



Yield loss management through fertilizers in *Banana bract mosaic virus* affected French plantain cv. Nendran (AAB)

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ABSTRACT

Plant virus infection significantly reduces the yield of many horticultural crops causing reduction in the production and productivity. Higher fertilizer application has often to overcome the yield reduction due to virus in many crops. A field experiment was conducted to find out the effect of increased doses of fertilizers on the banana bract mosaic virus (BBrMV) infected plants of French plantain cv. Nendran. The plant height, girth, number of leaves, number of fingers and the bunch weight had significantly increased with increased dose of fertilizer in the first and second crops with BBrMV infection. In the first crop, with the application of 125 and 150% of recommended dose of fertilizers (RDF), the BBrMV infected plants could produce bunches which were on par with that of healthy plants, receiving 100% RDF, but with prolonged days of flowering. In the second crop, though 125 and 150% RDF doses in the infected plants increased the bunch weight over 100% RDF by 14.60% and 18.33%, respectively, could not be able to compensate the yield loss due to virus infection. This may probably be due to the accumulation of virus over the period of two years. This is the first report on strategies for mitigating adverse effects of BBrMV in plantain.

Key words: Banana, BBrMV, Management, Nendran, Plantain, Virus

Banana (*Musa* spp) is one of the most important fruit crops of India which contributes 22 % to the global production with an annual production of 29.78 million tonnes from an area of 0.893 million ha. Many viral diseases impede banana production and cause significant reduction in yield. *Banana bract mosaic virus* (BBrMV), a member of the genus *Potyvirus*, family *Potyviridae*, is the causal agent of bract mosaic disease (BBrMD) (Thomas *et al.* 1997), which causes serious yield losses in banana and plantain in India and the Philippines (Selvarajan and Balasubramanian 2008, Magnaye and Espino 1990). BBrMD was first reported in 1966 in plantain cv. Nendran as *Kokkan* disease of unknown etiology in Kerala state in India by Samraj *et al.* (1966). Later the causal agent of *Kokkan* disease was authentically confirmed as BBrMV (Rodoni *et al.* 1997). BBrMD has been recorded in Kerala, Tamil Nadu, Karnataka and Andhra Pradesh and recognized as a disease of national importance in India (Balasubramanian and Selvarajan 2012). BBrMV induces spindle shaped dark reddish brown mosaic streaks on bracts of the inflorescence (Fig 1) and cause malformation in fruits making them not commercially fit

for sale. Bunches with unusually very long or very short peduncle, choking of bunches, raised corky growth on peduncle and aborted bunches are common symptoms of infected plants (Selvarajan and Jeyabaskaran 2006). This virus is transmitted by aphids, viz. *Rhopalosiphum maidis*, *Aphis gossypii* and *Pentalonianigro nervosa* in a non-persistent manner. However, in Tiruchirapalli, natural



Fig 1 Symptom of BBrMD: Spindle shaped dark reddish brown mosaic streaks on pseudostem (Left) and bracts of the inflorescence (Right)

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occurrence of banana aphids is not recorded probably due to the prevalence of high temperature. Infections with viruses cause disruption both in breeding programs and in certified plantlet production. Yield loss in Kerala and Tamil Nadu states of India due to BBrMD was estimated to range from 30 to 70 % in cultivars Nendran and Robusta (Selvarajan and Jeyabaskaran 2006, Cherian *et al.* 2002) respectively. Early infection of *banana bunchy top virus* (BBTV) results in 100 per cent loss, whereas BBrMV affected plants can yield a bunch of reduced economic value. There are no chemicals to control viral diseases of any crop species as done for fungal and bacterial diseases. However, weather factors influencing virus multiplication, integrated nutrient status of soil and vigour of plants are known to reduce the severity due to viral diseases in many crops. Plants respond to extra nitrogen, leading to mitigation of the yield reduction caused by *potato virus Y* (PVY) (Nolte *et al.* 2004). Our earlier studies indicated that additional application of 25-50% fertilizers than the recommended dose of fertilizers (RDF) reduced the yield loss due to BBrMV in the first crop of banana cultivars like Ney Poovan (AB) and Robusta (AAA) (Selvarajan *et al.* 2009, 2012). In south India, the BBrMV incidence has become widespread in the past two decades. Unlike BBTV, the diseased plants produce bunches of less weight of low economic value if the first-generation suckers are infected and the farmers are hesitant to remove the infected plants as recommended control measure. There is a need to reduce the loss due to virus in the infected plants of cultivar Nendran by applying higher dose of fertilizers than the recommended dose. The major objective of this study was to examine the effect of application of different level of fertilizers on the growth and yield parameters of BBrMV infected and healthy plants of French plantain cv. Nendran.

