EFFECT OF KOKKAN DISEASE CAUSED BY BANANA BRACT MOSAIC VIRUS ON THE GROWTH AND YIELD OF BANANA

BY

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THESIS
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DECLARATION

I hereby declare that this thesis entitled **"Effect of 'Kokkan' disease caused by banana bract mosaic virus on the growth and yield of banana"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

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TO

MY BELOVED PARENTS

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INTRODUCTION

1. INTRODUCTION

Banana – 'a meal in a peel' and the 'Queen of tropical fruits', provides a major staple food for millions of people and plays an important role in the social fabric of many rural communities. It is recognized as the fourth important food crop in terms of gross value exceeded by paddy, wheat and milk products. Owing to its multi-facet use and high economic returns, it is referred as 'Kalpatharu' (a plant of virtue).

Among the fruits grown in India, banana (*Musa* spp.) ranks first in production and second in area. Kerala has the largest area (72,000 ha) among the states growing banana (Aravindakshan, 1999). However the productivity (7.9 t/ha) is not very appreciable. Incidence of serious pests and diseases is one of the major factor for low productivity. Among these, banana bract mosaic disease, a viral disease, more popularly called the 'Kokkan' disease of banana is spreading fast causing enormous economic losses in almost all the banana varieties cultivated in Kerala. Only very little work has been done on the banana bract mosaic disease. So far, there is no authentic report on the effect of kokkan disease on banana and on the extent of loss caused by the disease in the different varieties of banana. Estimation of losses caused by a disease is a basic information necessary in the formulation of proper methods of management of the disease. Similarly, detailed description of symptoms and preparation of a method of scoring the disease are

also necessary to arrive at a correlation between the intensity of the disease and losses caused by the same. So this study was undertaken with the following objectives,

★ Survey on the occurrence of the disease

★ Symptomatology

★ Development of score chart for the disease

★ Effect of the disease on the important growth parameters

★ Estimation of yield losses caused by the disease

★ Estimation of biochemical changes of disease resistance

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Banana bract mosaic disease is a very destructive viral disease of banana, which causes serious economic losses. The actual amount of yield loss and effect of the disease on the growth parameters is not yet known. The study was initiated to obtain information on the yield loss, effect on growth and the development of symptoms associated with this disease. An attempt has been made to review the available literature on various aspects related to the study.

2.1 Symptomatology

Banana bract mosaic disease (BBrMD) was first reported in nendran cultivar from Thrissur, Kerala by Samraj *et al.* (1966) and was referred to as 'Kokkan' disease of banana. The disease was reported and confirmed as being caused by a virus by Frison and Putter (1989). Magnaye and Espino (1990) described banana bract mosaic virus (BBrMV) as a flexuous, filamentous virus belonging the potyvirus group. Singh *et al.* (1996) confirmed that banana bract mosaic virus causes the kokkan disease of nendran banana prevalent in Kerala.

Trials conducted at the Banana Research Station, Kannara, Thrissur showed that the suckers from kokkan affected plants carried the disease and were found to produce small and deformed bunches (Anon, 1987). Ravi *et al.* (1992) studied the significance of

necrotic streaks in the Kokkan disease of banana and found that the production of abnormal bunches depends on the intensity and duration of occurrence of the streaks. They have also reported that the disease was widespread in Kerala in varieties like palayankodan, monthan, kanchikela, kodappanillakunnan, poovan, karpooravally and red banana. Estelitta *et al.* (1993) reported that the disease caused reddish streaks first on the leaf sheaths, then on the peduncle and bract. They also observed that the fruits were small and deformed. George *et al.* (1993) identified the pigment in kokkan affected banana plants as anthocyanin. Balakrishnan *et al.* (1996) indicated that the characteristic symptoms included malformed and undersized banana bunches and reddish brown streaks on pseudostem with changes in activation, which gave the diseased plants the appearance of 'traveller's palm'.

Estelitta *et al.* (1996 a) described that the symptoms appeared first on the leaf sheath as longitudinal, irregular, reddish or pinkish streaks of varying sizes and at later stages the pseudostem became abnormally red in colour and spongy in texture. Estelitta *et al.* (1996 b) reported that in diseased plants phloem was not distributed whereas more number of mechanical tissues, that is the xylem and fibres (sclerides) were seen in diseased plants.

Radhakrishnan and Geetha (1996) reviewed that the diseased plants took 20-25 days more for flowering compared to healthy ones and the bunches were pale green to ash green coloured, slender, curved and distorted.

The characteristic reddish brown mosaic pattern on the bracts of the inflorescence distinguished Kokkan disease from all other known virus disease of banana (Thomas and Magnaye, 1996). They also indicated that the symptoms on leaf lamina may or may not occur and if present, the symptom consisted of spindle shaped chlorotic streaks running parallel to the veins. Rodoni *et al.* (1997) described symptoms of the disease as discontinuous streaks on the bracts of the banana inflorescence, spindle-shaped streaks irregularly scattered along the petiole, mottled discolouration of the pseudostem, severe mosaic on the leaf lamina and a mottled pattern on the petioles of the leaves.

2.2 Biometric characters

Thangavelu and Singh (1996) opined that the plants with symptoms of BBrMV had reduced plant girth. Rodoni *et al.* (1997) observed that the plants infected with banana bract mosaic virus appeared stunted.

Estelitta *et al.* (1996 a) reported that the affected plants bore leaves of almost normal size, but the outer leaf sheaths got detached gradually from the pseudostem. In case of severely infected plants the leaves were distorted (Rodoni *et al.*, 1997).

Balakrishnan *et al.* (1996) recorded that the fruits of infected plants took longer time to ripen (9 to 10 days) compared with fruits of healthy plants which took 4-5 days and the fruits started decaying from both ends before full maturation. Radhakrishnan and Geetha (1996) observed that the diseased plants took 20-25 days more for flowering compared to healthy ones.

2.3 Yield characters

Samraj *et al.* (1966) first reported that the kokkan affected plants produced very small unmarketable bunches bearing small malformed fingers which have a characteristic ashy grey colour. Ravi *et al.* (1992) observed that all the diseased plants which had the necrotic streaks continuously up to harvest produced only small and deformed bunches. Balakrishnan *et al.* (1996) opined that the disease had spread to almost all the banana growing areas in Kerala, causing heavy yield losses on almost all banana varieties grown.

Infection by kokkan causes severe yield decline producing poor, deformed and under developed bunches. The fingers were short and undersized having an ash grey colour and of poor quality (Estelitta *et al.* 1996 a). Radhakrishnan and Geetha (1996) noted that the disease reduced the yield by about 48 per cent. Studies conducted by Thangavelu and Singh (1996) revealed that the all the plants with symptoms of BBrMV had reduced bunch size. In severe case of infection finger filling was affected. Thomas and Magnaye (1996) recorded yield losses of up to 40 per cent in cv. cardaba and cv. lakatan (AA) in the Philippines. Rodoni *et al.* (1997) reported that banana bract mosaic potyvirus (BBrMV) a non persistently aphid-transmitted virus of bananas caused an yield loss of up to 40 per cent.

Sharma (1988) reported that in case of banana bunchy top disease, when infected suckers were planted the plants never flowered and resulted in 100 per cent yield loss. Alagiamanavalan *et al.* (1973) opined that when plants of variety Robusta got infected

just before flowering, the reduction in finger length, girth and weight were 31.4, 34.6 and 75 per cent respectively. Weight of bunch on infected plants was only 10.5 kg as compared to 31 kg in healthy plants. Time taken for maturity of fingers was 111 days in diseased plants compared to 93 days in healthy plants.

Estelitta *et al.* (1996 c) assessed the yield loss due to banana mosaic (infectious chlorosis) and found that the decrease in bunch weight caused by the disease in the commercial varieties 'nendran', 'palayankodan' and 'karpuravally' were 54, 45 and 62 per cent respectively.

2.4 Biochemical changes

2.4.1 Total carbohydrate

Nair and Wilson (1972) recorded higher percentage of carbohydrates in leaves of banana bunchy top infected plants than the healthy plants. An increase in total sugar content was reported by many workers in virus infected plants (Sarkar *et al.*, 1989; Prasad *et al.*, 1992; Sohal and Bajaj, 1993; Sarma *et al.*, 1995).

Johri and Padhi (1985) reported that the carbohydrate levels declined with severity of disease symptoms in okra due to the infection by yellow vein mosaic virus. Shukla *et al.* (1992) found that the diseased plants produced less cane sugar when compared to healthy plants infected with sugarcane mosaic virus. The amount of reducing sugar, non-reducing sugar, total sugars and starch content decreased in the

plants infected with yellow vein mosaic virus when compared with the healthy control (Sarma *et al.*, 1995; Thind *et al.*, 1996; Dantre *et al.*, 1996).

Bhagat and Yadav (1997) reported that healthy leaves of susceptible and highly susceptible cultivars showed higher content of reducing, non-reducing and total sugar than resistant one in case of bhindi yellow vein mosaic virus infected plants. It was also reported that increased sugar content in inoculated leaves of bhindi was due to their accumulation as a result of the disruption of normal phloem transport.

Sweich *et al.* (2001) observed that the leaves of both susceptible and resistant beet varieties exhibited an accumulation of sucrose, as much as 10-fold greater than controls, and 38-fold higher than that seen in beet curly top virus infected *N.benthamiana* per dm^2 leaf area.

2.4.2 Chlorophyll

Reduction in total chlorophyll, chlorophyll a and chlorophyll b due to virus infection was reported by many workers in various crops. In Bhindi infected with yellow vein mosaic, the chlorophyll levels were found to decline with severity of disease symptoms (Johri and Padhi 1985).

Shukla *et al.* (1992) reported that sugar cane mosaic virus reduced the chlorophyll to a tune of 29.8, 33.5 and 40.7 per cent in CO-1148, CO-1158 and BO-3 respectively. Yellow vein mosaic virus infection reduced the chlorophyll content of Bhindi (Sarma *et al.*, 1995). Studies by Dantre *et al.* (1996) on the biochemical changes induced by yellow

mosaic virus revealed that chlorophyll (total, a and b) were decreased in the infected leaves. Similar results were obtained by Thind *et al.* (1996) working with yellow mosaic virus infected moong. Mali *et al.* (2000) reported a reduction in content of chlorophyll a, b and carotenoids in susceptible than in resistant genotype following yellow mosaic virus infection in moth bean (*Vigna aconitifolia*).

2.4.3 Phenolic compounds

Ahmed *et al.* (1992) observed high levels of total phenols in virus free resistant varieties of okra infected with yellow vein mosaic virus. Similar results were obtained by Sarma *et al.* (1995) in okra and Dantre *et al.* (1996) in soyabean infected with the same virus. Sutha *et al.* (1997) reported that both total phenol and O-dihydroxy phenol increased in tomato spotted wilt virus infected plants. Resistant cultivars had higher contents of phenol, OD-phenol and flavanol due to cotton leaf curl virus infection when compared to susceptible varieties (Kaur *et al.*, 1998). Radhika (1999) reported that there was not much change in phenol content in both resistant and susceptible varieties of cowpea infected with black eye cowpea mosaic virus. Mali *et al.* (2000) reported that O-dihydroxy phenol was higher in healthy leaves than diseased leaves in case of yellow mosaic virus affecting moth bean.

