 rainy days were observed with 382.4 mm rainfall. The day and night temperatures during North East monsoon period showed increasing trend and there were fluctuations in the maximum and minimum relative humidity. Some of the heavily infected leaves were shed off but not much fresh leaves emerged out during this period. The slight increase in leaf infection during this period was due to fresh infections and enlargement of already developed leaf spots (Table 9).

From the beginning of the cool dry period, the disease index showed a decreasing tendency due to shedding of infected leaves and absence of fresh infection.

In 1979 also, almost a similar trend in the disease index was observed. During the end of warm dry period in 1979, the disease index was 0.120 compared to 0.104 in 1978. A similar trend was noticed during the pre-monsoon period also.

During the South West monsoon period in 1979 the disease index raised from 0.144 to 0.687 as compared to 0.125 to 0.807 in 1978 season. A similar trend was noticed during the monsoon break period and North East monsoon period also.

SPIKE INFECTION

Pepper usually produces new flushes from pre-monsoon period and new spikes emerge out from these flushes within a fortnight. The number of spike emerged out was maximum during the South West monsoon period and the production of new spikes lasted for about four fortnights. The colour of the newly emerged spikes, before fertilization, was cream yellow. After fertilization it turned pale green. As the berries developed the colour of the entire spike turned green. By the middle of November, the berries attained maturity and became dark green in colour.

Spike of pepper has three components, namely, pedicel, rachis and berries. The pedicel is attached to the rachis and the region will be free of berries. The rachis is a continuation of the pedicel and the berries are attached to the rachis. On the spike three types of infection by the pathogen Colletotrichum gloeosporioides were observed viz., i) pedicel infection, ii) rachis infection and iii) berry infection.

Pedicel infection

Infection on the pedicel of the spike was very common and it resulted in shedding of spike. Generally, the pathogen attacked the pedicels of the tender and young spikes. The colour of the tender spike was cream yellow or light green. The pedicel infection was first observed in the field during the first fortnight of June in both the years. The percentage of spike infected in the first fortnight of June was almost the same in both the years (0.268 per cent in 1978 and 0.232 per cent in 1979). During the peak period of monsoon the infection gradually increased. In 1978, maximum infection (0.714 per cent) was noticed in the second fortnight of August while in 1979 it was in the first fortnight of July (0.450 per cent). In both the years infection of pedicel was noticed till the first fortnight of November and thereafter no infection was observed (Table 11).

The data on the intensity of the pedicel infection and the climatic parameters were statistically analysed to find out the relationship between the weather parameters and the disease incidence. Coefficients of simple correlation between these variables showed that the number of rainy days, total rainfall and average minimum and maximum relative humidity in a fortnight have significant positive correlation with the intensity of pedicel infection. Among these factors maximum positive correlation was found in the case of total number of rainy days in a fortnight (0.738) followed by minimum average relative humidity (0.632), maximum average relative humidity (0.625) and total rainfall (0.513). The intensity of the disease was found to be negatively correlated with the average maximum temperature (-0.673) and average minimum temperature (-0.279) (Table 12).

Table 11. Influence of weather parameters on the incidence of Pollu disease - Spike - pedicel infection-1978 and 79

Sl.No. of the fort-nights	Rainfall		Temperature		Relative humidity %		Infection percentage on spike pedicel
	No.of rainy days	Fall in mm	max.	min.	max.	min.	
1	2	3	4	5	6	7	8
1	-	-	31.7	21.4	79.8	60.2	-
2	-	-	32.0	20.4	76.5	61.0	-
3	-	-	33.6	22.4	80.2	60.1	-
4	2	40.3	34.6	22.1	90.0	68.2	-
5	-	-	35.4	25.2	79.0	66.3	-
6	1	0.4	35.4	25.7	90.0	67.7	-
7	2	14.8	35.7	26.6	92.5	74.0	-
8	2	6.7	35.4	26.3	92.0	70.0	-
9	4	26.4	35.5	26.4	89.0	78.7	-
10	6	66.4	33.5	25.1	93.0	80.1	-
11	11	366.2	30.2	24.1	98.0	90.0	-
12	14	397.1	28.1	22.2	99.5	93.1	0.268
13	13	307.4	28.8	22.8	98.5	91.7	0.327
14	13	438.6	28.0	22.7	99.5	91.0	0.491
15	14	298.7	28.7	23.1	98.5	89.7	0.536
16	11	280.0	28.8	23.2	98.0	91.9	0.699
17	14	221.4	28.6	22.8	99.0	89.5	0.714
18	9	221.4	30.3	25.5	92.9	81.0	0.416
19	7	30.9	31.6	25.6	90.5	75.4	0.253
20	9	38.8	31.4	25.1	92.0	75.5	0.238
21	5	53.9	33.2	26.1	95.9	76.0	0.268
22	7	61.0	32.8	27.0	95.2	74.5	0.208

(Contd.)

Table 11. (Contd.)

1	2	3	4	5	6	7	8
23	4	224.4	32.5	26.7	93.0	80.7	-
24	2	43.1	33.3	26.8	90.0	72.2	-
25	-	-	33.3	24.2	90.0	70.5	-
26	3	43.9	32.9	23.8	91.5	74.0	-
27	-	-	31.0	21.4	86.8	63.2	-
28	-	-	31.1	22.8	86.9	63.1	-
29	-	-	32.0	23.0	88.6	67.4	-
30	4	22.0	34.6	26.1	91.0	73.4	-
31	1	3.2	34.5	28.1	90.0	66.5	-
32	-	-	35.6	29.1	91.2	69.6	-
33	-	-	37.0	29.6	91.5	68.0	-
34	3	37.7	37.4	29.6	93.0	69.6	-
35	2	38.8	37.1	30.1	95.6	80.0	-
36	7	111.5	32.6	24.4	98.0	91.0	-
37	2	13.6	33.5	25.0	96.7	86.0	-
38	9	231.4	32.0	23.0	100.0	93.0	0.232
39	14	532.6	29.0	22.0	99.5	94.5	0.377
40	14	574.5	29.0	22.0	99.0	92.0	0.450
41	11	256.4	28.0	23.0	99.5	93.5	0.275
42	14	385.0	29.7	22.0	96.0	90.0	0.391
43	7	135.2	31.0	23.0	96.0	90.0	0.348
44	1	7.8	31.0	24.0	94.5	87.0	0.319
45	11	92.4	30.0	23.0	95.5	88.5	0.377
46	9	119.7	32.0	23.0	97.5	89.5	0.333
47	7	85.1	32.0	24.0	96.5	89.0	0.261
48	9	43.4	31.0	23.6	96.0	88.0	0.304
49	7	105.8	32.5	25.1	97.5	89.5	-
50	8	199.2	33.3	25.5	98.0	88.0	-
51	-	-	31.0	23.0	87.0	72.0	-
52	-	-	31.0	22.0	87.0	65.0	-

Table 12. Coefficients of simple linear correlation (r) between weather parameters and intensity of spike pedicel infection

	Spike pedicel infection (y_1)	Rainy days (x_1)	Rainfall (x_2)	Maximum temperature (x_3)	Minimum temperature (x_4)	Maximum RH (x_5)	Minimum RH (x_6)
Spike Pedicel infection (y_1)	1	0.738*	0.513*	-0.673*	-0.279	0.625*	0.632*
Rainy days (x_1)		1	0.820*	-0.690*	-0.241*	0.857*	0.839*
Rainfall (x_2)			1	-0.685*	-0.342*	0.732*	0.727*
Maximum temperature (x_3)				1	0.642*	-0.473*	-0.540*
Minimum temperature (x_4)					1	-0.110^{NS}	-0.209^{NS}
Maximum RH (x_5)						1	0.941*
Minimum RH (x_6)							1

Weather parameters are recorded as fortnightly averages except for rainy days and rainfall which are the total of the fortnight.