MATERIALS AND METHODS

This study was conducted at the research farm of ICAR- National Research Centre for Banana, Tiruchirapalli, Tamil Nadu state during 2007–09. Tiruchirapalli is located at alt. 90 m, lat. 11.50° N, long. 74.50° E. The annual average maximum temperature, minimum temperature, relative humidity and the annual rainfall were 33.48°C, 24.16°C, 84.79% and 243 mm, respectively in 2007-2008, and 34.63°C, 24.16°C, 82.73 %, 315 mm, respectively in 2008-2009.

Uniform size of both healthy and BBrMV infected suckers (first generation of infection) weighing around 1.25 to 1.5 kg were selected for planting. Presence of bract mosaic virus in the symptomatic suckers (Fig 1) was confirmed by RT-PCR using bract I and II primers as per Rodoni *et al.* (1997). Healthy suckers without any BBrMD symptoms were also tested and confirmed to be negative for the virus. Paring and pralinage was done for all the suckers to control nematodes and weevil infection. Suckers were planted at 1.8m × 1.8m spacing in a 30 cm³ pit. The recommended dose (RD) of fertilizer for Nendran is 200g N, 50g P₂O₅ and 400g K₂O per plant applied in three splits @ 3rd, 5th

and 7th month after planting. The following five treatments were imposed in the field: T1: 50% of recommended dose of NPK (RD of NPK), T2: 75% RD of NPK, T3: 100% RD of NPK, T4: 125% RD of NPK and T5: 150% RD of NPK. All the recommended package of practices for banana was followed including management of leaf spot diseases by timely spraying of 0.1 % Propiconazole fungicide. For second crop, daughter suckers were extracted from the first crop after harvest of bunches. These suckers were given paring and pralinage treatments and replanted at the same spacing as first crop. Desuckering of side suckers was carried out at monthly intervals in order to encourage the growth of the mother plant.

Phenotypical characters such as plant height, stem girth, number of leaves, petiole length, leaf area, days taken for flowering and days taken for harvesting were recorded. The height of the pseudostem was measured from the junction of pseudostem and corm to the axil of the youngest leaf. The girth of the pseudostem was measured at 30cm height from the junction of the pseudostem and corm. The total number of leaves present at shooting was counted. The yield potential was studied by measuring the bunch weight, and number of hands and fingers in the bunch.

Both healthy and infected plants in different treatments were sampled after flowering. DAC-ELISA was performed as per the protocol described by Clark and Bar-Joseph (1984). One hundred mg of plant tissue was ground in 1 ml of carbonate buffer (15 mM Na₂CO₃, 35 mM NaHCO₃, pH 9.6) containing 2% polyvinylpyrrolidone (MW 40000) followed by centrifugation at 8000 × g for 2 min. One hundred micro liter of the extracts were coated to the 96-well ELISA plate and incubated at 4°C for overnight. Each sample had duplicated wells. After three washings with phosphate-buffered saline + Tween-20 (PBST; 137 mM NaCl, 8 mM Na₂HPO₄, 1.5 mM KH₂PO₄, 2.7 mM KCl, 0.05% Tween-20, pH 7.4), the ELISA plate was then blocked with 1% bovine serum albumin in PBS-T at 37°C for 1 hr. After three washings with PBST buffer, antiserum (1:2000 dilution, Agdia) was diluted in conjugate buffer (PBST with 2% BSA and 2% PVP) at 37°C for 2 hr. Plates were washed thrice with PBST buffer, 100 µl of 10000-fold diluted alkaline phosphatase (AP)-conjugated goat anti-rabbit secondary antibody was added and incubated at 37°C for 2 hr. Finally 100 µl of p-nitrophenylphosphate (PNP) substrate solution (1 mg/ml), dissolved in substrate buffer (9.7% diethanolamine, 0.5 mM MgCl₂, pH 9.8), was added after three washings with PBST buffer. The values of OD405 of each sample were measured by an ELISA reader after 60 min incubation. A sample was considered positive if the absorbance value was greater than thrice the mean value of the healthy controls.