2.4.4 Defence related enzymes

Sharma *et al.* (1984) studied the pathophysiology of muskmelon plants infected with cucumber mosaic virus and found enhanced activity of peroxidase and polyphenol

oxidase after inoculation. Ahmed *et al.* (1992) found that the enzymes peroxidase and polyphenol oxidase showed no significant differences in virus free, susceptible and resistant okra plants in response to infection by yellow vein mosaic virus. Zaidi *et al.* (1992) reported that there was an appreciable increase in phenylalanine ammonia-lyase in etched ring virus infected carnation plants as compared to the healthy control plants. Umamaheswaran (1996) reported that there was progressive increase in peroxidase, poly phenol oxidase and phenylalanine ammonia-lyase activity in inoculated and susceptible varieties of cowpea. Yunzhu *et al.* (1997) reviewed that after inoculation, soybean mosaic virus resistant cultivars showed an increase in peroxidase activity with peak at 24 hours after inoculation. Similar results were also obtained by Cuiming *et al.* (1999) in case of peroxidase and polyphenol oxidase with the same virus.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study aimed at assessing the effect of kokkan disease caused by banana bract mosaic virus on the growth and yield of banana was carried out in the Instructional Farm, College of Agriculture, Vellayani during 2000-2001. The details of the field experiment conducted and the statistical analysis carried out are provided hereunder.

3.1 Survey

Survey on the incidence of Kokkan disease on common varieties of banana, *viz.*, nendran, red banana, robusta, palayankodan and rasakadali (njali poovan) was carried out in two wards of Kalliyoor Panchayat by using simple random sampling technique.

Based on the data available at Kalliyoor Krishibhavan, two wards were selected at random. From each of the selected ward, 25 farmers were selected randomly.

To study the intensity of the disease, ten plants from each plot were scored using a 0-4 scale as follows.

0- No symptoms

1- Reddish brown streaks on 1-25 % area of the pseudostem.

2- Reddish brown streaks on 26-50 % area of the pseudostem.

3- Reddish brown streaks on 51-75 % area of the pseudostem.

4- Reddish brown streaks on more than 75 % area of the pseudostem

3.2 Field experiment

The field experiment was laid out in block IV of the Instructional Farm, College of Agriculture, Vellayani. Geographically, the area is located at 8.5^0 N latitude and 76.9^0 E longitude; at an altitude of 26 m above mean sea level.

3.2.1 Layout of the experiment

The experiment was carried out using healthy and diseased plants in two randomised block design with the following treatments.

Varieties : 5

T_1 : Nendran

T_2 :Red banana

T_3 : Robusta

T_4 : Palayankodan

T_5 : Rasakadali (Njalipoovan)

Replications : 3

Conditions : 2

Healthy (H) and Diseased (D)

Plot size : 30 cents

Spacing : 3m between rows

: 2 m within rows

Pit size : 50 x 50 x 50cm

Fifteen healthy and 15 diseased plants of all the varieties were planted. All the plants received uniform doses of cattle manure, N, P and K per plant as per Package of Practices (1996) for this crop recommended by Kerala Agricultural University. Application of Phorate was also done to all the plants as per the Package of Practices Recommendations.

3.2.2 Season

The period of crop growth was from March 2000 to April 2001 for the varieties nendran, robusta, palayankodan and rasakadali and upto August 2001 for red banana.

3.2.3 Planting materials

Three month old suckers of the varieties nendran, red banana, robusta, palayankodan and njalipoovan were procured for planting from the Instructional Farm, College of Agriculture, Vellayani. Fifteen diseased and 15 healthy suckers of each variety were procured and so a total of 150 suckers were collected and planted.

3.2.4 Irrigation

Irrigation was given at weekly intervals @ 20 litres water per plant upto third month after planting and 40 litres per plant upto harvest.

3.2.5 Weeding

Hand weeding was resorted to as and when required.

3.3 Symptomatology

The plants were grown as per Package of Practices Recommendations, Kerala Agricultural University (1996). During the course of growth, the individual plants were observed for the development of symptoms.

The plants were observed for the development of reddish brown or pinkish streaks. The time of appearance, the intensity and development of these streaks were also observed. Based on the intensity of the streaks, the plants were scored at an interval of three months using the 0-4 scale as indicated in 3.1.

Other symptoms like the appearance of necrotic streaks, traveller's palm appearance, unusual separation of leaf sheath, mosaic on bract, symptoms on leaf lamina, bunch characters, flower and fruit characters were also observed during the course of this investigation.

3.4 Biometric characters

Biometric characters were measured from all the 30 observation plants of each variety and the average was worked out.

3.4.1 Height of plant (cm)

Height of the plant was measured from the base of the pseudostem at the soil level to the axil of the youngest unopened leaf at monthly intervals.

3.4.2 Girth of pseudostem (cm)

Girth of pseudostem at 20 cm above the soil level was measured using a flexible measuring tape at monthly intervals.

3.4.3 Number of leaves per plant

The total number of functional leaves per plant was recorded at monthly intervals.

3.4.4 Leaf production rate

The number of leaves produced per month was recorded.

3.4.5 Leaf area index

Leaf area index was computed from the values of the total leaf area of the plant and the geographical area occupied by it using the formula.

$$\text{LAI} = \frac{\text{Total leaf area of the plant}}{\text{Geographical area occupied by the plant}}$$

The leaf area of the functional leaves was calculated using the formula.

Leaf area = L x B x 0.8 (a constant)

L = Length of lamina

B = Width of lamina

The length of lamina was measured from the base of leaf to the tip and the width, at the broadest point of the leaf in the middle region. The sum of the area of all the functional leaves in a plant was then calculated. These observations were recorded at

three stages, that is, early vegetative growth stage, flower bud development stage and at shooting.

3.4.6 Time taken for flowering (days)

The total number of days taken to flower was recorded from the date of planting.

3.4.7 Time taken for harvest (days)

The total number of days from the date of planting to the date of harvest was recorded.

3.4.8 Bunch maturity period (days)

The total number of days from the date of emergence of bunch to the date of harvest was noted.

3.4.9 Number of suckers per plant at harvest time

The total number of suckers produced was recorded at the time of harvest.

3.5 Yield characters

Yield characters were taken from all the 30 observation plants of each variety and the average was worked out. The following characters of the bunch contributing to yield were recorded immediately after harvest of the fully matured bunch. The disappearance of ridges followed by rounding of the fruit angles was taken as the indication of maturity.

3.5.1 Weight of bunch (kg)

The weight of bunch including the peduncle upto the first scar (exposed outside the plant) was recorded in kilograms.

3.5.2 Number of hands per bunch

The number of hands in a bunch for each treatment was noted.

3.5.3 Number of finger per bunch

The total number of fingers in a bunch for each treatment was counted and values were recorded.

3.5.4 Finger characters

The middle finger in the outerwhorl of the second hand was identified as the index finger and the following characters were recorded.

3.5.4.1 Length of finger (cm)

The length of finger was measured from the top of the finger to the point of attachment of the peduncle.

3.5.4.2 Girth of finger (cm)

The girth of finger was measured at the middle portion of the finger.

3.5.4.3 Weight of finger (g)

The weight of finger was determined after detaching it from the peduncle.

3.6 Biochemical studies

The biochemical studies were done in four stages. The first analysis was done three months after planting and the second analysis six months after planting. The third analysis was done nine months after planting, but it coincided with the emergence of flag leaf in nendran, robusta, palayankodan and rasakadali (njalipoovan). So in redbanana also, the analysis was done in the flag leaf stage. These three analyses were done using the tip of the newly emerged unfurled leaf. The fourth analysis was done using the bract and the innermost growing point was used for this.

3.6.1 Estimation of total carbohydrates

Total carbohydrate was estimated by Anthrone method (Hedge and Hofreiter, 1962). Hundred milligram samples were weighed out and hydrolysed with five ml. of 2.5 N hydrochloric acid (HCl) at 100^0C in a water bath. The hydrolysate was then neutralised with solid sodium carbonate until the effervescence ceased. The volume was made up to 100 ml and centrifuged at 5000 rpm for 15 minutes. From the supernatent, 0.5 ml aliquot was taken and made up to one ml. by adding distilled water. To this, four ml anthrone reagent was added and heated for eight minutes at 100^0C in a water bath. This was cooled rapidly and absorbance was measured at 630 nm, in a spectrophotometer (Systronics UV-VIS Spectrophotometer 118). Amount of carbohydrate present was calculated from standard graph prepared using glucose and expressed in terms of milligrams of glucose equivalent per gram of leaf tissue on fresh weight basis.

3.6.2 Estimation of chlorophyll

Chlorophyll was estimated by the method described by Arnon (1949). One gram of sample was ground in a mortar with 20 ml of 80 per cent acetone. The homogenate was centrifuged at 5000 rpm for five minutes and the supernatent was transferred to a 100 ml volumetric flask. The above procedure was continued till the residue became colourless. The final volume in volumetric flask was made up to 100 ml. Absorbance of the solution at 645 and 663 nm was read in a spectrophotometer against the solvent (80 per cent acetone) as blank. The chlorophyll content was calculated using the following equations and expressed as milligrams chlorophyll per gram tissue.

$$\text{Total chlorophyll} = 20.2\ (A\,645) + 8.02\ (A\,663) \times \frac{V}{1000 \times W}$$

$$\text{Chlorophyll a} = 12.7\ (A\,663) - 2.69\ (A\,645) \times \frac{V}{1000 \times W}$$

$$\text{Chlorophyll b} = 22.9\ (A\,645) - 4.68\ (A\,663) \times \frac{V}{1000 \times W}$$

where,

A = absorbance of specific wavelength,

V = final volume of chlorophyll extract in 80 per cent acetone and

W = fresh weight of tissue extracted.

3.6.3 Estimation of total phenol

The total phenol was estimated following the procedure described by Bray and Thrope (1954). One gram of sample was ground in ten ml of 80 per cent ethanol. The

homogenate was centrifuged at 10,000 rpm for 20 minutes, supernatent was saved and residue was extracted with five times the volume of 80 per cent ethanol and centrifuged. The supernatent was saved and evaporated to dryness. The residue was dissolved in five ml distilled water. An aliquot of 0.3 ml was pipetted out and made up to three ml with distilled water. Folin-Ciocalteau reagent (0.5 ml) was added and two ml of 20 per cent sodium carbonate solution was added to each tube after three minutes. This was mixed thoroughly and kept in boiling water for one minute. Further the tubes were cooled and absorbance was measured at 650 nm in a spectrophotometer against reagent blank. Standard curve was prepared using different concentrations of catechol and expressed in catechol equivalents as microgram per gram leaf tissue on fresh weight basis.

3.6.4 Estimation of peroxidase (PO)

The procedure described by Srivastava (1987) was used for determining the peroxidase activity. 200 mg samples were weighed and homogenised in one ml of 0.1 M sodium phosphate buffer (pH 6.5) to which a pinch of polyvinyl pyrrolidone (PVP) was added. The homogenisation was done at 4^0C. The supernatent was used as the enzyme extract for the assay of PO activity. The reaction mixture consisting of one ml of 0.05 M pyrogallol and one ml of one per cent hydrogen peroxide (H_2O_2) was taken in both reference and sample cuvettes, mixed and kept in a spectrophotometer and the reading was adjusted to zero at 420 nm. The enzyme reaction was started by adding 50 µl of

enzyme extract into sample cuvettes and change in absorbance was measured at 30s interval.

3.6.5 Estimation of polyphenol oxidase (PPO)

Polyphenol oxidase activity was determined as per procedure given by Mayer *et al.* (1965). The enzyme extract was prepared as per the procedure given for the estimation of peroxide.