NS = Non significant

* Significant at 5 per cent level

Rachis infection

The pathogen may attack any portion of the rachis and the berries may get dried downwards from the infected portion of the thread. The dried berries seldom get detached from the infected rachis. This type of infection was found to be negligible and hence not recorded.

Berry infection

The pathogen attacked both immature and mature berries but never tender berries. The infected berries got discoloured and dried but did not shed from the spike. This type of infection was very common. In both the years under observation berry infection started after July when most of the berries passed tender stage.

In 1978, the infection on berries started from the second fortnight of August when 0.137 per cent infection was noticed. But in 1979 the infection commenced early (first fortnight of August) and then only 0.071 per cent infection was noticed. The infection on berries increased and the maximum infection (0.729 per cent) was noticed in the first fortnight of November in 1978 and (0.911 per cent) in the second fortnight of November in 1979. During these years maximum infection was observed on mature berries. In the year 1978, the infection on berries was observed even at the end of December, but in 1979 no infection of berries was noticed during December. In 1978, there was some rain in the second fortnight of December and due to this the maximum and minimum relative humidity increased and the infection prolonged till the end of December. But in 1979, there was absolutely no rain in December and consequently no fresh infection was observed during this month (Table 13).

FUNGICIDAL STUDIES

Bioassay studies

The efficacy of seven fungicides was evaluated in the laboratory against Colletotrichum gloeosporioides by poison food technique (Zentmeyer, 1955). All the fungicides except Bordeaux mixture were tested at varying concentrations ranging from 100 to 2000 ppm as described under Materials and Methods. Bordeaux mixture was tested at 10,000 ppm only.

Table 13. Influence of weather parameters on the incidence of Pollu disease - Berry infection - 1978 and 1979

Sl.No. of the fort-nights	Rainfall		Temperature		Relative humidity %		Infection percentage on berry
	No.of rainy days	Fall in mm	max.	min.	max.	min.	
1	2	3	4	5	6	7	8
1	-	-	31.7	21.4	79.8	60.2	-
2	-	-	32.0	20.4	76.5	61.0	-
3	-	-	33.6	22.4	80.2	60.1	-
4	2	40.3	34.6	22.1	90.0	68.2	-
5	-	-	35.4	25.2	79.0	66.3	-
6	1	0.4	35.4	25.7	90.0	67.7	-
7	2	14.8	35.7	26.6	92.5	74.0	-
8	2	6.7	35.4	26.3	92.0	70.0	-
9	4	26.4	35.5	26.4	89.0	78.7	-
10	6	66.4	33.5	25.1	93.0	80.1	-
11	11	366.2	30.2	24.1	98.0	90.0	-
12	14	397.1	28.1	22.2	99.5	93.1	-
13	13	307.4	28.8	22.8	98.5	91.7	-
14	13	438.6	28.0	22.7	99.5	91.0	-
15	14	298.7	28.7	23.1	98.5	89.7	-
16	11	280.0	28.8	23.2	98.0	91.9	-
17	14	221.4	28.6	22.8	99.0	89.5	0.137
18	9	221.4	30.3	25.5	92.9	81.0	0.230
19	7	30.9	31.6	25.6	90.5	75.4	0.269
20	9	38.8	31.4	25.1	92.0	75.5	0.415
21	5	53.9	33.2	26.1	95.9	76.0	0.325
22	7	61.0	32.8	27.0	95.2	74.5	0.282

(Contd.)

Table 13. (Contd.)

1	2	3	4	5	6	7	8
23	4	224.4	32.5	26.7	93.0	80.7	0.729
24	2	43.1	33.3	26.8	90.0	72.2	0.171
25	-	-	33.3	24.2	90.0	70.5	0.069
26	3	43.9	32.9	23.8	91.5	74.0	0.036
27	-	-	31.0	21.4	86.8	63.2	-
28	-	-	31.1	22.8	86.9	63.1	-
29	-	-	32.0	23.0	88.6	67.4	-
30	4	22.0	34.6	26.1	91.0	73.4	-
31	1	3.2	34.5	28.1	90.0	66.5	-
32	-	-	35.6	29.1	91.2	69.6	-
33	-	-	37.0	29.6	91.5	68.0	-
34	3	37.7	37.4	29.6	93.0	69.6	-
35	2	38.8	37.1	30.1	95.6	80.0	-
36	7	111.5	32.6	24.4	98.0	91.0	-
37	2	13.6	33.5	25.0	96.7	86.0	-
38	9	231.4	32.0	23.0	100.0	93.0	-
39	14	532.6	29.0	22.0	99.5	94.5	-
40	14	574.5	29.0	22.0	99.0	92.0	-
41	11	256.4	28.0	23.0	99.5	93.5	-
42	14	385.0	29.7	22.0	96.0	90.0	0.071
43	7	135.2	31.0	23.0	96.0	90.0	0.128
44	1	7.8	31.0	24.0	94.5	87.0	0.255
45	11	92.4	30.0	23.0	95.5	88.5	0.262
46	9	119.7	32.0	23.0	97.5	89.5	0.300
47	7	85.1	32.0	24.0	96.5	89.0	0.169
48	9	43.4	31.0	23.6	96.0	88.0	0.119
49	7	105.8	32.5	25.1	97.5	89.5	0.138
50	8	199.2	33.3	25.5	98.0	88.0	0.911
51	-	-	31.0	23.0	87.0	72.0	-
52	-	-	31.0	22.0	87.0	65.0	-

C. gloeosporioides took eight days to completely cover a petridish of 90 mm diameter in the untreated check. The percentage of inhibition was calculated based on the growth of the fungus on the 8th day in different treatments. The inhibition of the growth of the fungus varied in different concentrations of different fungicides (Table 14).

Among the fungicides tried at 100 ppm, Difolatan induced the maximum inhibition (90.10 per cent) followed by Bayleton (73.26 per cent) and Antracol (69.90 per cent). All other fungicides showed only less than 40 per cent inhibition.

In the next highest concentration tried (250 ppm), the maximum inhibition of the growth was observed in Difolatan (92.43 per cent) followed by Bayleton (91.0 per cent) and Antracol (76.23 per cent). All other fungicides tried at this concentration showed less than 50 per cent inhibition. The least inhibition was noticed in Fycop (25.43 per cent).

At 500 ppm concentration, maximum inhibition of growth (94.2 per cent) was observed in Bayleton followed by Difolatan (93.23 per cent) and Antracol

Table 14. Per cent of inhibition in growth of <u>Colletotrichum gloeosporioides</u> by poison food technique with seven fungicides in different concentrations after eight days incubation.