Bunches were harvested at the green maturity stage. During harvest, the marketable bunch weight and number of hands and fingers per bunch were recorded. Individual bunch weight was converted to ha (3000 plants/ha) and expressed as total yield (tonnes/ha). The cost of cultivation was worked out taking into account various inputs used

for cultivation during the entire experimental period. The following economic analyses were carried out during the study as described by Kuttimani *et al* (2013).

Total variable cost (TVC): The cost incurred from field preparation to harvest was worked out for each treatment of the study and expressed as ₹/ha.

Gross return: The crop yield was computed per ha and the total income (₹/ha) was worked out based on the minimum market rate prevalent during the period of study.

Benefit-cost ratio (BCR): Benefit-cost ratio (BCR) was calculated based on gross return and cost of cultivation as given below.

$$BCR = \frac{\text{Gross return (₹/ha)}}{\text{Total variable costs (₹/ha)}}$$

The experiment was carried out in a split plot design. Each treatment was replicated nine times. All data were analyzed using Indian NARS Statistical Computing Portal(<http://stat.iasri.res.in/sscnarsportal>). The data recorded on various characters were analysed by ANOVA. Means were compared by Tukey’s multiple range tests ($P \leq 0.05$).

RESULTS AND DISCUSSION

Phenotypical characters

The effect of graded doses of fertilizer on the plant growth and yield parameters for the first crop of cv. Nendran is furnished (Table 1). The growth and yield parameters progressively increased with the application of increased dose of fertilizers in both infected and healthy plants and were significantly correlated except for number of fingers. The mean height of infected plants was 246.24 cm which is significantly less than the healthy plants (263.49 cm). Virus infection (BBTV and BBrMV) caused reduction in height of plant in banana due to BBTV and BBrMV (Selvarajan and Jeyabaskaran 2006, Hooks *et al.* 2008). Interestingly, with the application of 125 and 150% RDF, the height of the infected plants also increased significantly. The healthy plants recorded more mean girth (59.91 cm) than the infected plants (58.47 cm). In the first crop, at 100% RDF level the difference in the girth of infected and healthy plants was 5.89 cm, whereas at higher dose, the girth was greater in infected plants. But similar trend was not observed in the second crop. The increase could be attributed to the higher uptake of nutrients, particularly nitrogen. This result is supported by the works of Nalina *et al.* (2009) who have reported that the uptake of nitrogen, the chief constituent of chlorophyll, proteins and amino acids is accelerated through its increased supply at appropriate time to the plants. Reduction in the growth parameters by BBrMV infection has been reported in cv Robusta, Ney Poovan and Nendran (Selvarajan and Jeyabaskaran 2006, Selvarajan *et al.* 2009; 2012). In first crop, the average number of days taken for flowering was greater in infected plants (268.0 days) than in healthy plants (253.56 days). Among the infected plants, the number of days taken for flowering varied (261.50-283.63) among

Table 1 Effect of graded dose of fertilizers on growth and yield parameters in BBrMV infected and healthy plants of banana cv. Nendran (First crop)

Treatment#	Height (cm)			Girth(cm)			No of leaves			No of fingers			Bunch weight (kg)		
	H	I	Mean	H	I	Mean	H	I	Mean	H	I	Mean	H	I	Mean
T1	230.56	226.89	228.72 ^d	54.33	55.89	55.11 ^c	7.44	7.22	7.33 ^c	51.67	49.00	50.33 ^c	10.98	8.36	9.67 ^e
T2	249.44	237.89	243.67 ^c	57.33	56.22	56.78 ^c	7.78	7.56	7.67 ^{bc}	54.22	51.44	52.83 ^{bc}	12.42	9.57	10.99 ^d
T3	276.56	243.89	260.22 ^b	62.67	56.78	59.72 ^b	8.33	7.67	8.00 ^{ab}	57.44	52.78	55.11 ^{ab}	14.01	12.30	13.16 ^c
T4	281.89	274.89	278.39 ^a	62.78	61.56	62.17 ^a	8.56	8.11	8.33 ^a	60.33	57.56	58.94 ^a	15.56	13.99	14.77 ^b
T5	279.00	278.33	278.67 ^a	62.44	61.89	62.17 ^a	8.44	8.22	8.33 ^a	59.22	57.89	58.56 ^a	15.51	15.11	15.35 ^a
Mean	263.49 ^{a*}	252.38 ^b		59.91 ^a	58.47 ^b		8.11 ^a	7.66 ^b		56.58 ^a	53.73 ^b		13.70 ^a	11.88 ^b	
Tukey's HSD @5%	10.28			2.90			NS			NS			0.63		
M × S															