The reaction mixture contained 1.0 ml of 0.1 M sodium phosphate buffer pH 6.5 and one ml of 0.01 M catechol. The cuvettes were placed in a spectrophotometer and absorbance was set to zero. The reaction was started after adding 50 µl of enzyme extract. The changes in absorbance was recorded at 495 nm and PPO activity was expressed as changes in the absorbance of the reaction mixture per minute per gram on fresh weight basis.

3.6.6 Estimation of phenylalanine ammonia-lyase (PAL)

PAL activity was analysed based on the procedure described by Dickerson *et al.* (1984).

The enzyme extract was prepared by homogenising one gram leaf sample in five ml 1.0 M sodium borate buffer (pH 8.7) containing a pinch of polyvinyl pyrrolidone using chilled pestle and mortar. The homogenate was centrifuged at 10,000 rpm for 20 min at 4^0C. The supernatent was used for the assay of PAL activity. The reaction mixture contained three ml of 0.1 M sodium borate buffer pH 8.7, 0.2 ml enzyme extract and 0.1

ml of 12 mM L-phenyl alanine prepared in the same buffer. The blank contained 3 ml of 0.1 M sodium borate buffer pH 8.7 and 0.1 ml phenyl alanine. The reaction mixtures and blank were incubated at 40^0C for 30 min and reaction was stopped by adding 0.2 ml of 3 N hydrochloric acid (HCl). The absorbance was read at 290 nm in a spectrophotometer. Standard curve for trans cinnamic acid was prepared using different concentrations of cinnamic acid and PAL activity was expressed as microgram of cinnamic acid produced/min/g on fresh weight basis.

3.7 Statistical analysis

Survey data was analysed for testing the significance of the difference in the infestation between the two wards. Difference among the varieties for percentage incidence of kokkan in each of the study ward was also carried out.

For the field experiment, pooled analysis was carried out for the data obtained and the comparison was carried out to study the difference (i) between the two conditions and (ii) among the varieties under both the conditions. Covariance analysis was worked out after identifying the two stages where maximum correlation was noted between yield and disease scores.

RESULTS

4. RESULTS

4.1 Survey

A survey was carried out in two wards of Kalliyoor Panchayat (Ward Nos: IV and VI) in Thiruvananthapuram district. The survey revealed that banana bract mosaic disease is prevalent in the area. The disease was found to appear three to four months after planting and destruction of the diseased plants was the commonly adopted control measure.

The symptoms observed were reddish brown or pinkish streaks on the pseudostem, necrotic streaks on the leaf petiole and leaf sheaths, ' traveller's palm' appearance and bract mosaic symptoms. The diseased plants were in general weak and with reduced vegetative growth.

The percentage of incidence was assessed based on the data obtained on the number of plants infected in a plot. The percentage of incidence in Ward IV ranged between 7-72 per cent and in Ward VI between 4-70 percent. The study also revealed the pattern of infestation. In both the wards redbanana plants showed the maximum percentage of infestation followed by nendran and was significantly higher than robusta, palayankodan and rasakadali (njalipoovan). There was no significant difference between the two wards in the percentage of incidence of the disease (Fig 1).

Fig 1. Percentage of incidence of kokkan disease in two wards of Kalliyoor panchayat

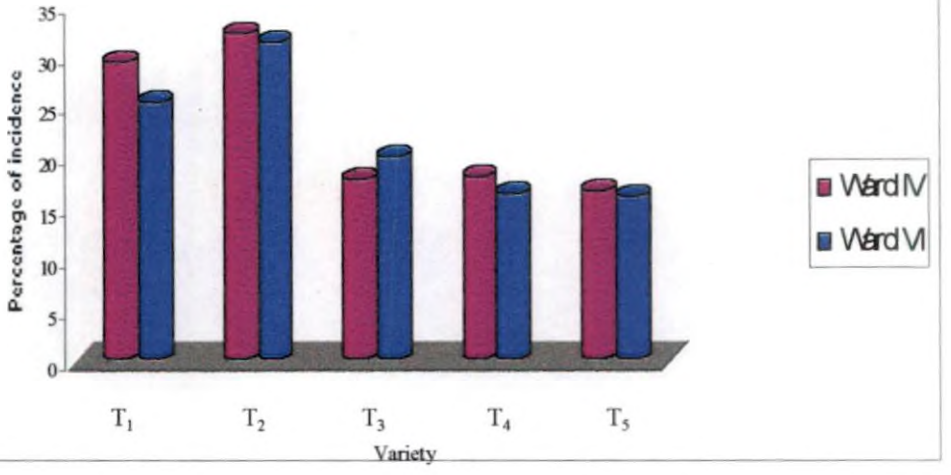


Fig 2. Intensity of incidence of kokkan disease in two wards of Kalliyoor panchayat

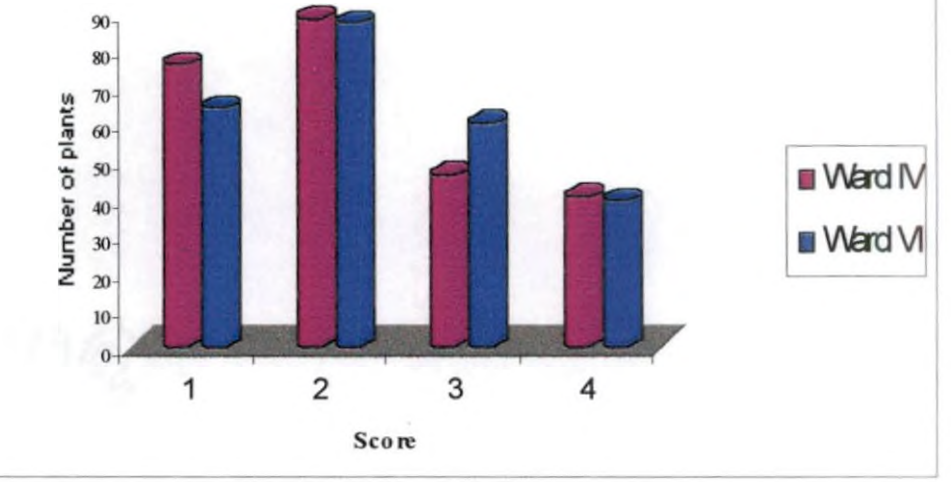


Plate 1. Score chart for kokkan disease of banana

A. Nendran

B. Redbanana

C. Robusta

D. Palayankodan

E. Rasakadali (njalipoovan)

A

B

C

D

E

Plate 1

Plate 2.Pinkish/ Reddish streaks on the pseudostem

A. Palayankodan

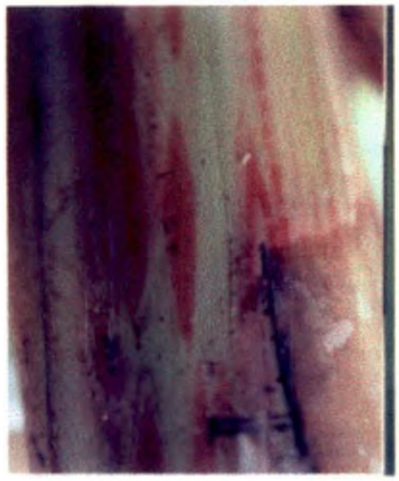
B. Rasakadali

Plate 3.Reddish Brown streaks on the pseudostem

A. Robusta

B. Nendran

C. Redbanana



A

B

Plate 2

A

B

C

Plate 3

To assess the intensity of the disease, ten diseased plants were randomly scored in each plot. The two wards were on par in the intensity of the disease (Fig. 2).

4.2 Field experiment

4.2.1 Symptomatology

The plants were periodically observed for the development of symptoms.

4.2.1.1 Pseudostem symptoms

Suckers with reddish or pinkish streaks were scored based on the 0-4 scale proposed and were planted in the field (Plate 1). The diseased suckers of all the five varieties, viz., nendran, red banana, robusta, palayankodan and rasakadali (njalipoovan) had the pinkish streaks at the time of planting. The intensity of the streaks varied within and between varieties and were scored based on the proposed 0-4 scale at trimonthly intervals. At the time of planting, kokkan affected nendran, palayankodan and rasakadali (njalipoovan) varieties showed pinkish streaks, while reddish streaks were seen in case of red banana and robusta (Plate 2). The streaks became darker as the disease progressed and covered the whole pseudostem. In nendran the streaks were either reddish brown or pinkish. In red banana and robusta the streaks were reddish brown to dark brown while in palayankodan and rasakadali the streaks were darker shades of pink (Plate 3). The streaks could be viewed clearly when the outer dried lead sheaths were removed. The streaks were initially spindle shaped, longitudinal, irregular and later on joined together to form

Plate 4.Spindle shaped streaks on the pseudostem

Plate 5.Necrotic streaks

A. On the petiole

B. On the pseudostem

Plate 4

A

B

Plate 5

Plate 6.Traveller's palm symptoms

A. Redbanana

B. Robusta

A

B

Plate 6

elongated streaks (Plate 4). The streaks could be seen on the pseudostem, leaf petiole, leaf sheath and bracts. But the streaks were more prominent on the pseudostem and the presence of reddish or pinkish streaks could be taken as a diagnostic symptom of the disease.

4.2.1.2 Necrotic streaks

Necrotic streaks could be seen in nendran variety three to four months after planting. The necrotic streaks were seen on the pseudostem, leaf petioles and leaf sheaths (Plate 5). The necrotic streaks could be detected in the leaf petiole and leaf sheaths of palayankodan also. But robusta, red banana and rasakadali (njalipoovan) were free of necrotic streaks. It could be noted that if the necrotic streaks appear early in the vegetative stage of the crop and if the intensity is more than 50 per cent, then it would result in almost complete loss of the crop.

4.2.1.3 Traveller's palm symptoms

The appearance of traveller's palm symptom was a characteristic symptom of the disease. This symptom could be observed in all the varieties in varying degrees in red banana, robusta and nendran (Plate 6). This symptom was usually seen six to seven months after planting.