Sl. No.	Fungicide	Concentrations in ppm					
		100 (A)	250 (B)	500 (C)	1000 (D)	2000 (E)	Means
1	Antracol	69.90 (56.73)	76.23 (60.82)	85.20 (67.38)	87.60 (69.39)	100.00 (90.00)	83.78 (68.86)
2	Bayleton	73.26 (58.65)	91.00 (72.80)	94.20 (76.06)	95.40 (77.64)	100.00 (90.00)	90.77 (75.03)
3	Fycop	14.43 (22.32)	25.43 (30.28)	38.23 (38.19)	45.76 (42.38)	75.20 (60.13)	39.81 (38.66)
4	Difolatan	90.10 (71.74)	92.43 (74.03)	93.23 (74.92)	93.56 (75.32)	100.00 (90.00)	93.86 (77.20)
5	Dithane Z - 78	30.86 (33.75)	36.03 (36.88)	43.03 (40.99)	55.56 (48.19)	75.03 (70.02)	48.10 (43.96)
6	Ziride	36.20 (36.98)	42.63 (40.76)	55.46 (48.13)	75.32 (60.20)	86.46 (68.42)	59.21 (50.89)
7	Bordeaux mixture 1%						100.00 (90.00)

(Figures given in parantheses are angular transformed values)

CD (0.05) between fungicides excluding B.M. = 0.441

CD (0.05) for comparing B.M. with other fungicides = 0.761

CD (0.05) between concentrations within fungicides = 0.9879

Conclusions

1. Comparison of fungicides

7 4 2 1 6 5 3

2. Comparison of concentrations

Difolatan	E	D	C	B	A	Ziride	E	D	C	B	A
Bayleton	E	D	C	B	A	Dithane Z-78	E	D	C	B	A
Antracol	E	D	C	B	A	Fycop	E	D	C	B	A

(85.20 per cent). All other fungicides tested at this concentration gave only less than 60 per cent inhibition of growth.

At 1000 ppm strength, none of the fungicides gave 100 per cent inhibition. The maximum inhibition (95.4 per cent) was observed in the case of Bayleton followed by Difolatan (93.56 per cent) and Antracol (87.6 per cent). All other fungicides, gave less than 80 per cent inhibition.

At the highest concentration of 2000 ppm, 100 per cent inhibition was noticed in Antracol, Bayleton and Difolatan. All other fungicides gave more than 60 per cent inhibition.

Bordeaux mixture was tried only at one per cent concentration. At this concentration, the growth of C.gloeosporioides was completely inhibited.

On comparing the efficacy of different fungicides, one per cent Bordeaux mixture was found to be the best followed by Difolatan, Bayleton and Antracol.

A comparison of the effect of different concentration under each fungicide showed that of the highest concentration tried was superior. There were significant difference at the different concentrations of fungicides inhibiting the growth of *Colletotrichum gloeosporioides.*

Difolatan at 1000 ppm concentration was found to be on par with 500 ppm and 500 ppm was found to be on par with 250 ppm in inhibiting the growth. All other fungicides were significantly different in efficacy at different concentrations tried and efficacy of fungicides increased with increasing concentration (Table 14).

In general the effect of Difolatan at two nearest concentrations tried was on par while there was significant difference between the effect of alternate concentrations.

Field studies

Of the seven fungicides tested *in vitro*, only four fungicides were found to give more than 60 per cent inhibition of growth. These fungicides

(Antracol, Bayleton, Bordeaux mixture and Difolatan) were used in the field trials.

The intensity of the disease on the leaf before the fungicidal spray ranged from 0.450 to 0.462 per cent and the difference was not satistically significant (Table 15 and 16).

The first fungicidal spray was given in the first fortnight of July 1979. The intensity of the disease on leaf, one month after the first spray, was found to be maximum in the untreated check (0.616 per cent) and minimum in plots which received one per cent Bordeaux mixture (0.586 per cent). Bordeaux mixture was found to be on par with Bayleton. Bayleton, Antracol and Difolatan were on par. Antracol and Difolatan, in turn, were found to be on par with the untreated check (Table 15 and 16).

The shedding of spikes due to C.gloeosporioides during the period between the first and second fungicidal sprays was 0.310 per cent in untreated check and the minimum was in the Difolatan as well as Antracol treated plots (0.041 per cent). All other fungicide treated plots showed a reduced per cent of

Table 15. Comparative efficacy of different fungicides in the control of 'Pollu' disease of pepper

Treatments	Disease index in per cent at different intervals of time				
	Pre-spraying	1 month after 1st spray	1 month after 2nd spray	1 month after 3rd spray	Pooled data of three sprayings
Antracol 0.1%	0.451	0.602	0.697	0.759	0.690
Bayleton 0.1%	0.462	0.595	0.682	0.735	0.670
Bordeaux mixture 1.0%	0.450	0.586	0.647	0.682	0.640
Difolatan 0.2%	0.459	0.599	0.674	0.723	0.670
Control	0.450	0.616	0.728	0.813	0.720

Table 16. Comparative efficacy of different fungicides in the control of 'Pollu' disease of pepper

		Result of statistical analysis				
Period of observation	CD	Conclusion				
1st observation (pre-spraying)	NS	T_5	T_3	T_1	T_4	T_2
2nd Observation one month after first spraying	0.059	T_3	T_2	T_1	T_4	T_5
3rd Observation (one month after 2nd spraying)	0.038	T_3	T_4	T_2	T_1	T_5
4th Observation (one month after 3rd spraying)	0.045	T_3	T_4	T_2	T_1	T_5
Pooled analysis	0.196	T_3	T_4	T_2	T_1	T_5

T_1 = Antracol

T_2 = Bayleton

T_3 = Bordeaux mixture

T_4 = Difolatan

T_5 = Control

infection (0.110 per cent for Bordeaux mixture and 0.12 per cent for Bayleton) (Table 17 and Fig.7).

The second spray was given one month after the first spray and the disease index on leaf was recorded one month after the second spray. Here also, the maximum disease intensity was noted in the untreated check (0.728 per cent) and the minimum in the Bordeaux mixture treated plots (0.647 per cent). Difolatan (0.674 per cent), Bayleton (0.682 per cent) and Antracol (0.697 per cent) were found to be on par and significantly superior to untreated check (Table 15 and 16).

The observation on spike shedding during the period showed that there was no shedding in Bayleton and Bordeaux mixture treated plots. Difolatan and Antracol treated plots had an average of 0.041 per cent shedding. The maximum shedding was observed in the untreated check (0.201 per cent) (Table 17).

The third spraying was given one month after the second spray and the observation one month after the third spray showed minimum intensity of the disease on the leaf in the Bordeaux mixture treated

Table 17. Effect of fungicides against spike shedding and berry infection due to 'Pollu' disease of pepper

Sl. No.	Treatments	Percentage of spike shedding				Per cent of berry infection after harvest
		Within 1 month after 1st spray	Within 1 month after 2nd spray	Within 1 month after 3rd spray	Averages	
1	Antracol 0.1%	0.043	0.043	0.073	0.053	0.35
2	Bayleton 0.1%	0.123	0.00	0.100	0.074	0.52
3	Bordeaux mixture 1.0%	0.110	0.00	0.00	0.036	0.00
4	Difolatan 0.2%	0.041	0.041	0.00	0.027	0.01
5	Control	0.310	0.201	0.265	0.258	0.82

Comparative efficacy of different fungicides in the control of pollu disease of pepper.