I: BBrMV infected plants; H: Healthy plants. * Within the same column, values followed by the same letter are statistically identical according to Tukey's test ($P < 0.05$) # T1: 50% of recommended dose of NPK (RD of NPK), T2: 75% RD of NPK, T3: 100% RD of NPK, T4: 125% RD of NPK and T5: 150% RD of NPK.

sub treatments. The variations in fertilizer doses did not have strong influence on the days taken for flowering in Nendran banana. Delayed flowering with prolonged duration in BBrMV infected banana has been previously reported in banana (Thangavelu *et al.* 2000). An average of 8.11 and 8.09 leaves were recorded in healthy plants as compared to 7.66 and 7.60 leaves in the infected plants in the first and second crops, respectively. However, the infected plants which received 25 and 50% higher dose of NPK recorded 7.89 and 8.22 leaves which are on par with healthy plants.

In 2008-09, suckers from the infected and healthy plants of first crop were extracted and planted and the same treatments were imposed. The effect of graded doses of fertilizers on growth and yield parameters of BBrMV infected and healthy plants in the second crop of cv. Nendran are furnished in Table 2. The growth parameters, viz. height, girth and no. of leaves increased with higher doses of fertilizer application and were maximum at 150% of RDF application which recorded significantly higher values than 100% RDF application. The mean height of infected plants was 234.29 cm significantly less than healthy plants (262.58 cm). Interestingly, with the application of 125-150% of RDF, the height of the infected plants increased significantly. The healthy plants recorded more mean girth (56.69 cm) than the infected plants (50.91 cm). In the second crop at 100% RDF level, the difference in the girth of infected and healthy plants was 4.27 cm, whereas at higher dose, the girth increased in infected plants. Among the infected plants, the number of days taken for flowering varied among sub treatments. The average number of days taken for flowering was greater in infected plants (266.57 days) than the healthy plants (247.7 days).

Yield

The total number of fingers in a bunch determine the bunch weight. The average number of fingers in healthy plant (56.58) was greater than in infected plants (53.73) in the first crop. In second crop, the numbers of fingers were reduced to 51.11 and 50.13 in healthy and infected plants respectively. A significant reduction in healthy and infected plants receiving nutrients below RDF for bunch weight was recorded. In the first crop, significant increase in the weight of bunch in healthy plants (13.70 kg) was recorded as compared to infected plants (11.88 kg). The infected plants applied with 50% and 75% of recommended dose of fertilizers yielded 23.86% and 22.94% less respectively than healthy plants, whereas in 100 % RDF applied plants the per cent yield reduction was 12.2% only. Similar observation was reported by Hull and Watson (1947) in the yield of sugar beet infected with BMV. Selvarajan *et al.* (2006) reported that under low soil fertility condition the yield loss due to BBrMV was higher than in high fertile soils. The increased fertilizer dose has significantly increased the yield irrespective to the health status of plants. In general, banana responds better to the application of N and K fertilizers and both the infected and healthy plants of cv. Nendran responded well to the application of

Table 2 Effect of graded dose of fertilizers on growth and yield parameters in BBrMV infected and healthy plants of banana cv. Nendran (Second crop)