Plate 7. Bract mosaic

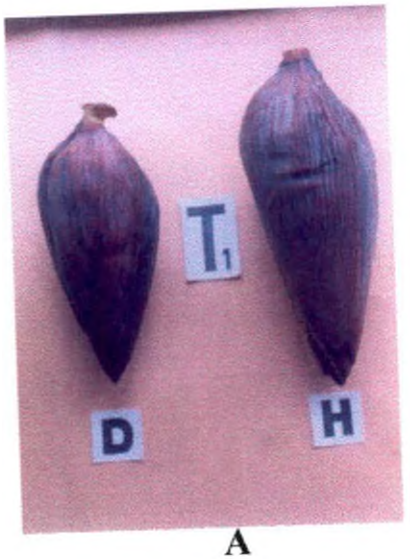
A. Nendran

B. Redbanana

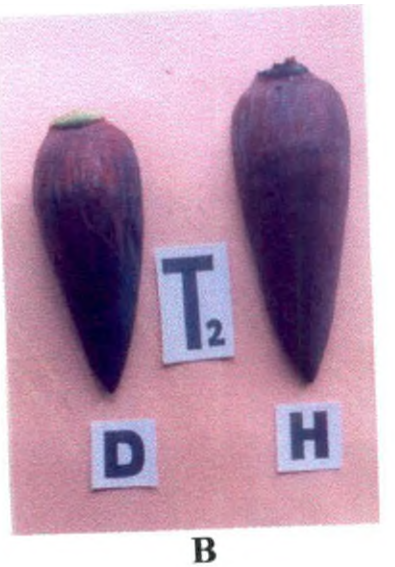
C. Robusta

D. Palayankodan

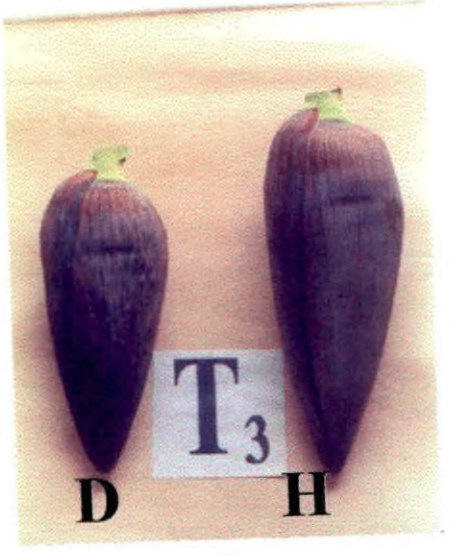
E. Rasakadali (njalipoovan)



A



B



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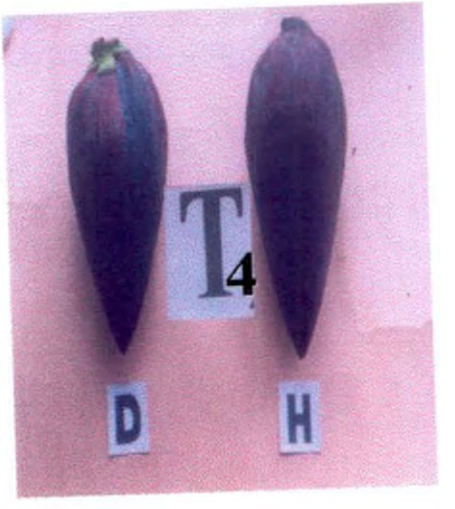
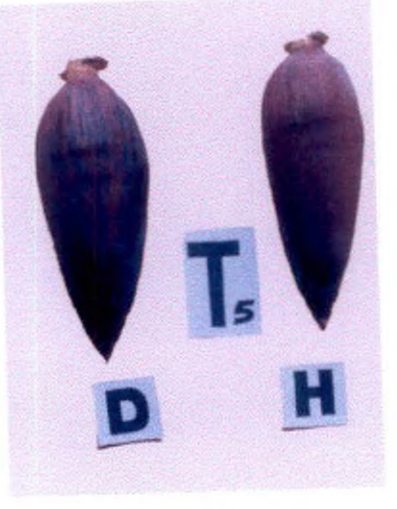


D



E

Plate 7

Plate 8.Mosaic symptom on the leaf lamina

Plate 9.Streaks on the peduncle

A. Palayankodan

B. Redbanana

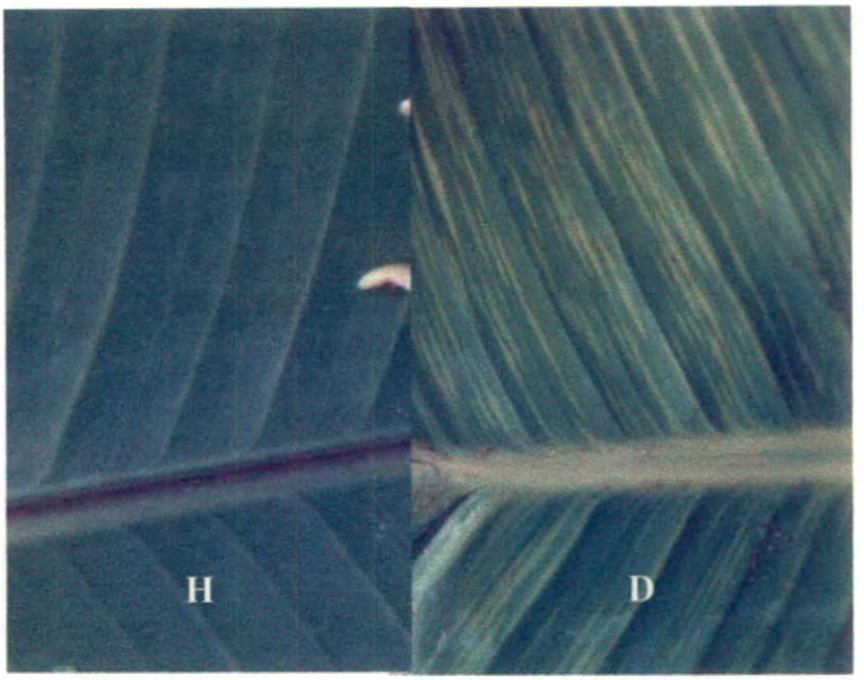


Plate 8

A **B**

Plate 9

4.2.1.4 Bract mosaic symptoms

All kokkan affected plants invariably produced the bract mosaic symptoms. Reddish brown streaks could be observed on the bracts and this was a confirmatory symptom of the disease observed in this investigation. (Plate 7).

4.2.1.5 Streaks on the male flowers

Reddish streaks could be observed in the male flowers of nendran, robusta, palayankodan and rasakadali. This reddish streaks were absent in diseased male flowers of red banana and the reddish streaks could be seen only in the healthy male flowers.

4.2.1.6 Leaf mosaic symptoms

Mosaic symptoms could be observed in the leaf lamina of some Kokkan affected plants. The leaf mosaic symptoms were more common in nendran, palayankodan and rasakadali (Plate 8). This symptom was present in less than 20 per cent of the Kokkan affected plants. The symptom appeared as discontinuous spindle shaped chlorotic streaks running parallel to the veins.

4.2.1.7 Streaks on the peduncle

Reddish streaks were observed in the peduncle of nendran, palayankodan and red banana plants affected by kokkan. The streaks were dark brown in colour in case of red banana (Plate 9).

Plate 10. Reduction in bunch size due to kokkan disease

A. Nendran

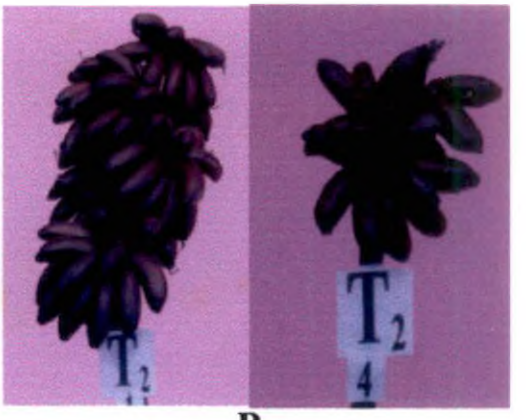
B. Redbanana

C. Robusta

D. Palayankodan

E. Rasakadali (njalipoovan)

A



B

C

D

E

Plate 10

Plate 11. Separation and splitting of leaf sheaths

Plate 11

4.2.1.8 Deformed and undersized bunches.

Most of the kokkan affected plants produced undersized bunches (Plate 10). The fingers were found to be deformed only in case of severe infection of the disease when the presence of reddish brown streaks on the pseudostem exceeds 50 per cent (*ie*. a score of 3 or 4).

4.2.1.9 Streaks on the fruits.

Dark brown streaks could be observed on the fruits of some kokkan affected red banana plants.

4.2.1.10 Separation and splitting of leaf sheaths from pseudostem.

In plants severely infected with the disease the leaf sheaths were found to be loosely packed. This symptom was observed in red banana and nendran varieties. Splitting of the leaf sheaths was also found (Plate 11).

4.3 Biometric characters

4.3.1 Height of pseudostem

The mean values on the height of pseudostem for the different treatments from the time of planting to harvest (at monthly intervals) are given in Table 1. The results showed that the banana bract mosaic virus infection adversely affected the height of the plants in all five varieties. There was significantly higher height for plants in the healthy condition than plants in the diseased condition. Statistical analysis revealed that there was no

Table 1. Effect of BBrMV infection on the height of pseudostem (cm)

Treatments	Month after planting															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
T_1H	42.93	61.53	87.60	116.67	140.80	159.20	184.60	211.93	233.93	255.27	258.77	-	-	-	-	-
T_2H	89.20	96.27	102.27	109.67	115.47	125.00	155.00	189.40	224.00	257.47	268.63	275.87	282.07	292.77	298.73	305.6
T_3H	57.60	66.87	76.87	87.67	95.93	105.67	127.33	147.07	163.67	182.40	188.13	-	-	-	-	-
T_4H	102.07	113.20	123.27	131.80	141.73	154.60	181.47	207.93	231.87	251.00	255.23	-	-	-	-	-
T_5H	106.80	116.13	124.67	133.93	143.87	154.40	199.60	232.73	260.47	280.13	283.23	-				
Mean (H)	79.72	90.80	102.93	115.95	127.56	139.77	169.65	197.81	222.78	245.25	250.80					
T_1D	42.87	56.67	69.73	82.73	96.20	112.87	132.80	156.60	168.40	198.27	200.67	-	-	-	-	-
T_2D	67.40	73.47	79.60	87.00	94.87	104.60	130.27	161.07	194.33	223.33	230.63	237.90	243.13	247.67	251.87	255.70
T_3D	46.53	56.20	67.27	77.07	86.47	97.93	121.13	143.60	160.27	173.40	177.43	-	-	-	-	-
T_4D	60.47	71.87	86.80	98.87	115.07	128.60	159.07	195.33	217.47	233.67	238.00	-	-	-		-
T_5D	84.00	90.20	98.53	108.20	116.53	127.00	155.13	183.87	210.40	233.53	236.23	-	-	-	-	-
Mean (D)	60.65	69.68	80.39	90.77	101.83	114.20	139.68	168.07	190.17	212.44	216.57	-	-	-	-	-
CD (0.05)																
Varieties x conditions	19.79	20.27	19.74	21.87	21.40	23.49	22.91	28.05	28.37	29.30	29.72					
Conditions	8.85	9.06	8.83	9.78	9.59	10.57	10.25	12.54	12.68	13.10	13.29					

significant difference between T_1H and T_1D plants upto two months after planting (MAP). But there was significant difference from the third MAP. At harvest stage T_1H had an average height of 258.77 cm and T_1D had an average height of 200.67 cm.

T_2H and T_2D differed significantly upto three MAP and from six MAP upto harvest. The treatments were on par in the fourth and fifth MAP. At harvest stage T_2H had an average height of 305.60 cm and T_2D had an average height of 255.70 cm. The treatments T_3H and T_3D were on par at all stages of growth with an average height of 188.13 cm and 177.43 cm respectively at harvest stage. T_4H and T_4D differed significantly upto fifth MAP, but there after the treatments were on par upto harvest stage with an average height of 255.23 cm and 238.00 cm respectively at harvest stage. T_5H and T_5D differed significantly at all stages of growth with average heights of 283.23 cm and 236.23 cm respectively at harvest stage.