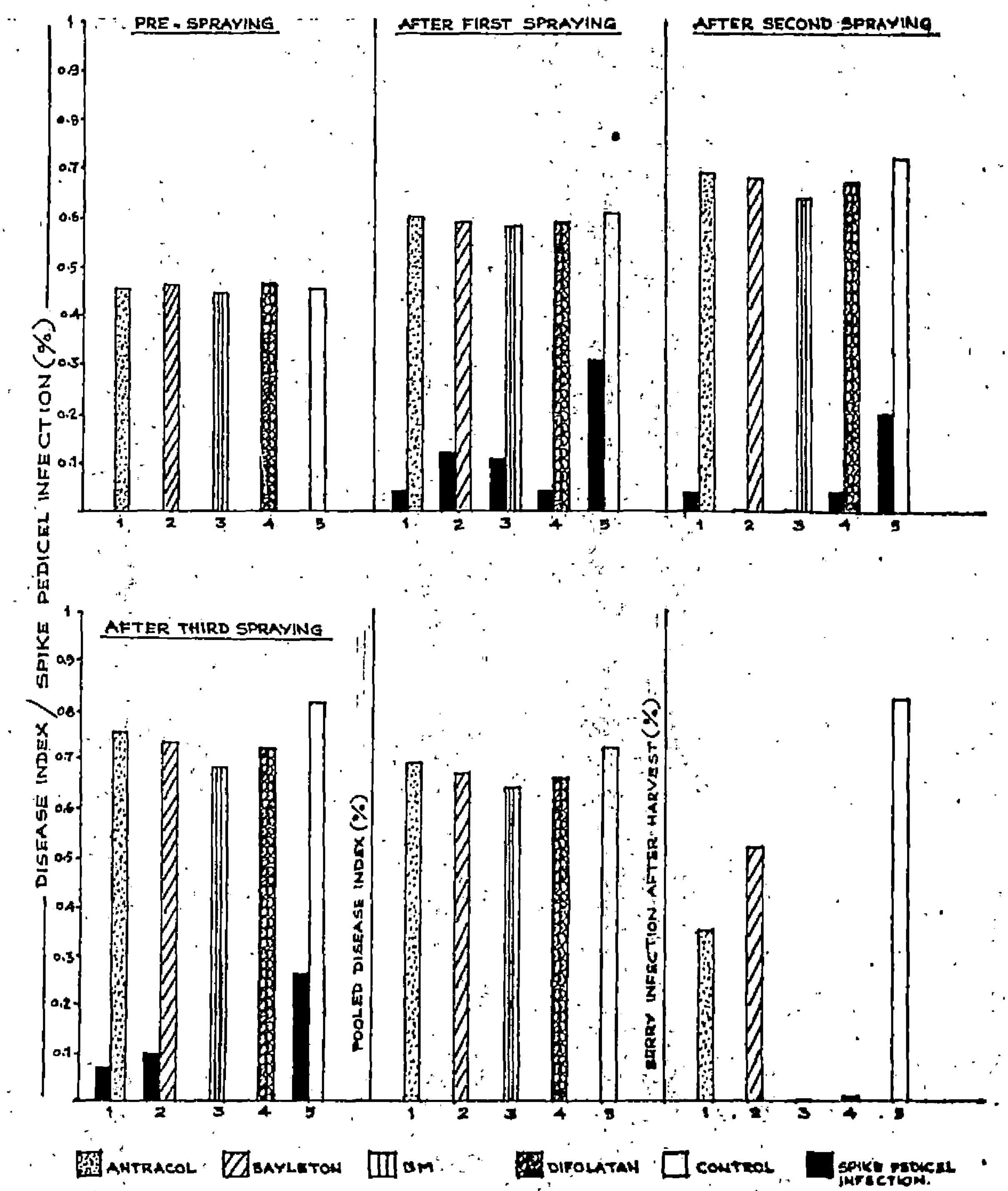


Fig.7

plots (0.682 per cent) followed by Difolatan (0.723 per cent), Bayleton (0.735 per cent) and Antracol (0.759 per cent). The maximum (0.813 per cent) intensity of the disease was observed in the untreated check (Table 15).

Statistical analysis of the data revealed that the differences in disease intensity between the fungicide treated plots and untreated plot were statistically significant. Among the fungicidal treatments, one per cent Bordeaux mixture was found to be superior to all other treatments followed by Difolatan which was on par with Bayleton (Table 16).

After the third spraying, no spike shedding was observed in plots which received Bordeaux mixture and Difolatan. However, the Bayleton treated plots which showed no spike shedding after the second spray, showed very low incidence of the disease and the spike shedding was only 0.100 per cent. The incidence of the spike shedding in the Antracol treated plots during this period was very less compared to the Bayleton treated plots and it was only 0.073 per cent. The maximum shedding due to infection was in the untreated check (Table 17).

The pooled analysis of the data on the intensity of disease on leaf revealed that the intensity of leaf infection was maximum in the untreated check plot (0.72 per cent) and minimum in the plot which received Bordeaux mixture (0.64 per cent) followed by Difolatan (0.67 per cent), Bayleton (0.67 per cent) and Antracol (0.69 per cent) treated plots.

The statistical analysis of the data showed that all fungicidal treatments reduced the intensity of leaf infection. One per cent Bordeaux mixture was found to be superior to all. Difolatan was found to be on par with Bayleton. Among the fungicide treated plots the maximum disease intensity was observed in the plot treated with Antracol (Table 16 Fig.7).

Observation on berry infection was taken after the harvest. Maximum berry infection was seen in the untreated check (0.82 per cent) followed by Bayleton (0.52 per cent), Antracol (0.35 per cent) and Difolatan (0.01 per cent) treated plots. There was no berry infection in the Bordeaux mixture treated plot (Table 17).

Effect of fungicidal treatment on the yield of pepper

The yield data showed that the maximum average yield of green pepper was observed in Bordeaux mixture treated plot which gave 2.783 kg per plot followed by Difolatan treated plot (2.749 kg/plot). The minimum yield was recorded in the untreated control plot (2.560 kg/plot). Influence of the fungicides on the increase in yield was not significant, eventhough there were slight increases over the control (Table 18).