Treatment	Height (cm)			Girth(cm)			No. of leaves			No. of fingers			Bunch weight (kg)		
	H	I	Mean	H	I	Mean	H	I	Mean	H	I	Mean	H	I	Mean
T1	223.33	205.56	214.44 ^d	48.44	45.22	46.83 ^d	7.11	6.89	7.00 ^C	45.00	41.44	43.22 ^b	9.24	7.31	8.28 ^d
T2	238.33	216.56	227.44 ^c	52.22	47.44	49.83 ^c	7.78	7.22	7.50 ^B	42.67	42.22	42.44 ^b	11.02	8.08	9.55 ^c
T3	279.22	238.89	259.06 ^b	59.11	50.56	54.83 ^b	8.33	7.78	8.06 ^A	53.78	55.00	54.39 ^a	13.89	11.02	12.46 ^b
T4	281.78	253.00	267.39 ^{ab}	61.22	54.56	57.89 ^a	8.44	7.89	8.17 ^A	56.67	55.00	55.83 ^a	14.41	12.63	13.52 ^a
T5	290.22	257.44	273.83 ^a	62.44	56.78	59.61 ^a	8.78	8.22	8.50 ^A	57.44	57.00	57.22 ^a	15.28	13.04	14.16 ^a
Mean	262.58 ^{**}	234.29 ^b		56.69 ^a	50.91 ^b		8.09 ^a	7.60 ^b		51.11	50.13		12.77 ^a	10.42 ^b	
Tukey's HSD @5%		NS			NS			NS		NS				NS	
M × S															

I: BBrMV infected plants; H: Healthy plants. * Within the same column, values followed by the same letter are statistically identical according to Tukey's test ($P < 0.05$)

higher doses of fertilizers than RDF. The objective of the experiment was to increase the yield of BBrMV infected plants with higher application of fertilizers to compensate the yield loss due to disease severity. The bunch weight of infected plants at 125% RDF was 14 kg/plant which was on par with the healthy plants with 100% RDF. This finding clearly proved that application of 25% more than the RDF could compensate the yield loss caused due to the infection of BBrMV. Interestingly, the bunch weight of infected plants further increased to 15.11 kg with 50% additional to RDF application. This corroborates the results in cv. Ney Poovan and Robusta banana (Selvarajan *et al.* 2009, 2012). Arraudeau (1987) and Ogbe *et al.* (1993) reported that application of a balanced NPK fertilizer to cassava varieties susceptible to cassava mosaic disease (CMD) can control the incidence and severity of the disease. Omorusi and Ayanru (2011) have reported that CMD infection was diminished by the application of higher doses of NPK (100 kg/ha) as compared low dosage (10 kg/ha). Pacumbaba *et al.* (1997) also observed that application of muriate of potash (MOP) at higher rate, i.e. 150 and 200 kg/ha decreased the incidence of *soybean mosaic virus* and increased the yield of soybean.

In the second crop, the bunch weights of infected plants were significantly less than healthy plants irrespective of the fertilizer doses. Application of graded doses of fertilizer has significantly increased the yield irrespective of the state of the plants. However, the interaction between the type of the plants and the fertilizer doses was not significant. The average bunch weight was 12.63 and 13.04 kg in infected and 14.41 and 15.28 kg in healthy plant with the application of 125 % and 150 % of RDF respectively. The bunch weight of healthy plants at 100 % RDF was 13.89 kg/plant, whereas only 11.02 kg/plant of infected plant was obtained which was 20.60 % less than the healthy. With the application of 125% and 150% RDF to the infected plants, 14.60 % and 18.33% increase in the yield was achieved. However, reduction in the yield due to the virus could not be compensated with the application of 125-150% RDF to the infected plants. Interestingly, the bunch weight of the healthy plants increased with the application of higher dose of fertilizers (125-150% of RDF). These results indicated that additional dose of 25-50% RDF to the infected plants could bring down the loss of bunch weight considerably. Overall in the second crop, there was a reduction in the average yield as compared to the first crop irrespective of the additional application of fertilizers; however, yield reduction due to the virus infection was noticed in all the treatments. This might be due to the accumulation of more viruses in the second crop. The titre of virus in ELISA showed a significant increase compared to the first crop.