4.3.2 Girth of pseudostem

The girth of pseudostem at 20 cm above the ground level recorded at monthly intervals from the time of planting upto harvest stage are presented in Table 2. The results revealed that the incidence of the disease adversely affected the girth of the pseudostem. There was significantly higher girth for plants in the healthy condition than plants in the diseased condition. T_1H and T_1D differed significantly in case of plant girth upto eight MAP, while the treatments were comparable in the 9^{th} and 10^{th} MAP. The average value of plant girth was 54.50 cm and 50.50 cm in treatments T_1H and T_1D respectively at

Table 2. Effect of BBrMV infection on the girth of pseudostem (cm)

Treatments	Month after planting															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
T_1H	19.27	24.20	27.47	33.00	37.40	40.80	44.73	48.00	50.37	52.67	54.50					
T_2H	28.80	29.27	32.80	35.87	39.27	42.40	45.47	55.47	64.87	73.27	81.00	84.37	88.07	89.80	91.73	92.3
T_3H	29.40	26.73	29.27	30.20	35.40	38.40	41.27	48.00	53.20	58.20	62.13					
T_4H	26.07	25.87	30.40	34.23	38.07	41.60	44.80	50.80	55.00	59.60	63.27					
T_5H	26.80	30.07	33.00	36.67	40.33	43.87	47.20	53.27	58.73	63.47	66.93					
Mean (H)	25.07	27.23	30.58	34.01	38.09	41.41	44.69	51.11	56.43	61.44	65.57					
T_1D	14.33	17.80	21.93	25.33	28.80	32.00	34.17	38.93	42.87	47.07	50.50					
T_2D	22.20	25.20	28.73	30.87	34.07	36.80	39.60	49.80	58.47	66.40	73.07	71.93	75.07	77.57	79.33	80.47
T_3D	19.27	22.00	26.40	29.33	31.87	34.33	37.07	45.20	51.27	55.73	58.73					
T_4D	18.60	22.67	26.07	29.13	32.80	36.20	39.00	47.27	52.67	57.53	58.77					
T_5D	21.07	24.33	28.67	32.40	36.27	40.07	43.27	49.60	54.53	58.20	60.93					
Mean (D)	19.09	24.40	26.36	29.41	32.76	35.88	38.62	46.16	51.96	56.98	60.40					
CD (0.05)																
Varieties x Conditions	3.37	3.85	3.36	4.42	5.07	6.43	7.12	6.12	5.64	5.85	6.14					
Conditions	1.51	1.72	1.50	1.97	2.26	2.87	3.18	2.75	2.52	2.61	2.74					

harvest stage. Plant girth of T_2H and T_2D differ significantly upto four MAP and the treatments were on par in the fifth, sixth and seventh MAP. There was significant difference from the eight MAP upto harvest stage, with an average value of 92.30 cm in T_2H and 80.46 cm in T_2D. T_3H and T_3D differed significantly only during the first two MAP, with average values of 62.13 cm and 58.73 cm respectively at harvest stage. T_4H and T_4D differed significantly in the early stages of plant growth and were on par from the fourth MAP. At harvest stage T_4H had an average girth of 63.27 cm and that of T_4D was 58.77 cm. T_5H and T_5D differed significantly upto the second MAP and later on the treatments were comparable with average values of 66.93 cm and 60.93 cm respectively at harvest stage.

4.3.3 Number of leaves

The number of leaves produced at monthly intervals is presented in Table 3. The results indicated that there was significant difference in the healthy and diseased plants in the number of leaves produced only at some stages of plant growth. T_1H and T_1D were on par in the first two MAP and also from the eight MAP, while the treatments differed significantly in all the other months. The treatments T_2H and T_2D were comparable upto the ninth MAP and differed significantly only at harvest stage. T_3H and T_3D were also on par at all stages of plant growth except two MAP. The treatments T_4H and T_4D were on par at all the stages of growth except in the first two months. T_5H and T_5D also did not vary significantly during the different months after planting except during the first month.

Table 3. Effect of BBrMV infection on the number of leaves

Treatments	Month after planting															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
T_1H	3.53	4.13	6.20	7.33	9.13	10.93	10.73	9.33	8.80	7.80	6.17					
T_2H	2.87	3.60	5.40	6.13	6.93	7.73	8.53	9.67	10.27	10.80	11.07	11.00	9.93	9.73	9.57	8.76
T_3H	4.20	4.53	6.00	6.53	7.53	8.73	9.13	9.13	9.07	8.73	7.60					
T_4H	3.53	5.13	6.07	6.47	6.87	7.67	8.07	8.67	9.07	9.13	7.83					
T_5H	3.53	5.07	6.60	8.00	9.40	11.20	11.13	10.33	9.93	9.47	8.23					
Mean (H)	3.53	4.49	6.05	6.89	7.97	9.25	9.52	9.43	9.43	9.19	8.18					
T_1D	3.33	4.00	4.93	5.40	6.00	7.00	8.20	8.00	8.07	7.40	6.07					
T_2D	2.87	3.47	5.13	5.93	6.60	7.33	8.27	9.27	9.73	9.60	9.00	8.93	8.30	8.47	8.30	8.30
T_3D	3.93	4.67	5.13	6.13	7.40	8.40	9.33	9.07	8.60	8.07	6.80					
T_4D	3.13	4.07	4.60	5.53	6.13	7.33	8.53	8.60	8.93	8.60	7.00					
T_5D	3.40	4.00	6.00	7.47	9.27	11.07	10.40	10.00	9.40	8.47	7.93					
Mean (D)	3.33	4.04	5.16	6.09	7.08	8.23	8.95	8.98	8.95	8.43	7.36					
CD (0.05)																
Varieties x Conditions	0.50	0.68	0.75	1.03	1.32	1.82	1.29	0.83	0.92	1.27	1.38					
Conditions	0.23	0.30	0.33	0.46	0.59	0.82	0.58	0.37	0.41	0.57	0.62					

4.3.4 Leaf production rate

The rate of leaf production per month is shown in Table 4. The results indicated that there was significant difference between the healthy and diseased plants in all the treatments. Highest leaf production rate was observed in T_3H (5.40) and lowest in case of T_4D (3.40).

4.3.5 Leaf area index

The leaf area index of leaves taken at three different stages *ie.* maximum vegetative growth stage, flowering stage and shooting stage are presented in Table 5. There was considerable difference in the leaf area index between the healthy and diseased plants in all the varieties in all the three growth stages. Maximum leaf area index was observed in T_2H (2.00) at shooting stage and minimum in T_1D (0.70) at shooting stage.

4.3.6 Time taken for flowering (days)

The number of days taken for flowering varied significantly only between treatments T_1H (258.67 days) and T_1D (293.33 days). Diseased plants took more number of days for flowering when compared to the healthy plants. T_2D took the longest time to flower (419.20 days) and T_1H took the shortest time (258.67 days). (Table 6)

4.3.7 Time taken for harvest (days)

The days taken from planting to harvest did not differ significantly in all the treatments except between T_1H (341.47 days) and T_1D (378.67 days). T_2D took the

Table 4. Effect of BBrMV infection on the leaf production rate (per month)

Treatments	
T_1H	4.90
T_2H	5.06
T_3H	5.40
T_4H	4.90
T_5H	4.53
Mean (H)	4.96
T_1D	4.16
T_2D	3.73
T_3D	3.97
T_4D	3.40
T_5D	3.67
Mean (D)	3.78
CD (0.05) Varieties x Conditions Conditions	 0.69 0.31

Table 5. Effect of BBrMV infection on the leaf area index

Treatments	Maximum. vegetative growth stage	Flowering stage	Shooting stage
T_1H	0.86	1.12	1.17
T_2H	0.95	1.75	2.00
T_3H	0.76	1.10	1.23
T_4H	0.68	0.97	1.19
T_5H	0.75	0.11	1.21
Mean (H)	0.803	1.21	1.36
T_1D	0.34	0.65	0.70
T_2D	0.45	0.88	1.08
T_3D	0.49	0.73	0.89
T_4D	0.45	0.69	0.81
T_5D	0.53	0.65	0.97
Mean (D)	0.45	0.72	0.89
CD (0.05) Varieties x Conditions Conditions	0.14 0.06	0.13 0.06	0.12 0.05

longest time to harvest (531.07 days) and T_1H took the shortest time (341.47 days). (Table 6)

4.3.8 Bunch maturity period (days)

The results indicated in Table 6 shows that BBrMV infection increases the bunch maturity period. The treatments T_1H (82.80 days) and T_1D (85.53 days) and also T_5H (104.53 days) and T_5D (108.73 days) were on par, while the other treatments showed significant difference in the bunch maturity period. The highest value noted for the time taken for bunch maturity was in case of T_2D (111.90) and lowest value was recorded by T_1H (82.80 days).

4.3.9 Number of suckers per plant at harvest time

All the treatments differed significantly in the number of suckers present per plant at harvest time except the treatments T_3H (3.40) and T_3D (2.73) (Table 6). Maximum number of suckers was produced in the treatment T_2H (4.90) and lowest number by the treatment T_1D (2.07). It could be noted that in all the diseased plants lower number of suckers were present during harvest stage when compared to the healthy plants.

4.4 Yield characters

4.4.1 Bunch weight (kg)

There was significant difference in bunch weight due to the disease among the various treatments. The disease was found to decrease the bunch weight considerably.

Table 6. Effect of BBrMV infection on the time taken for flowering, harvest, bunch maturity and number of suckers

Treatments	Time taken for flowering	Time taken for harvest	Time taken for bunch maturity	Number of suckers
T_1H	258.67	341.47	82.80	4.00
T_2H	408.07	512.67	104.60	4.90
T_3H	288.73	379.47	90.73	3.40
T_4H	296.47	393.00	96.53	3.87
T_5H	287.67	392.07	104.53	4.53
Mean (H)	307.92	403.73	95.84	4.14
T_1D	293.33	378.67	85.53	2.07
T_2D	419.20	531.07	111.90	3.63
T_3D	307.20	406.07	98.87	2.73
T_4D	304.87	413.33	108.47	2.87
T_5D	300.47	409.20	108.73	3.40
Mean (D)	325.01	427.67	102.70	2.93
CD (0.05) Varieties x Conditions	29.17	29.69	5.68	0.67
Conditions	13.05	13.28	2.54	0.30

Table 7. Effect of BBrMV infection on the yield characters

Treatments	Bunch weight (kg)	No.of hands	No.of fingers	Length of finger (cm)	Girth of finger (cm)	Weight of finger (g)
T_1H	6.67	4.60	37.53	20.37	14.80	224.00
T_2H	9.43	5.00	61.30	14.97	15.10	189.67
T_3H	13.20	8.33	112.53	20.90	14.27	180.33
T_4H	12.67	11.93	186.93	11.03	10.70	74.67
T_5H	10.20	10.60	181.07	9.30	9.00	54.67
Mean (H)	10.43	8.09	115.87	15.31	12.77	144.67
T_1D	3.43	3.60	23.73	14.40	10.97	98.33
T_2D	4.80	3.80	43.50	12.83	12.77	164.33
T_3D	9.83	7.00	90.60	15.00	11.73	119.33
T_4D	9.67	9.93	157.73	9.10	8.83	55.33
T_5D	7.43	9.47	163.13	8.03	7.97	37.67
Mean (D)	7.03	6.76	95.74	11.87	10.45	95.00
CD (0.05) Varieties x Conditions	1.97	1.01	18.42	1.56	1.05	15.68
Conditions	0.88	0.45	8.23	0.69	0.47	7.01

The percentage decrease in bunch weight due to the disease in the various varieties is T_1 (48.57 %), T_2 (49.09 %), T_3 (25.5 %), T_4 (23.68 %) and T_5 (27.16 %). The highest mean bunch weight of 13.20 kg per plant was recorded by the treatment T_3H and it was on par with the treatment T_4H (12.67 kg per plant). The treatment T_1D showed the lowest mean bunch weight (3.43 kg per plant) (Table 7).

