The Bioscan 9(3): 1237-1242, 2014 (Supplement on Plant Pathology)
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.in

EPIDEMIOLOGICAL STUDY OF SPVD TRANSMISSION IN WEST BENGAL

B. SINHA* AND J. TARAFDAR[1]
*Department of Plant Pathology, College of Agriculture,
Central Agricultural University, Imphal- 795 004, Manipur, INDIA
Department of Plant Pathology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur - 741 252, West Bengal, INDIA
e-mail: bireswarsinha@gmail.com

KEYWORDS
Vector
SPVD
Meteorological factor

Received on :
06.03.2014

Accepted on :
15.08.2014

***Corresponding author**

ABSTRACT

A preliminary worked on SPVD transmission and its relationship with weather parameters and vector population were conducted. The populations of vectors (*Aphis gossypii*, *Myzus persicae* and *Bemisia tabaci*) at 30 DAP were less in initially and later increased with days of maturation of sweetpotato cultivars. Variations in the vector population among different cultivars were observed. The SPVD incidences were ranges from 1.11 to 17.70 percent among the sweetpotato cultivars. At 30-90Days after planting (DAP) population of *Aphis gossypi* were ranges from 1.3 to 8.33 and for *Myzus persicae* it was 1.6 to 7.33. The population of *Bemisia tabaci* was observed higher in numbers (10.3 in 30DAP and 19.6 in 90DAP) than the other aphid vector population in sweetpotato cultivars. The peak population was observed during March for both the years (*A. gossypi*, *M. persicae* and *B. tabaci*). Multiple regression equation of vectors population with meteorological factors (Temperature, Relative humidity and rainfall) showed both significant and non significant results.

INTRODUCTION

Sweetpotato [*Ipomoea batatas* L. (Lam); Convolvulaceae] is an important starchy tuberous root crop grown in many tropical and subtropical regions of the world. It ranks fifth after cereals and grain legumes and is grown in more than 100 countries.

Tuber crops are the most important food crops of man after cereals and grain legumes and thus find an inevitable niche in socio-economics of small and marginal farmers in Southern, Eastern and North-Eastern regions of India. In India it is cultivated in Orissa, Bihar, Uttar Pradesh, West Bengal and in South-Indian states as commercial scale. Sweetpotato often infects by more than one viruses forming disease complex like SPVD (Bireswar Sinha and J. Tarafdar, 2007). It is the most important disease economically because the disease plants produce almost no usable yield (Gibson *et al.*, 1998; Karyeija *et al.*, 1998).Transmission of SPVD occurred by cuttings, tubers as well as viruliferous vectors (aphids and whitefly). There is very less studies made in India regarding the transmission of the SPVD and relationship of the SPVD with vector population, weather parameters (temperature, relative humidity and rainfall). So, the present investigations were carried out with the objective to find out relationship of the SPVD with vector population and weather parameters.

MATERIALS AND METHODS

Insect populations' viz. *Aphis gossypii, Myzus persicae* and *Bemisia tabaci* were counted by following methods of Schaefers and Terry (1976) by observing three parts of the plants, like upper, middle and lower leaf of five randomly selected plants and average insect population was calculated at 30, 45, 60, 75 and 90 days after planting (DAP) in some selected cultivars (Tripty, BCSP-5, WBSP-4, S-594, 187017-1 and ST-14) during sweetpotato growing season of the year 2005-2006 and 2006-2007. Meteorological data particularly maximum and minimum temperature, humidity, total rainfall and total rainy days were collected from All India Coordinated Research Project on Agro meteorology (ICAR), B.C.K.V centre located at Kalyani. Data on insect population and disease incidence was analyzed statistically with the dependent variables of average monthly numbers of *Aphis gossypii* (Y1), *Myzus persicae* (Y2) and *Bemisia tabaci* (Y3) with taking average monthly meteorological factors such as maximum temperature (X1), minimum temperature (X2), maximum relative humidity (X3), minimum relative humidity (X4), total rain fall (X5) and total rainy days (X6) as an independent variables. Multiple regression was also analyzed taking meteorological factors as an independent variables for determine the combined effects of all these factors on the build up of vectors population as outlined by Drapper and Smith (1981).