Table 18. Effect of fungicidal treatment on the intensity of 'Pollu' disease and yield of pepper

Sl. No.	Treatments	On leaf		Spike shedding due to pedicel infection		Yield	
		Overall increase in disease index (per cent)	Per cent decrease over control	Total (per cent)	Per cent decrease over control	Average kg/plant	Per cent increase over control
1	Antracol 0.1%	0.308	0.055	0.159	0.617	2.650	3.515
2	Bayleton 0. .1%	0.273	0.090	0.223	0.553	2.674	4.450
3	Bordeaux mixture 1%	0.232	0.131	0.110	0.666	2.783	8.710
4	Difolatan 0.2%	0.264	0.099	0.082	0.694	2.749	7.380
5	Control	0.363	-	0.776	-	2.560	-

Discussion

DISCUSSION

The climate of the Horticultural College farm where the present investigation was carried out was typically monsoonic, there being two monsoons i.e., South West monsoon (June to August) and the North East monsoon (September to November). The high temperature of dry summer of the tropics was not experienced in this area since South West monsoon was active during that period. The maximum and minimum fortnightly average temperatures recorded during the two years under observation were 37.4°C and 20.4°C respectively. The relative humidity was always very high during the major part of the year. A critical analysis of climatic pattern of this area revealed six well distinct periods in a year namely, (1) Warm dry period (2) Pre-monsoon period (3) South West Monsoon period (4) Monsoon break period (5) North East monsoon period and (6) Cool dry period. Cheeran (1974) also observed similar climatic pattern in the moist forest of the Western Ghats. These six periods were made distinctly different by variations in rainfall, temperature and relative humidity. The succession of the season in this area completely depended upon rainfall and the six seasons remained constant from year to year though marginal shifts in the time of occurrence took place. In contrast to other parts of the country, the four well defined seasons namely, summer, autumn, spring and winter are not seen in this area.

The warm dry period is the hottest period of the year and it extends usually from middle of February to first fortnight of May. The highest temperatures of day and night of the year were recorded during this period, which ranged from 35.5°C to 37.4°C in a day and 23.2°C and 29.6°C at night. Unlike other parts of the country the relative humidity was found to be high and it varied from 76.5 to 95.6 in the morning and 66.3 to 80.0 per cent in the afternoon. A few summer showers were also obtained during this period and the number of rainy days and intensity of the rain varied year after year (Table 2 and Fig.2).

The pre-monsoon period is very pronounced with intermittent rains. There was gradual reduction in the day and night temperatures and an increase in the relative humidity, both maximum and minimum compared to that of the warm dry period (Table 3).

The South West monsoon period usually starts from June and extends upto the end of August with heavy and continuous rainfall. This period is characterised by cloudy skies and moist atmosphere. The day and night temperatures come down and the relative humidity reaches to saturation level in almost all days, there being little difference in mornings and afternoons. This period can be designated as the cool wet period of the year (Table 4 and Fig.3).

The monsoon break period lasts for one or two fortnights after the South West monsoon. During this period there were only a few showers. The temperature showed slight increase and there was marked variation in the relative humidity compared to the South West monsoon period. This period was the beginning of the warm moist period (Table 5).

The North East monsoon period usually starts in the second fortnight of September and extends upto the last fortnight of November. This monsoon sometimes brings heavy showers to this area and there is a great deal of variation in rainfall from year to year. Unlike the South West monsoon the absence of continuous showers is particularly conspicuous during this period.

The day and night temperatures showed a further increase and the relative humidity varied widely. This period can be designated as the warm moist period of the year (Table 6 and Fig.4).

The cool dry period usually starts from the first fortnight of December and extends upto the first fortnight of February. The main features of this period are low day and night temperatures and a very low relative humidity. This period is dry and cool when compared to other periods of the year (Table 7 and Fig.5).

The climate has a marked influence on the growth of pepper vine and production of pepper. The change in the weather brings about a corresponding change in the growth pattern. The chief features of the warm dry season were shedding of senescent leaves and lack of new growth of the vines. Due to the intermittent rain in the pre-monsoon period, the soil moisture increased and new flushes appeared.

At the beginning of the South West monsoon new flushes appeared from the laterals which carried the flowers. The fertilization of the flowers and the development of the spike take place during the South West monsoon period. During this period large number of physiologically active leaves could be observed on pepper vines. The fertilization of the flowers mainly depends upon the intensity and distribution of the rain during South West monsoon. Berry development occurs during the monsoon break period as well as the North East monsoon period and maximum number of mature leaves could be seen during this period.

During the cool dry period the berries get matured and start ripening. This is the time for the harvest. By the end of cool dry period the soil moisture status is very low and further growth of the pepper plant is checked and almost all the leaves become fully matured.

The "fungal pollu" is an important disease of pepper causing considerable damage. Rao (1926) estimated the loss of produce due to the disease as 0.5 to 13.0 per cent and Krishna Menon (1949) reported the loss as three to ten per cent. The disease is observed in almost all pepper growing tracts of the world. Apart from the spike, the pathogen also attacks the leaves and tender shoots.

The pathogen causing this disease was first reported by Rao (1926) as C.necator and later almost all workers used the same name for Colletotrichum isolated from Piper nigrum. Vinukatananda and Celino (1940) correctly named the pathogen as the imperfect stage of Glomerella cingulata. Later Mei (1956) reported that Glomerella cingulata was responsible for anthracnose of pepper in Ceylon. However, the perfect stage of the pathogen has not been reported from India on pepper.

Arx (1957) made a detailed study of the genus Colletotrichum and he clearly established that all straight spored Colletotrichum spp. are the imperfect stage of Glomerella cingulata. He grouped about 600 species of Colletotrichum into a single species and used the name Colletotrichum gloeosporioides. One among the 600 species listed by Von Arx (1957) was C. necator.

In the present study also the pathogen causing the disease is a straight spored Colletotrichum sp.

Thus the correct name of the pathogen causing anthracnose should be Colletotrichum gloeosporioides, the imperfect stage of Glomerella cingulata (Stonem) Spauld and Schrenk.

The symptoms of the disease, appeared on different parts of the pepper vine, were described by earlier workers (Rao, 1926; Thomas and Menon, 1939; Vinukatananda and Celino, 1940 and Krishna Menon, 1949). However, none of the earlier workers made a detailed study of the disease syndrome. On all aerial parts of the plants, the initial symptom observed on the infection court was a chlorotic speck. This turned to dark brown in colour within two days. The final stages of the symptom on leaves observed in the present study are similar to that observed by earlier workers (Thomas and Menon, 1939 and Krishna Menon, 1949).

The expression of symptom on leaves varies according to the climatic factors prevalent at the time of infection and spread of the disease. Under dry conditions, when rainfall and relative humidity were low, the development of necrotic area on the leaf was very slow and a definite dark coloured raised margin was observed around the plesionecrotic area. Krishna Menon (1949) recorded similar symptoms on pepper leaves. Under humid moist conditions the leaf spot enlarged very quickly and there was no definite margin around the plesionecrotic area. The holonecrotic area was surrounded by a dark coloured plesionecrotic area which in turn was surrounded by a bright yellow halo. Under this condition the infected leaves shed within fifteen days. Vinukatananda and Celino (1940) observed this type of symptom development under humid conditions but they didnot observe defoliation. The yellow halo around the plesionecrotic area is an indication that some diffusible toxic metabolite is produced in the host tissue either by the pathogen or by the host pathogen interaction. Similar observations were also made by many other workers on leaf spotting fungi. Alternaria blight of tomato and potato plants caused by Alternaria solani Sorauer blast of rice caused by Pyricularia oryzae Cav. anthracnose of Digitalis spp. caused by Glomerella cingulata (Colletotrichum fuscum) are examples for this type of halo formation.

Eventhough many workers have reported the death of the shoot and vines by the fungal infection, none of the workers have described the symptoms in detail. On shoot and vines typical anthracnose symptoms were observed on the young plants.