Disease scoring was done at four stages of plant growth *ie.* at the time of planting, maximum vegetative growth stage, flowering stage and at harvest stage. Correlation was worked out between the disease caused and the yield of individual plant and it was found to be significant at all stages. Maximum correlation was found at flowering stage (0.52) and harvest stage (0.56). Having established the correlation of the disease score with the yield at the later phases of crop growth *viz.*, flowering stage and harvest stage, the yield was adjusted for the variation in the disease score at these two stages. Analysis of covariance was hence resorted to with the disease score at the flowering stage as the covariate and also the disease score at harvest stage separately. The mean yield adjusted for the disease scores is given in Table 8. The adjusted values at flowering stage will be more helpful for an early prediction and hence given more importance than the adjusted values at harvest stage. It may be noted from the table that T_3, T_4 and T_5 were superior in respect of the yields obtained, than T_1 and T_2 and the adjusted values for these two varieties were only slightly less than that of the actual yield levels, indicating that the disease impact on the yield for these two varieties is marginal. It was also noted that the adjusted yield levels of the variety T_2 was considerably higher

Table 8. Association between disease score and plant yield

Treatments	Mean disease score		Yield (kg / plant)		
	At flowering stage	At harvest stage	Actual yield	Adjusted for the disease score	
				At flowering stage	At harvest stage
T_1	2.46	2.47	2.97	3.17	3.45
T_2	2.53	2.60	4.80	5.22	4.68
T_3	2.20	2.67	9.83	9.70	9.81
T_4	2.00	2.33	9.67	9.20	9.15
T_5	2.27	2.80	7.43	7.41	7.61
CD (0.05)				1.17	0.99

than that of the actual levels. This could be due to the fact that this variety is more susceptible to the disease. Variety T_1 was found to be yielding the lowest (3.17 kg/plant) even after adjustment of the disease score at flowering stage. No other variety yielded so low.

4.4.2 Number of hands / bunch

The results showed that significant difference in the number of hands between treatments T_2H (5.00) and T_2D (3.80), T_3H (8.33) and T_3D (7.00) and T_5H (10.60) and T_5D (9.47), while there was no significant difference between treatments T_1H (4.60) and T_1D (3.60) and T_4H (11.93) and T_4D (9.93). Maximum number of hands was produced by the treatment T_4H (11.93) and the lowest number by the treatment T_1D (3.60) (Table 7).

4.4.3 Number of fingers / bunch

The observations in the Table 7 indicate that, there was significant difference in the number of fingers among treatments. Maximum number of fingers per bunch (186.93) was noticed in T_4H and was on par with T_5H (181.07). The number of fingers per bunch was lowest for the treatment T_1D (23.73) (Table 7).

4.4.4 Length of finger (cm)

The length of fingers indicated in Table 7 showed significant difference among treatments except T_5H (9.30) and T_5D (8.03) which were on par. T_3H recorded the highest value (20.90 cm) while the treatment T_5D registered the lowest value (8.03 cm).

4.4.5 Girth of finger (cm)

Significant differences between the healthy and diseased fruits were noticed on this character (Table 7). T_2H registered maximum girth of finger (15.10 cm) followed by T_1H (14.80 cm). T_5D recorded the lowest value of 7.97 cm.

4.4.6 Weight of the finger (g)

As evident from Table 7, the disease had significantly affected the weight of finger. The weight of the diseased fingers was found to be less when compared to the healthy fruits. The maximum finger weight of 224 g was recorded in T_1H. The lowest weight of finger (37.67 g) was recorded by T_5D.

4.5 Biochemical changes of host pathogen interaction

4.5.1 Estimation of total carbohydrate

The estimation was done according to the procedure given by Hedge and Hofreiter (1962). The disease significantly influenced carbohydrate content at all stages of analyses (Table 9).

In the case of healthy nendran plants (T_1H) the carbohydrate content was on par with the diseased plants of the same (T_1D) at all stages of analyses with the exception of bract, where there was significant difference. Healthy red banana plants (T_2H) were also on par with the diseased plants (T_2D) of the same at all stages of analyses except in the carbohydrate content of the flag leaf. Significant difference was observed in the

Table 9. Changes in total carbohydrate content (mg / g) of banana plants in response to BBrMV infection

Treatments	3 MAP	6 MAP	% increase from 3 MAP to 6 MAP	Flag leaf	Bract
T_1H	9.47	26.47	179.59	16.53	28.93
T_2H	10.33	22.40	116.84	43.87	17.47
T_3H	13.13	36.00	174.18	20.70	4.67
T_4H	12.93	23.93	85.07	26.20	10.33
T_5H	17.73	22.13	24.82	20.73	5.80
Mean (H)	12.72	26.19		25.61	13.44
T_1D	7.87 (-16.90)	23.47 (-11.33)	198.22	26.53 (60.50)	62.67 (60.98)
T_2D	8.80 (-14.81)	19.00 (-15.81)	115.91	21.67 (-50.60)	19.73 (12.94)
T_3D	6.07 (-53.77)	19.03 (-47.14)	213.51	21.47 (3.72)	7.33 (56.96)
T_4D	10.40 (-19.57)	18.33 (-23.40)	76.25	20.67 (-21.11)	28.13 (172.31)
T_5D	12.67 (-28.54)	18.60 (-15.95)	46.80	29.07 (40.23)	8.07 (39.14)
Mean (D)	9.16	16.69		23.88	25.19
CD (0.05) Varieties x conditions	6.87	9.17		12.02	6.53
Conditions	3.07	4.10		5.37	2.92

Figures given in parenthesis is % increase or decrease over healthy

carbohydrate content of healthy (T_3D) and diseased (T_3D) robusta plants three MAP and six MAP and the treatments were on par in the carbohydrate content of the flag leaf and bract. Healthy palayankodan plants (T_4H) and diseased plants (T_4D) did not differ significantly in the carbohydrate content at all stages of analyses except in the carbohydrate content of bracts. Healthy (T_5H) and diseased (T_5D) rasakadali plants were on par in the carbohydrate content at all stages of plant growth.

In general, the carbohydrate content was higher in the healthy plants in comparison to the diseased plants of all five varieties three MAP and six MAP. The percentage increase in carbohydrate content in both healthy and diseased plants from three MAP to six MAP is shown. The table indicates that maximum increase was observed in T_3D (213.51 %) and the least was by T_5H (24.82 %).

Carbohydrate content in the flag leaf was more in the diseased plants than healthy ones in all varieties except red banana and palayankodan. Carbohydrate content of the bract was more in the diseased plants of all the varieties. The percentage increase or decrease of the carbohydrate content over healthy plants is shown in parenthesis.

4.5.2 Estimation of chlorophyll (Table 10)

4.5.2.1 Total chlorophyll

The results indicated that there was considerable reduction in the chlorophyll content of diseased plants when compared with the healthy plants. The total chlorophyll content of healthy (T_1H) and diseased (T_1D) nendran plants were on par in all the three

Table 10. Changes in chlorophyll contents (mg / g leaf tissue) of banana plants in response to BBrMV infection

	Total chlorophyll				Chlorophyll 'a'				Chlorophyll 'b'			
Treatments	3 MAP	6 MAP	Y.decrease from 3 MAP to 6 MAP	Flag leaf	3 MAP	6 MAP	Y.decrease from 3 MAP to 6 MAP	Flag leaf	3 MAP	6 MAP	Y.decrease from 3 MAP to 6 MAP	Flag leaf
T_1H	1.66	0.64	61.45	2.30	1.24	0.39	68.55	1.74	0.42	0.25	40.47	0.56
T_2H	2.32	0.33	85.77	1.69	1.77	0.19	89.26	1.16	0.56	0.14	75.00	0.53
T_3H	2.95	0.80	72.88	1.85	2.23	0.57	74.44	1.56	0.72	0.24	66.67	0.29
T_4H	2.74	0.74	72.99	1.27	2.00	0.54	73.00	0.97	0.74	0.20	72.97	0.30
T_5H	2.33	0.55	76.39	1.48	1.83	0.47	74.32	1.17	0.49	0.08	83.67	0.31
Mean (H)	2.40	0.61		1.72	1.82	0.43		1.38	0.58	0.18		0.34
T_1D	1.52 (-8.43)	0.50 (-21.87)	67.11	2.01 (-12.61)	1.14 (-8.06)	0.40 (2.56)	64.91	1.48 (-14.94)	0.37 (-11.90)	0.10 (-60.00)	75.67	0.53 (-5.20)
T_2D	1.44 (-37.93)	0.23 (-30.30)	84.03	1.10 (-34.91)	1.02 (-42.37)	0.14 (-26.32)	86.27	0.73 (-37.06)	0.42 (-25.00)	0.09 (-35.71)	78.57	0.36 (-32.00)
T_3D	1.12 (-62.03)	0.23 (-71.25)	79.46	1.03 (-44.32)	0.77 (-65.47)	0.18 (-68.42)	76.62	0.73 (-53.20)	0.34 (52.78)	0.05 (-79.17)	69.05	0.29 (0)
T_4D	1.62 (-40.87)	0.14 (-81.08)	91.35	1.09 (-14.17)	1.07 (-46.50)	0.12 (-77.77)	88.78	0.80 (-17.53)	0.54 (-27.03)	0.02 (-90.00)	96.29	0.28 (-6.63)
T_5D	1.64 (-29.61)	0.20 (-63.64)	87.80	1.01 (-31.76)	1.36 (-25.68)	0.15 (-68.08)	88.97	0.76 (-35.04)	0.24 (-51.02)	0.05 (-37.50)	79.17	0.25 (-19.35)
Mean (D)	1.47	0.26		1.25	1.07	0.20		0.90	0.39	0.06		0.34
CD (0.05) Varieties x conditions	0.41	0.17		0.34	9.31	0.10		0.27	0.19	0.08		0.11
Conditions	0.18	0.07		0.15	0.14	0.04		0.12	0.09	0.04		0.05

stages of analyses. T_2H and T_2D differed significantly three MAP and in the flag leaf stage, while the treatments were on par six MAP. T_3H and T_5H when compared with T_3D and T_5D respectively were found to be significantly different in the total chlorophyll content in all the stages of analyses. Total chlorophyll content of T_4H and T_4D were significantly different at three and six MAP, while the treatments were on par in the flag leaf stage.

In general there was a decrease in the total chlorophyll content from three MAP to six MAP. The table indicates that maximum decrease was observed in T_4D (91.35 %) and the least was by T_1H (61.45 %).

The percentage increase or decrease of the chlorophyll content over healthy plants is also shown in parenthesis.

4.5.2.2 Chlorophyll 'a' and 'b'

Chlorophyll 'a' was found to be higher than chlorophyll 'b' at all stages of analyses and in all the five varieties.

Chlorophyll 'a' showed the same trend in all the varieties as in the case of total chlorophyll.

Chlorophyll 'b' differed significantly in treatments T_3H, T_4H and T_5H when compared with the diseased plants of the respective varieties at three MAP, while the same varieties were on par in the flag leaf stage. T_1H and T_2H that were on par with the respective diseased plants three MAP were found to differ significantly in the flag leaf

stage. Treatments T_5H and T_5D were found to be on par six MAP, while the other treatments differed significantly six MAP.

4.5.3 Estimation of total phenols

The estimation was done according to the procedure given by Bray and Thorpe (1954). Phenol content was significantly influenced by the disease at all stages of analyses (Table 11).

The phenol content of T_1H was on par with T_1D three MAP and in the bract stage. In these two stages of analyses, the phenol content was lower in diseased plants when compared to that of healthy plants. There was significant difference six MAP and in the flag leaf stage.

T_2H and T_2D were significantly different in the content of phenol at all stages of analyses, with the exception of bract. The diseased plants had more phenol content at all stages of analyses.