A regression equation was derived to compare the yield increase due to increased doses of fertilizer both in infected and healthy plants of Nendran banana. The yield increased proportionately but the yield gap between infected and healthy plants narrowed down with increasing levels of fertilizer in the first crop. The regression analysis showed

Table 3 Effect of increased dose of fertilizer to mitigate BBrMD on economics of banana cultivation

Treatments	First crop						Second crop									
	Yield (t/ha)		Cost of cultivation (₹/ha)		Gross income (₹/ha)		B:C ratio		Yield (tonnes/ha)		Cost of cultivation (₹/ha)		Gross income (₹/ha)		B:C ratio	
	H	I	H	I	H	I	H	I	H	I	H	I	H	I	H	I
T1	32.94	25.08	273500	988200	752400	3.61	2.75	27.72	21.93	273500	831600	657900	3.01	2.41		
T2	37.26	28.71	287750	1117800	861300	3.88	2.99	33.06	24.24	287750	991800	727200	3.45	2.53		
T3	42.03	36.90	302000	1260900	1107000	4.17	3.67	41.67	33.06	302000	1250100	991800	4.14	3.28		
T4	46.68	41.97	316250	1400400	1259100	4.43	3.98	43.23	37.89	316250	1296900	1136700	4.10	3.59		
T5	46.53	45.33	330500	1395900	1359900	4.22	4.11	45.84	39.12	330500	1375200	1173600	4.16	3.55		

Data statistically not analyzed. I: BBrMV infected plants; H: Healthy plants.

a linear trend but the yield gap did not narrow in second crop (Data not shown). This might be due to the increased severity of the virus infection in second crop as compared to first crop and also the less vigour of the plants due to overload of viral inoculum. In the present study, there was significant positive correlation between the graded levels of fertilizers with the bunch weight from both BBrMV infected and healthy plants in first crop of Nendran. In corroboration with our findings, Selvarajan *et al.* (2009, 2012) reported that application of increased dose of fertilizer has compensated the yield loss due to BBrMV in the plant crop of cv. Ney Poovan and Robusta. French plantain, cv. Nendran was the first cultivar in India reported to be infected with BBrMV which is one of the largely cultivated dual purpose bananas in India and also in the West African countries, positive response of infected plants to the higher dose of fertilizer application could compensate the yield loss and increase the profit to the farmers.

Benefit - cost (B : C) ratio analysis

The benefit-cost ratio worked out for the first and second crops are furnished in Table 3. In the first crop, application of 100% RDF (T3) gave the B : C ratio of 4.17 in healthy plants, whereas the BBrMV infected plants gave 3.67 only. With the additional 25% RDF B : C ratio increased to 4.43 and 3.98 in healthy and virus infected plants respectively. Further, another 25% increase, i.e 150% of RDF did not increase the B : C ratio in healthy but in the virus infected plants, the B : C ratio increased to 4.11 which showed that the additional dose of fertilizer to the infected plants has helped to augment the yield. In case of second crop, the B : C ratio has not considerably increased in healthy plants and infected plants receiving 25% additional dose gave 3.59% compared to 3.28 in 100% RDF received plants. The B : C ratio analysis based on the additional cost incurred and benefit obtained for the application of 25% higher dose of fertilizers to the virus infected plants was worked out. With respect to addition of 25% RDF a higher B : C ratio of 10.67 and 10.21 was obtained in the first and second crop respectively. This result shows that the infected plants responded to the additional dose of fertilizers thereby increasing the B : C ratio leading to the additional net profit of ₹1.38 and ₹1.31 lakh/ha respectively.

The field experiment conducted in two seasons showed that the application of 125% RDF has significantly increased the yield in the first crop of BBrMV infected French plantain cv. Nendran, and the increase was on par with that of healthy plants receiving 100% RDF (200g N, 50g P and 400g K₂O). It was concluded that the effect of BBrMD can be mitigated in Nendran banana with application of 125% and 150% of recommended dose of fertilizers in first crop.