Detailed symptoms, when the pathogen attacks on the pedical of the spike, have not been reported by earlier workers. However, Thomas and Menon (1939) and Krishna Menon (1949) noticed rotting of the pedicel due to the attack by the pathogen resulting in shedding of the spike. In the present investigation it was clearly observed that in the shedding of the spike due to the attack of the pathogen there was complete rotting of the basal end of the pedicel. When the shedding was due to the physiological factors, callus formation was observed on this end of the pedicel.

The symptoms observed on mature and immature berries as a result of infection are different. In both the cases the affected berries did not shed. When the young berries were attacked, the initial symptom was a chlorotic speck which turned dark brown in colour within a few days. Later, these berries shrivelled and dried. On mature berries, the initial symptom and further development were almost the same as that observed in immature berries but the rind of the berries became pulpy in some cases and it cracked in others. Thomas and Menon (1939) and Krishna Menon (1949) also observed similar type of symptom development on berries but did not describe the appearance of symptom at different stages.

During the present investigation the infection on the rachis of the spike was also observed. This type of infection was not observed by the earlier workers. As a result of the infection on the rachis all the berries below the infected portion dried and became dark coloured. The weight and quality of such dried berries depended on the stage of the spike at which the fungus infected the berries. When the berries were infected during the early stages of the development complete shrivelling and drying took place and there was maximum reduction in the pungency.

The pathogen, host and environmental conditions are the major factors which influence the epidemiology of the disease (Miller, 1953). Thus three very important factors, i.e., susceptible plants in a vulnerable stage, disease causing organism in a virulent stage and favourable environmental conditions acted in harmony for the establishment of the disease. It has been proved that C.gloeosporioides (Penz) Sacc. was the casual organism of the disease. Some workers also reported about the same organism causing anthracnose disease of pepper (Thomas and Menon, 1939; Nambiar et al., 1978).

The source of primary infection was not studied in the present investigation. It is persumed that the primary source of infection might have been from the infected leaves which was retained in the crop during the last seasons or from the spores that developed on dead fallen leaves.

From the present investigation it has been observed that the fresh infection of the year started during the pre-monsoon period. In both the years i.e., 1978 and 1979, there were good pre-monsoon showers and new flushes appeared during this period. After a few pre-monsoon showers sufficient spores might have been developed on the infected older leaves or on the infected fallen leaves. By this time, the new flushes became physiologically active and new infection initiated even though the infection rate was low. This period was noticed in both the years under observation. The infection rate increased suddenly during the cool moist period and this reached the maximum when the South West monsoon period became active. However, there was a decrease in the rate of fresh infection after the second fortnight of July in 1978 and first fortnight of July in 1979 when the monsoon slightly subsided (Table 8 and Fig.6).

During the South West monsoon period there was rain almost every day in both the years and consequently there was sudden fall in the maximum and minimum temperatures and increase in relative humidity. It is a well established fact that most foliicolous fungi favour cool moist environment for germination, penetration and establishment (Clayton, 1942; Kaiser and Lukezic, 1966; Cochrane, 1960). The above observations have been found very significant in the present study and the pathogen, Colletotrichum gloeosporioides infected the pepper leaves in these conditions. Maximum infection on the leaves of pepper vine was observed during the cool moist period of the year (Table 8 and Fig.6). This period also coincided with the maximum number of mature and physiologically active leaves, the ideal stage for infection. From the above facts it can be clearly established that the South West monsoon period is the most congenial time for the maximum fresh infection on leaves. This is due to the facts that the pepper leaves were in the most vulnerable stage, and the cool moist condition prevailing in that period.

The leaf infection rate reduced during the monsoon break period and North East monsoon period. There was no fresh infection after the North East monsoon period.

After the South West monsoon period, there were changes in the climatic parameters viz., reduction in the number of rainy days, total rainfall, maximum and minimum relative humidity and an increase in the maximum and minimum temperature. These resulted in a warm moist condition during the North East monsoon period. This may be the reason for reduction in the rate of fresh infection eventhough the susceptible host in a vulnerable stage and the disease causing pathogen in an infective stage are present (Table 8 and Fig.6). It clearly indicates that the stage of the host and the pathogen are not the only factors which decide rate of fresh infection but favourable weather factors are also equally important.

There was no fresh infection after the North East monsoon because there was no rain during the cool dry period and warm dry period except a few summer showers.

From the above factors it can be reasonably assumed that rainfall is the pre-requisite factor for the fresh infection. The importance of rainfall and rainy days for infection and spread of the disease caused by the same pathogen on different crops had been worked out by early workers (Singh and Prasad, 1967 on Dioscorea; Wastie, 1972 on Rubber; Denhan and Waller 1981, on Citrus). The present findings strengthen the findings of the earlier workers.

Among the environmental factors, the number of rainy days and total rainfall and averages of maximum and minimum humidity of that fortnight have significant positive correlation with the degree of fresh infection (Table 9). It is interesting to note that the maximum positive correlation was observed in the case of rainy days. The averages of maximum and minimum temperature of that fortnight have shown negative correlation with the fresh leaf infection. Similar observation has been made by many other workers (Ocfemia and Agati, 1925; Roy, 1948; Togashi, 1949; Krishna Menon, 1949; Kaiser and Lukezic, 1966; Singh and Prasad, 1967; and Wastie, 1972) who have worked on the infection pattern of *Colletotrichum gloeosporioides* in different crop plants including *Piper nigrum*.

The disease index of anthracnose of pepper was calculated based on the leaf infection. The infection on other parts of the plant was not considered for calculating the disease index because the infected parts get detached from the plant soon after the infection and hence the expression of the syndrome of the disease on these parts was not possible. Since the pathogen was perennial it was easy to record the intensity of the disease on leaf throughout the year. The minimum intensity of the disease was observed during the warm dry period (summer month) of the year. This may be due to the fact that there was no fresh infection during that period and the leaves which had taken infection during the wet period became senescent and most of the infected leaves shed off (Table 10 and Fig.6). During the pre-monsoon period there were a few rains with subsequent increase in humidity. Due to the above facts, there was an increase in the size and development of the existing leaf spot by which a slight increase in disease index was noticed (Table 10 and Fig.6).

During the cool moist period, there was an increase in the number of physiologically active leaves and the number of fresh infection considerably increased and some of the leaves showed necrotic spots. Due to this fact the disease index increased in this period.

The maximum disease index in both the years under observation was noticed during the warm moist period of the year. The reason for the maximum disease index was that a large number of leaves became mature and all the leaves which had taken infection during the South West monsoon period developed large necrotic area on the leaves. Most of the leaves which had shown large necrotic area were retained in the vines itself and very few infected leaves were fallen off. This resulted cumulative effect on the disease index (Table 10 and Fig.6).

During the cool dry period, the disease index slowly came down. This is due to the fact that when the atmosphere became dry the development of necrotic area on the leaves was restricted and all the leaves which had shown large necrotic area became senescent and were shed. Thus the number of infected leaves on the vine and the number of necrotic area on the leaves became small, which reduced the disease index (Table 10 and Fig.6).