The treatments T_3H and T_3D were on par at all stages of analyses, except in the phenol content of bract, which differed significantly. It was also found that the phenol content was more in T_3D than T_3H at all stages of analyses, except in the bract.

Phenol content of T_4H and T_4D were on par at three and six MAP while they differed significantly in the flag leaf stage and bract. The phenol content was found to be more in T_4D at all stages of analyses, with the exception of bract.

Table 11. Changes in total phenol content (mg /g sample) of banana plants in response to BBrMV infection

Treatments	3 MAP	6 MAP	% increase from 3 MAP to 6 MAP	Flag leaf	Bract
T_1H	2799.7	1977.6	-29.36	2777.5	372.2
T_2H	1822.1	1410.9	-22.57	2355.3	289.9
T_3H	2088.7	2566.4	22.87	2977.5	605.5
T_4H	2933.0	2588.7	-11.74	2955.3	1044.3
T_5H	2144.2	1688.7	-21.24	2877.5	777.7
Mean (H)	2357.5	2046.5		2788.6	617.9
T_1D	2721.9 (-2.78)	2744.0 (38.46)	0.81	3577.4 (28.79)	268.9 (-27.75)
T_2D	2366.5 (29.88)	3699.6 (162.22)	56.33	3921.8 (66.51)	363.3 (25.32)
T_3D	2122.0 (1.59)	3221.9 (25.54)	51.83	2944.2 (-1.12)	394.4 (-34.86)
T_4D	2944.2 (0.38)	3166.4 (22.32)	7.55	3377.4 (14.28)	783.3 (-24.99)
T_5D	3177.4 (48.18)	2410.9 (42.77)	-24.12	3088.6 (7.34)	524.4 (-32.57)
Mean (D)	2666.4	3048.6		3381.9	466.8
CD (0.05) Varieties x conditions	484.16	705.2		368.02	183.19
Conditions	216.52	315.40		164.58	81.92

Figures given in parenthesis is % increase or decrease over healthy

T_5H and T_5D were significantly different at all stages of analyses, except in the flag leaf stage. The phenol content was more in T_5D at all stages of analyses, except in the bract.

The percentage increase or decrease in phenol content in both healthy and diseased plants from three MAP to six MAP as shown in the table indicates that there is an increase in phenol content in all the diseased plants except T_5D and that there was decrease in phenol content in all healthy plants except T_3H.

4.5.4 Estimation of defence related enzymes

4.5.4.1 Peroxidase (PO)

The peroxidase activity of T_1H and T_1D were significantly different 3 MAP and 6 MAP and were on par in the flag leaf stage and bract. T_2H and T_2D were on par in the peroxidase activity at all stages of analyses except in the flag leaf stage. The treatments T_3H and T_4H when compared with T_3D and T_4D respectively were on par at all stages of analyses except 3 MAP. Peroxidase activity of T_5H and T_5D were also on par on the flag leaf stage and bract and differed significantly 3 MAP and 6 MAP (Table12).

There was increased peroxidase activity in both T_1H and T_1D 6 MAP when compared to 3 MAP. The peroxidase activity was found to be decreased in all the other treatments. Activity was more in diseased plants than in healthy plants at all stages of analyses.

Table 12. Changes in peroxidase activity (per minute per gram tissue) in banana plants in response to BBrMV infection

Treatments	3 MAP	6 MAP	Flag leaf	Bract
T_1H	1.11	2.63	0.08	0.01
T_2H	1.78	1.75	0.99	1.15
T_3H	2.16	1.41	0.10	1.27
T_4H	2.12	1.65	0.06	0.69
T_5H	1.31	1.12	0.08	1.15
Mean (H)	1.69	1.71	0.26	0.85
T_1D	3.07	3.88	0.13	0.48
T_2D	2.71	1.87	1.53	1.25
T_3D	3.95	1.81	0.13	2.35
T_4D	3.51	2.53	0.11	0.75
T_5D	3.66	2.87	0.10	2.03
Mean (D)	3.38	2.59	0.40	1.37
CD (0.05) Varieties x conditions	1.23	0.93	039	1.08
Conditions	0.55	0.41	0.18	0.48

Table 13. Changes in polyphenol oxidase activity (per minute per gram tissue) in banana plant in response to BBrMV infection

Treatments	3 MAP	6 MAP	Flag leaf	Bract
T_1H	0.59	0.75	0.93	0.02
T_2H	0.50	0.52	0.44	0.25
T_3H	0.52	0.26	0.98	0.36
T_4H	0.63	0.56	0.82	0.12
T_5H	0.57	0.59	1.16	0.23
Mean (H)	0.56	0.54	0.86	0.19
T_1D	0.94	0.75	1.16	0.17
T_2D	0.51	0.60	0.49	0.28
T_3D	0.74	0.56	1.31	0.45
T_4D	0.74	0.92	0.84	0.12
T_5D	0.78	0.99	1.51	0.23
Mean (D)	0.74	0.76	1.06	0.26
CD (0.05) Varieties x conditions	0.33	0.33	0.36	0.09
Conditions	0.15	0.15	0.16	0.04

Table 14. Changes in pheylalanine ammonia-lyase activity (µM. trans cinnamic acid / h /g fresh weight) in banana plants in response to BBrMV infection

Treatments	3 MAP	6 MAP	Flag leaf	Bract
T_1H	301.13	796.12	1253.02	3184.49
T_2H	321.90	785.73	2911.04	7587.39
T_3H	304.60	401.52	903.42	4655.58
T_4H	481.13	636.98	1502.25	5143.64
T_5H	512.28	979.56	1090.34	6427.82
Mean (H)	384.21	719.98	1532.01	5399.78
T_1D	522.67	1138.80	1342.91	4769.81
T_2D	415.37	1038.42	4153.68	7926.61
T_3D	325.37	761.50	1128.41	5285.56
T_4D	584.87	851.48	2142.61	5690.55
T_5D	581.55	1142.27	1519.55	7590.86
Mean (D)	485.96	986.49	2057.43	6252.68
CD (0.05) Varieties x conditions	165.79	185.98	277.46	940.87
Conditions	74.14	83.17	124.08	420.77

4.5.4.2 Polyphenol oxidase (PPO)

The polyphenol oxidase activity of T_1H and T_1D were significantly different 3MAP and in the bract and were on par 6 MAP and in the flag leaf stage. The treatments T_2H and T_3H when compared with T_2D and T_3D respectively were found to be on par at all stages of analyses. PPO activity of T_4H and T_5H when compared with T_4D and T_5D were found to be comparable at all stages of analyses, except 6 MAP (Table 13).

PPO activity was found to be more in diseased plants than in healthy plants at all stages of analyses.

4.5.4.3 Phenylalanine ammonia-lyase (PAL)

The PAL content of T_1H and T_1D were found to be significantly different at all stages of analyses except in the flag leaf stage. The treatments T_2H and T_2D were on par 3 MAP and in the bract, while they differed significantly 6 MAP and in the flag leaf stage. T_3H and T_3D were found to be comparable at all stages of analyses, except 6 MAP. PAL content of T_4H and T_4D were found to be on par 3 MAP and in the bract PAL content while they differed significantly 6 MAP and in the flag leaf stage. T_5H and T_5D were found to be on par 3 MAP and 6MAP and differed significantly in the flag leaf stage and in bract (Table 14).

The PAL activity was found to increase progressively in both the healthy and diseased plants and maximum value was recorded in the bract.

DISCUSSION

5. DISCUSSION

Banana is one of the most important fruit crop grown throughout the world, providing food security to millions of people. This is a crop with major export potential, but is seems to be nowhere in the word's export front. This is mainly due to the diseases and pests of banana. Among these, the viral diseases have significant impact and at present the banana bract mosaic disease is of much importance.

5.1. Survey

Survey was carried out in two wards of Kalliyoor panchayat in Thiruvananthapuram district and it revealed that banana bract mosaic disease is widely prevalent in the area. Different types of symptoms like reddish brown/pinkish streaks, traveller's palm appearance, bract mosaic, necrotic streaks and reduced vegetative growth were observed.

In the present investigations, no variation in disease incidence and intensity was observed between the two wards.

5.2. Field experiment

5.2.1 Symptomatology

In the field studies conducted using the five different varieties of banana, it was found that the kokkan affected plants invariably produced the pinkish or reddish brown

streaks. The streaks were present on the sucker at the time of planting itself in diseased plants and were found to be present throughout the growth period of the crop, even though the intensity of the streaks varied in the different varieties. The observation was almost similar to that by Estelitta *et al.* (1996 a). They had also observed that the symptoms appear first on the leaf sheath as longitudinal irregular, reddish or pinkish streaks of varying sizes. Necrotic streaks were seen on the leaf petiole, leaf sheaths and pseudostem of nendran and palayankodan varieties. Ravi *et al.* (1992) studied the significance of necrotic streaks in the Kokkan disease of banana and found that the production of abnormal bunches depend on the intensity and duration of occurrence of the streaks. Other characteristic symptoms observed were the traveller's palm appearance, bract mosaic and streaks on the male flowers. Balakrishnan *et al.* (1996) reported the association of the disease with changes in aestivation, giving the plants the appearance of traveller's palm. The presence of discontinuous streaks on the bracts of the banana inflorescence was reported by Rodoni *et al.* (1997). Thomas and Magnaye (1996) have described the presence of bract mosaic as a confirmatory symptom of the disease, which distinguishes the diseases from all other known virus diseases of banana. Balakrishnan *et al.* (1996) had observed that the male buds become dark purple with pale streaks in case of infection by BBrMV. The present study is in confirmation with this observation but in case of red banana, the healthy male flowers only produced the reddish streaks. This may be because of disruption of production of anthocyanins due to virus infection. Mosaic symptoms on the leaf lamina were observed, even though it did not

occur on all kokkan affected plants. This findings is in confirmation with the findings of Thomas and Magnaye (1996) and Rodoni *et al.* (1997). Symptoms like reddish streaks on the peduncle and fruits, small and deformed bunches and separation of leaf sheaths from the pseudostem were observed. Similar results were also reported by Estelitta *et al.* (1993), Balakrishnan *et al.* (1996) and Radhakrishnan and Geetha (1996).

5.3 Biometrical characters

In general changes in morphological and biometrical characters in a plant may lead to change in the yield of that plant. In the present study the effect of kokkan disease on the different growth parameters were studied.

The results indicated a significant reduction in plant height in BBrMV infected plants of all varieties by harvest time except in case of robusta variety. Plant girth was also comparatively reduced in diseased plants even though at harvest stage it was significantly different only in redbanana plants. This is in agreement with the finding of Rodoni *et al.* (1997).

The present findings revealed that the number of leaves present at monthly intervals varied significantly at all stages of growth except at the time of planting. The leaf production rate and leaf area index were also significantly reduced due to BBrMV infection. Contrary to the present findings, Estelitta *et al.* (1996 a) reported that the kokkan affected plants bear leaves of almost normal size. But supporting the present

findings Rodoni *et al.* (1997) has found that in case of severely infected plants the leaves were distorted.

The time taken for flowering, bunch maturity and harvest was more in the kokkan affected plants in all varieties. But significant difference in the time taken for harvest and flowering was found only in nendran variety. Time taken for bunch maturity was significantly different only in redbanana, robusta and palayankodan. Balakrishnan *et al.* (1996) reported that the fruits of infected plants took longer time to ripen compared to healthy fruits Radhakrishnan and Geetha (1996) observed that the diseased plants took 20-25 days more for flowering compared to healthy ones.