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REFERENCES

- Arraudeau M. 1987. African cassava mosaic disease and its control. (In) *Proceedings of the International Seminar: African Cassava Mosaic Disease and its Control*, CTA, FAO, ORSTOM, IITA, IAPC, Yamoussoukro, 4-8, May 1987, Ivory-Coast, pp 177-82.
- Balasubramanian V and Selvarajan R. 2012. Complete genome sequence of a banana bract mosaic virus isolate infecting the French plantain cv. Nendran in India. *Archives of Virology* **157**: 397-400.
- Cherian K A, Menon R, Suma A, Nair S and Sudeesh M V. 2002. Effect of banana bract mosaic disease on yield of commercial varieties in Kerala. Presented in Global conference on banana and plantain held at Bangalore, p 155.
- Clark M F and Bar-Joseph. 1984. Enzyme immunosorbent assays in plant virology. (In) *Methods In Virology*, Vol VII, pp 51-85.
- Maramorsch K and Koprowski H (Eds). Academic Press, New York.
- Hooks C R R, Wright M G, Kabasawa D S, Manandhar R and Almeida R P P. 2008. Effect of banana bunchy top virus infection on morphology and growth characteristics of banana. *Annals of Applied Biology* **153**:1-9.
- Hull R and Watson M. 1947. Factors affecting the loss of yield of sugar beet caused by beet yellow virus. II. Nutrition and variety. *Journal of Agricultural Science* **37**: 301-10.
- Kuttimani R, Velayudham K, Somasundaram E and Muthukrishnan P. 2013. Effect of Integrated Nutrient Management on yield and economics of banana. *Global Journal of Biology, Agriculture and Health Sciences* **2(4)**:191-5.
- Magnaye L V and Espino R R C. 1990. Banana bract mosaic, a new disease of banana I. Symptomatology. *Philippine Agriculturist* **73**:55-9.
- Nalina L, Kumar N, Soorianathasundram K and Jeyakumar P. 2009. Effect of different nutrient levels on growth and development of tissue cultured banana cv. Robusta (AAA). *Indian Journal of Horticulture* **66(2)**:169-74.
- Nolte P, Whitworth J L, Thornton M K and McIntosh C S. 2004. Effect of seed borne Potato virus Y on performance of Russet Burbank, Russet Norkotah, and Shepody potato. *Plant Disease* **88**: 248-52.
- Ogbe F O, Ohiri A C and Nnodu E C. 1993. Effect of NPK fertilization on symptom severity of African cassava mosaic virus. *International Journal Pest Management* **39**: 80-3.
- Omorusi VI and Ayanru D K G. 2011. Effect of NPK fertilizer on diseases, pests, and mycorrhizal symbiosis in cassava. *International Journal of Agricultural Biology* **13**:391-5.
- Pacumbaba R P, Brown G F, Pacumbaba R and O Jr. 1997. Effect of fertilizers and rates of application on incidence of soybean diseases in northern Alabama. *Plant Disease* **81**:1459-60.
- Rodoni B C, Ahlawat Y S, Varma A, Dale, J L and Harding R M. 1997. Identification and characterization of banana bract mosaic virus in India. *Plant Disease* **81**:669-72.
- Samraj K S, Menon M R and Christudas S P. 1966. Kokkan a new disease of banana. *Agricultural Research Journal of Kerala* **4**: 116.
- Selvarajan R and Jeyabaskaran K J. 2006. Effect of Banana bract mosaic virus (BBrMV) on growth and yield of cultivar Nendran (Plantain, AAB). *Indian Phytopathology* **59**:496-500.
- Selvarajan R and Balasubramanian V. 2008. Banana viruses. (In) *Characterization, Diagnosis and Management of Plant Viruses*, pp 109-124, Rao G P (Ed). Studium Press, Houston.

- Selvarajan R, Balasubramanian V, Jeyabaskaran K J, Pandey S D and Mustaffa M M. 2009. Management of banana bract mosaic disease through higher dose of fertilizer application in banana cv. Ney Poovan (AB). *Indian Journal of Horticulture* **66**(3): 301–5.
- Selvarajan R, Balasubramanian V, Jeyabaskaran K J, Pandey S D and Mustaffa M M. 2012. Mitigating the effect of banana bract mosaic disease through application of increased dose of fertilizers in banana cultivar Robusta (AAA). *Journal of Plant Disease Sciences* **7** (2): 158–61.
- Thangavelu R, Selvarajan R and Singh H P. 2000. Status of *banana streak virus* and *banana bract mosaic virus* diseases in India. (In) *Banana: Improvement, Production and utilization*. Singh H P and Chadha KL). Proceedings of the Conference on Challenges for Banana Production and Utilization in 21st Century, AIPUB, NRCB, Trichy, India, pp 364–76.
- Thomas J E, Geering A D W, Gambley C F, Kessling A F and White M. 1997. Purification, properties and diagnosis of banana bract mosaic potyvirus and its distinction from abaca mosaic potyvirus. *Phytopathology* **87**: 698–705.