The observations on the pattern of infection and disease development for the two years clearly showed that the pathogen C. gloeosporioides favours a cool moist period for the production, dispersal and germination of the spores and infection of the host. Ayyar *et al.*,(1921), Vinukatananda and Celino (1940), Krishna Menon (1949) and Yarwood (1956) also observed that continuous rain and humid climatic condition favour the infection by *C.gloeosporioides* on *Piper nigrum*. Roy (1948) observed the same conditions for the infection of the same pathogen on betel vine. Other workers have also observed that the same climatic conditions favoured infection by *C. gloeosporioides* on different crops like avacado and mango (Ocfemia and Agati (1925), papaya (Baker *et al.*, 1940), *Dioscorea* (Singh and Prasad, 1967) and rubber (Wastie, 1972).

The maximum development of the symptom on the leaf and maximum disease index were observed during the warm moist period. This clearly shows that the pathogen is more active in host tissue at slightly higher temperature and low relative humidity than that is required for infection. Maximum symptom development was observed on mature leaves. The earlier workers also observed almost the same conditions for the maximum symptom development (Amin *et al.*, 1979; Chung and Bae, 1979; Omgupta and Nema, 1979).

The pathogen infects different parts of the spike viz., pedicel, rachis and berries. Among this, pedicel infection has more significance because all the infected spikes fall off within a week resulting in total loss. The infection pattern on pedicel during both the years under observation is found to be the same as that of the leaf infection. The pedicel infection starts during the South West monsoon period and the maximum infection was also observed during that period in both the years. The peak period of pedicel infection synchronised with continuous rainfall of the season (Table 17 and Fig.6).

The intensity of pedicel infection has a direct positive correlation with number of rainy days, total rainfall and relative humidity. Among these factors, maximum positive correlation was observed in the case of total number of rainy days and total rainfall. The total pedicel infection per cent during 1979 was low when compared to that of 1978. During the pedicel infection period in 1978 there was 2939.8 mm rainfall in 131 days and the total pedicel infection was 4.42 per cent. During this period in 1979 the total rainfall was 2582.9 mm received in 115 days and the pedicel infection was only 3.34 per cent. Both the maximum and minimum temperatures have negative correlation with pedicel infection in both the years under observation.

The findings of the present investigation supported the earlier observation on the infection pattern of Colletotrichum gloeosporioides on different crops including pepper (Sukumara Pillai et al., 1977, on pepper; Roy, 1948, on betel vine; Ocfemia and Agati, 1925, on avocado and mango; Singh and Prasad, 1967, on dioscorea; Wastie, 1974 on rubber; Denhan and Waller, 1981, on citrus).

After the North East monsoon the spikes became mature and, eventhough there was rain, no infection, was observed on the pedicel. This may be due to the fact that by that time the pathogen could not attack mature pedicel inspite of the favourable climatic factors.

The pathogen attacks mature and immature berries. When the pathogen attacks the immature berries, it completely shrivells and becomes light.

When the pathogen attacks the mature berries, only the pericarp is affected and the seed was found to be intact. This may be due to the fact that the seed coat of mature berries becomes hard and the pathogen is not able to penetrate the seed.

The berry infection usually starts in the beginning of August and the peak period of infection was noticed during September in both the years. (Table 13 and Fig.6). But in 1978 the infection continued till the end of December. This may be due to a few showers received during the second half of December. The above findings are in conformity with the report from the Pepper Research Station, Panniyoor (Anonymous, 1979).

When compared to 1978 the infection per cent was slightly low in 1979 and the total rainfall received during 1978 was much higher (2018.8 mm) with an infection per cent of 2.59 and in 1979 the total rainfall received was 1430 mm and the infection per cent was 2.35. This indicates that the rainfall is the major factor for berry infection also.

In the bioassay of the seven fungicides tried, Difolatan, Bayleton and Antracol at 2000 ppm and

Bordeaux mixture one per cent gave cent per cent inhibition of growth of _Colletotrichum gloeosporioides_ in solid medium. All other fungicides were found to be less effective and the inhibition per cent was below ninety per cent.

The efficacy of Difolatan for inhibiting the growth of _C. gloeosporioides_ has been well established by earlier workers (Chung, 1970; Kader _et al._, 1977). Similarly, the efficacy of Bayleton and Antracol for inhibiting the growth of fungus was also proved by other workers (Pimentel _et al._, 1971; Bastos and Medeiros, 1979). The present investigation confirms the findings of earlier workers.

The efficacy of four different fungicides namely, Antracol, Bayleton, Bordeaux mixture and Difolatan in controlling the anthracnose disease of pepper was tested in the field. The fungicides were sprayed on the crop at one month interval. Altogether three sprayings were given. Observations were recorded only for leaf disease index and spike shedding. In general, there was significant reduction in the leaf disease index and spike shedding as a result of fungicidal spraying (Table 15, 16 and 17). There was significant difference between the effect of fungicides in checking the disease. The plots sprayed with one per cent Bordeaux mixture have found to be superior to all other fungicides. The efficacy of Bordeaux mixture for controlling Colletotrichum gloeosporioides which attacks pepper has been well established by earlier workers, Rao (1926), Sundararaman (1928), Thomas and Menon (1939). The efficacy of Bordeaux mixture in controlling C.gloeosporioides has been established in Piper betle by Dastur (1935), Su (1937), Bertus (1942), Choudary (1945) and Chathopadhyay (1967). The effect of Bordeaux mixture against C.gloeosporioides on other crops was also proved by Shear (1926), Simmonds (1933), Venkatakrishniah (1952), Tandon and Singh (1968) and Subramonian et al. (1971).

In general, Difolatan was found to be the next to Bordeaux mixture in controlling the disease in the field. But, after the first spray, this fungicide was found to be on par with Bayleton and Antracol. Later, it established the supremacy over the other organic fungicides. Difolatan was found to be a very good fungicide in controlling the anthracnose fungi on different crops by Chauhan and Duhan (1977), Brook (1977), Navarro and Pusserta (1978), Madaan and Grover (1979), Raju et al. (1979), Schroeder et al. (1979) and Chauhan et al. (1980).So far, there is no report on the control of anthracnose disease of pepper using this fungicide.

In the case of first spraying, Bayleton came next to Bordeaux mixture, but subsequently this fungicide was found to be less effective than Difolatan. However, this fungicide was found to be superior to Antracol in controlling the disease. The reports on the efficacy of Bayleton in controlling the anthracnose disease of crops are very scanty. The present study reveals that Bayleton can also control the anthracnose disease to some extent in the field.

Antracol is one of the best fungicides available against so many leaf spot diseases (Kim, 1972; Karan et al., 1974). Here, for controlling the anthracnose disease of pepper this fungicide was found to be less effective when compared with the other three fungicides tried.

Similar trend has been observed in the control of the spike shedding of pepper. Bordeaux mixture was found to be superior to other fungicides followed by Difolatan, Bayleton and Antracol.

As the percentage of spike infection was very low during the period under study, the statistical analysis was not carried out. The comparison was made on the basis of the intensity of infection in the field experiment. In the fungicidal trial to control the anthracnose disease, data on leaf and spike infection showed that all the four fungicides tested namely, Bordeaux mixture one per cent, Difolatan, Bayleton and Antracol can check the disease to a great extent and one per cent Bordeaux mixture was found to be superior to the other fungicides tested. This may be due to the fact that Bordeaux mixture has more adhesive property and good persistent action than all other fungicides tested.

Yet another reason may be the time lag of one month between the subsequent sprayings. The organic fungicides tested in the field may not have that much persistent action as that of Bordeaux mixture to retain the fungal toxicity continuously on the host plant.