The number of suckers produced per plant was found to be less in diseased plants and was found to differ significantly in all the varieties except robusta.

5.4 Yield characters

The present study was mainly intended to study the effect of BBrMV infection on the yield of banana plants. The results clearly indicated that BBrMV infection significantly affected the bunch weight, weight of finger and girth of finger in all the varieties. The length of fingers was also significantly affected in all varieties except in rasakadali, but here also the length was comparatively less. The number of hands present was significantly affected in the varieties redbanana, robusta, and rasakadali. A significant reduction in the number of fingers was observed in robusta and palayankodan only. The maximum reduction in bunch weight due to infection by BBrMV was observed

in redbanana (49.09 %) followed by nendran (48.57 %). Palayankodan was comparatively more resistant (23.68 %), followed by robusta (25.50 %) and rasakadali (27.16 %).

Many workers have reported the reduction in bunch weight and size due to kokkan disease (Samraj *et al.*, 1966; Ravi *et al.*, 1992; Estelitta *et al.*, 1996a, Radhakrishnan and Geetha, 1996; Thomas and Magnaye, 1996; Rodoni *et al.*, 1997).

Disease scores were correlated with the yields and high correlation was obtained in all the four stages analysed, even though maximum correlation was obtained in the flowering and harvest stages. With the increase in the intensity of the streaks, high reduction in yield was noted and so it can be concluded that the proposed 0-4 scale is effective in assessing the yield losses caused by kokkan disease.

5.5 Biochemical changes of host pathogen interaction

Plant virus infections will always produce some biochemical changes in the host plants. Such changes may be different in diseased and healthy plants and may vary with the age of the crop and the virulence of the pathogen.

5.5.1 Total Carbohydrates

The present study revealed that total carbohydrate content was significantly altered in both healthy and diseased varieties due to BBrMV infection. An increase in value was noted for healthy plants 3 MAP and 6 MAP. In the flag leaf stage healthy redbanana and palayankodan plants showed an increase while the other varieties showed

a decrease in the carbohydrate content. In the bract stage, the diseased plants showed an increase in carbohydrate content than the healthy plants. Studies on the changes in total carbohydrates due to BBrMV infection had not been conducted earlier. However, many authors reported increased carbohydrates content (Nair and Wilson, 1972; Mayoral *et al.*, 1989; Radhika, 1999; Sweich *et al.*, 2001) and decreased (Ramaiah, 1978; Johri and Padhi 1985; Shukla *et al.*, 1992; Sarma *et al.*, 1995; Thind *et al.*, 1996 and Srivastava and Tiwari, 1998) total carbohydrate content due to viral infections in various plants.

Narayanasamy and Ramakrishnan (1966) suggested that reduction in the level of carbohydrate in virus inflected plants to provide the substrate for accelerated respiration. Estelitta *et al.* (1993) reported that a good number of starch granules were found in the kokkan affected flower primordia when compared to the healthy one. This finding explains the presence of more carbohydrate in the diseased bracts when compared to the healthy ones.

5.5.2 Chlorophyll

In general in the present study total chlorophyll, chlorophyll a and chlorophyll b were considerably reduced in the diseased plants, though not significant at all stages of plant growth analysis.

The reduction in total chlorophyll, chlorophyll a and chlorophyll b content was also reported by many other workers in other crops (Johri and Padhi 1995; Shukla *et al.*, 1992; Sarma *et al.*, 1995; Dantre *et al.*, 1996; Thind *et al.*, 1996). The reduction in

chlorophyll content might be due to increased chlorophyllase activity as observed by Ramiah *et al.* (1978) and Ahmed *et al.* (1992).

5.5.3 Total phenols

Accumulation of phenolics is a capacity endowed within the plants to defend itself against pathogens.

In the present study, it was found that the levels of phenolic content increased in response to BBrMV infection in almost all the varieties at all stages of analysis, except in the bract stage.

Perusal of the available literature showed that earlier workers did not investigate the importance of phenolic compounds in providing resistance against virus diseases of banana.

Increase in total phenols due to virus infection was reported by many workers in other crops (Ahmed *et al.*, 1992; Sarma *et al.*, 1995; Banerjee and Kalloo, 1998; Srivastava and Tiwari, 1998).

5.5.4 Defence related enzymes

Defence related enzymes are reported to play an important role in the induction of resistance (Dasgupta, 1988).

The present study revealed that there was an increase in the activity of PO and PPO in kokkan affected plants, but significant difference between healthy and diseased plants could be observed only at some stages of analysis. The change in phenylalanine

ammonia-lyase was also comparatively higher in the diseased plants but was significant only at some stages of analysis and varied between varieties. Sohal and Bajaj (1993) reported that there was no change in PAL and PO activity due to mungbean yellow mosaic virus in both susceptible and resistant varieties tested.

Ahmed *et al.* (1992) suggested that higher amount of phenols and their oxidation products like quinones formed by increased peroxidase and polyphenol oxidase may be responsible for reduced virus multiplication and finally could lead to resistant reaction in yellow vein mosaic virus infected okra. Similar results were obtained by Zaidi *et al.* (1992) in carnation etched ring virus and found that the substantial increase in the level of PAL activity along with the increase in phenolic content in response to infection, show a good correlation and suggest that virus infection has altered the activity of enzyme (s) of phenyl propanoid pathway and hence lead to accumulation of phenolics. Increased levels of PPO activity was also observed by Pal *et al.* (1989) in bell pepper dwarf mosaic virus infection, Yunzhu *et al.* (1997) in soyabean mosaic virus infection and by Cuiming *et al.* (1999) with the same virus.

SUMMARY

SUMMARY

The present study, "Effect of Kokkan disease caused by banana bract mosaic virus on the growth and yield of banana" was carried out at the Instructional Farm, College of Agriculture, Vellayani during 2000-2001. The objective of the research programme was to assess the effect of 'kokkan' disease caused by banana bract mosaic virus (BBrMV) on the growth and yield of five common varieties of banana, viz.,nendran, redbanana, robusta, palayankodan and rasakadali (njalipoovan).

The salient findings of the study are summarized below.

A survey conducted in two wards of Kalliyoor Panchayat in Thiruvananthapuram district showed that the disease was widespread in these areas. In both the wards, there was significant difference between the varieties in the percentage of incidence of the disease and was highest in red banana. Ten diseased plants were randomly scored to find the intensity of incidence of the disease and was found to be comparable in the two wards.

Typical symptoms of kokkan disease like the reddish brown / pinkish streaks traveller's palm appearance, bract mosaic, necrotic streaks and reduced vegetative growth were observed.

Symptomatology of diseased plants was studied from the field experiment using five varieties of banana, *viz.*, nendran, redbanana, robusta, palayankodan and rasakadali

(njalipoovan). The characteristic symptom of kokkan was found to be invariably the presence of reddish brown / pinkish streaks which are present on the pseudostem throughout the growth period of the crop. Changes in aestivation of the plants giving the appearance of 'traveller's palm', discontinuous streaks on the bracts, necrotic streaks on the leaf sheaths and leaf petiole, pinkish streaks on the male flowers, peduncle and leaf petiole, abnormal separation of the leaf sheaths from the pseudostem, leaf mosaic and small and deformed bunches were found to be other distinguishable symptoms of the disease.

Biometric characters were significantly influenced by the disease. There was a significant reduction in plant height, girth, number of leaves, leaf area index and leaf production rate in the diseased plants when compared to the healthy plants. The time taken for flowering and harvest was delayed in the diseased plants even though significant difference was observed only in nendran variety. Bunch maturity period was also delayed due to the disease in red banana, robusta and palayankodan. The number of suckers produced was lower in all the varieties with the exception of robusta.

The disease also significantly influenced yield characters. Red banana was found to be the most affected due to the disease in terms of percentage reduction in bunch weight (49.09 %) followed by nendran (48.57 %), rasakadali / njalipoovan (27.16 %), robusta (25.5 %) and palayankodan (23.68 %). The number of hands per bunch was significantly reduced in red banana, robusta and rasakadali. The number of fingers per bunch was significantly reduced in all the five varieties. The disease was found to have a

profound influence on the length, girth and weight of finger in all the varieties except in the length of finger of rasakadali.

The proposed 0-4 scale was found to be highly correlated with yields and it was found that as the intensity of the streaks increases there was reduction in yield. So the proposed scale is effective in assessing the yield losses caused by the disease.

The biochemical changes due to virus infection was studied in the diseased plants and compared with the healthy plants. The carbohydrate content in leaves of diseased plants was found to be lower, while in the bract the content was higher than the healthy plants. Significant increase in the level of phenol was observed in leaves of diseased plants and lower content was noted in the bract .The content of total chlorophyll, chlorophyll a and chlorophyll b was lower in the leaves of diseased plants. Activities of defence related enzymes like peroxidase, polyphenol oxidase and phenylalanine ammonia-lyase was higher in the diseased plants when compared to the healthy plants.

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APPENDIX –I

Buffers for enzyme analysis

0.1M sodium phosphate buffer (pH 6.5)

Stock solutions

A: 1.56 g of monobasic sodium phosphate ($Na\ H_2\ PO_4$) in 100 ml

B: 1.42 g of dibasic sodium phosphate ($Na_2\ H\ PO_4$) in 100 ml

68.5 ml of A is mixed with 31.5 ml of B

0.1M sodium borate buffer (pH 8.8)

A: 0.2 M solution of boric acid (12.4 g in 1000 ml)

B: 0.05 M solution of borax (19.05 g in 1000 ml)

50 ml of A is mixed with 30 ml of B, diluted to a total of 200 ml

EFFECT OF KOKKAN DISEASE CAUSED BY BANANA BRACT MOSAIC VIRUS ON THE GROWTH AND YIELD OF BANANA

BY

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ABSTRACT OF THE THESIS
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ABSTRACT

A study was conducted in the `Instructional Farm, College of Agriculture, Vellayani during 2000-2001 on the " Effect of kokkan disease caused by banana bract mosaic virus on the growth and yield of banana. A survey conducted in two wards of Kalliyoor panchayat revealed that red banana plants were the most affected by the disease followed by nendran. The intensity of incidence of the disease was found to be comparable in both the wards. Studies on symptomatology of the disease was carried out using five varieties of banana *viz*., nendran, redbanana, robusta, palayankodan and rasakadali (njalipoovan). The characteristic symptoms of the disease were reddish / pinkish streaks on the pseudostem, bract mosaic, 'traveller's palm', necrotic streaks, leaf mosaic, streaks on the male flowers, streaks on the peduncle and leaf petiole, separation of the leaf sheaths from the pseudostem, splitting of the leaf sheaths and small and deformed bunches. The disease significantly influenced the biometric characters. Plant height, girth, number of leaves, leaf production rate and leaf area index were significantly reduced in the diseased plants. Delay in time taken for flowering, bunch maturity and time taken for harvest were observed. The number of suckers produced was also reduced in the diseased plants. Significant reduction in bunch yield, weight of fingers, length of fingers, girth of fingers, number of fingers, number of hands could also be noted. The proposed 0-4 scale was found to be highly effective in estimating the yield losses caused

by the disease. Biochemical changes indicated a lower carbohydrate content in leaves of diseased plants and higher content in the bract. Phenol content was increased in the leaves of diseased plants and was decreased in the bract. Chlorophyll content decreased in the diseased plants due to virus infection. Peroxidase, polyphenol oxidase and phenylalanine ammonia-lyase activities increased in the diseased plants.