Summary

SUMMARY

The present study on the etiology and ecology of "fungal pollu" in pepper was conducted at Pepper Research Station attached to College of Horticulture, Vellanikkara during the years 1978 and 1979 using the variety Panniyoor-I.

(1) The pathogen causing the "fungal pollu" was found to be *Colletotrichum gloeosporioides*, the imperfect stage of *Glomerella cingulata*.

(2) The pathogen was found to be perennial on the host and infected all the aerial parts of the pepper vine except root and well matured stem.

(3) Leaf infection took place only on physiologically active and mature leaf.

(4) The initial symptom observed on the infection court was a chlorotic speck. Later it turned dark brown within two days.

(5) The well developed leaf spots under dry condition were circular to irregularly circular in shape. The holonecrotic area of the spot was slightly depressed

and ashy white to papery white in colour. This area was surrounded by a dark coloured plesionecrotic area which was encircled by dark coloured raised margin. The infected leaves usually did not shed.

(6) Under humid moist conditions, the leaf spot enlarged quickly and the holonecrotic area was ashy white in colour. This area was surrounded by dark coloured plesionecrotic area without any distinct margin, but there was a bright yellow halo around this necrotic area. The infected leaves shed within two weeks.

(7) On the tender shoots, the initial symptom was similar to that on leaves. The necrotic area was very dark in colour. The shoot got dried when the infection spread around the shoot.

(8) The pathogen attacked all parts of the spike namely pedicel, rachis and berries.

(9) Pedicel infection resulted in shedding of the spike

(10)The initial symptom on the pedicel was as that on the leaves and tender shoots.

(11) The difference between the physiological shedding and shedding due to *Colletotrichum gloeosporioides* can easily be distinguished by the fact that in the case of former, there will be callus formation at the base of the pedicel whereas in the latter case, the infected portion of the pedicel was found to be rotten and dark in colour. Pedicel infection was not observed on mature spikes.

(12) Rachis infection usually occurred on half mature spikes. All the berries below the infected portion were found to be dried and did not get detached from the rachis.

(13) On berries, two types of infection were noticed. In the case of immature berries, the infected berries became completely shrivelled, dark in colour and light in weight. Infection on mature berries caused cracking of the skin of the pericarp and rotting of the pericarp. The seed of the berry, however, remained intact without much reduction in weight.

(14) The climate of Vellanikkara tract was typically monsoonic consisting of South West and North East monsoons.

(15) Observations on the weather parameters revealed that the climate of the tract could be categorised into six well defined periods in an year namely (1) warm dry period (2) pre-monsoon period (3) south west monsoon period (4) monsoon break period (5) North East monsoon period (6) cool dry period.

(16) The fresh infection by the pathogen was found during the pre-monsoon period and the peak period of infection was during the South West monsoon period.

(17) Rate of infection reduced during the monsoon break period. Later, during the North East Monsoon period the infection slightly increased.

(18) No fresh infection was observed during cool dry and warm dry periods.

(19) The intensity of the fresh infection was found to be significantly and positively correlated with number of rainy days, total rainfall and averages of maximum and minimum temperature.

(20) The minimum disease index was observed during the warm dry periods. The disease index slightly increased during pre-monsoon period. During the South West monsoon period, the disease progressed and by the end of this period the disease index reached 0.868 per cent from 0.125 per cent recorded during the beginning of this period. The disease index also progressed during the monsoon break period.

(21) The increase in the disease index during the North East monsoon period was negligible.

(22) During the cool dry period the intensity of the disease gradually decreased and attained the minimum index during the warm dry period.

(23) The maximum infection on the pedicel of the spike was found during the South West monsoon period. The coefficient of simple correlation of the pedicel infection with weather parameters namely number of rainy days, total rainfall, averages of maximum and minimum temperature and averages of maximum and minimum relative humidity were significant.

(24) Significant negative correlation was observed

between the intensity of pedicel infection with the average maximum and minimum temperature of the fortnight.

(25) The berry infection commenced during the late part of the South West monsoon and it progressed during the monsoon break period and North East monsoon period. The mature berries got more infection than the immature ones.

(26) Out of seven fungicides tried *in vitro*, only four fungicides were effective in getting more than 75 per cent inhibition. They were Bordeaux mixture, Difolatan, Bayleton and Antracol respectively in the decreasing order of efficacy. Bordeaux mixture one per cent, Difolatan, Antracol and Bayleton each at 2000ppm gave cent per cent inhibition of fungal growth. The least inhibition of growth was noticed in Fycop (25.43 per cent).

(27) The four fungicides namely Bordeaux mixture, Bayleton, Difolatan and Antracol which were proved effective in checking the growth were taken for field studies. All the fungicides tried in the field significantly decreased the intensity of infection as compared to that of control.

(28) Among the fungicides, Bordeaux mixture one

per cent was found to be the best in controlling the disease in the field closely followed by Difolatan.

(29) The maximum yield of pepper was observed in Bordeaux mixture treated plot followed by Difolatan. However, the influence of fungicides on the yield was not statistically significant.

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*Original not seen

STUDY ON THE ETIOLOGY AND ECOLOGY OF "FUNGAL POLLU" IN PEPPER

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ABSTRACT OF A THESIS

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ABSTRACT

Laboratory and field experiments of the "study on the etiology and ecology of fungal pollu" was conducted at Pepper Research Station, attached to the College of Horticulture, Vellanikkara from 1978-1979.

The pathogen associated with the disease was found to be Colletotrichum gloeosporioides. The initial symptom of the disease observed on leaves tender shoots and berries was chlorotic specks. Only physiologically active leaves were infected. The well developed leaf spot under dry condition were circular to irregularly circular in shape. Under humid moisture conditions, the leaf spot enlarged quickly and the holonecrotic area was ashy white in colour. Pedicel infection caused the shedding of the spike. Infected tender shoots dried. Rachis infection was noticed rarely. The infected berries became dried, shrivelled, dark in colour and light in weight. Infection on mature berries caused cracking of the rind.

The climate of Vellanikkara tract is typically monsoonic, consisting of South West and North East monsoons.

The fresh leaf infection by the pathogen was found during the pre-monsoon period and the peak period of infection was during South West monsoon period. The intensity of the fresh leaf infection was found to be significant and positively correlated with number of rainy days total rainfall and averages of maximum and minimum temperature. Maximum disease index was observed during the South West monsoon period. The minimum disease index was observed during the warm dry periods.

Maximum infection on the pedicel of the spike was found during the South West monsoon period. The coefficient of simple correlation of the pedicel infection with weather parameters namely number of rainy days, total rainfall and averages of maximum and minimum relative humidity were significant.

The berry infection commenced during the late part of the South West monsoon period. Mature berries got more infection than immature berries.

Out of seven fungicides tried, _in vitro_ one per cent of Bordeaux mixture, Difolatan 2000 ppm, Antrocal 2000 ppm and Bayleton 2000 ppm gave cent per cent inhibition of the fungal growth.

In the field one per cent of Bordeaux mixture was found to be the most effective fungicide in controlling the disease, followed by Difolatan. Maximum yield of pepper was observed in Bordeaux mixture treated plot followed by Difolatan.