RESULTS AND DISCUSSION

Disease percentage and vector population

Sweetpotato often infects by more than one viruses forming disease complex like SPVD. With the discovery of more complex disease, more or less synonyms to SPVD, the name of SPVD retained specifically to the association invading SPCSV and SPFMV. Transmission of SPVD occurred by viruliferous vectors aphids and whitefly. The SPFMV is readily transmitted or spread non-persistently by aphid vectors namely *Aphis gossypii* and *Myzus persicae* and SPCFV by whitefly (*Bemisia tabaci*) (Scherfers and Terry, 1976; Cohen *et al.*, 1992).

Vector populations (*Aphis gossypii*, *Myzus persicae* and *Bemisia tabaci*) were observed within the selected cultivars of sweetpotato along with disease incidence at 30, 45, 60, 75 and 90 DAP for consecutively for two years and the results are presented in Table 1 and 2. In the year 2005-2006, it was observed that at 30 DAP a very less or minimum disease percentage of SPVD. Except the cultivars Tripty and S-594 there was no disease appearance at 30DAP. The disease incidence gradually increased with increasing the age of the sweetpotato plant. It was also observed that increased in the vector population with increased of the plant age. Variation in the vector population among the cultivars was also observed.

During cropping season of 2005-2006 at the initial stage of planting (30 DAP) *Aphis gossypi* population ranges from 1.3 to 6.3 and highest population was found in cultivars Tripty (6.3). The increase in the aphid population and also of the disease incidence was correlated positively but non significant (r= 0.77) at 30 DAP in Tripty and also in S-594 (r= 0.711) for the year 2005-2006, where as in other cultivar they were correlated positively and also significant (Table 1). Similar result of positive and significant correlation had been observed in respect of varieties, disease incidence and vector population during the year 2006-2007 (Table 2). It is distinctly evident that incidence of disease (SPVD) under field condition directly related with the varieties and vector population.

During the cropping season of 2005-2006 the population of *Myzus persicae* was ranges from 1.6 to 4 (30 DAP), 2 to 3.3 (40 DAP), 2.3 to 6.4 (60 DAP), 3 to 6.6 (75 DAP) and 4.3 to 7.3 (90 DAP) respectively. Highest number of population was observed to the cultivar Tripty (7.3) and its population was positive correlated with disease incidence to other cultivars and also significant (Table 1).

The population of *Bemisia tabaci* was observed much higher in numbers than the other two aphid vector population in sweetpotato cultivars. In this case also similar trend of increase of the disease incidence along with increase in population of whitefly was observed. The whitefly population ranges from 10.3 to 11.3 (30 DAP), 11 to 14.6 (45 DAP), 12.6 to 16.6 (60 DAP), 14.3 to 19.3 (75 DAP) and 15.0 to 19.6 (90 DAP). It was observed that the whitefly population was correlated positively and significant with the cultivars of SPVD percentage at different days after planting. It was also observed a variation in the insect vector population among the cultivars.

In the planting season 2006-2007, almost same trend of the insect population and SPVD percentage was found with slightly increased than the previous year (Table 2). Our findings are also supported by the findings of Ramappa *et al.* (1998) and Zeiden *et al.* (1998) that whitefly population was increased gradually from 1-3 weeks age of planting in tomato and also increased in the leaf curl disease incidence.

Relationship of weather parameters and vector population

The investigation on the abundance of insect vector (*Aphis gossypii, Myzus persicae* and *Bemisia tabaci*) was taken up for two consecutive years of 2005-2006 and 2006-2007. Primary information on the effects of different meteorological factors on the build up of vector populations was studied. Data on monthly average of insect vector population with

Table 1: Correlation between disease incidence and vector population during rabi season of 2005-2006 in six sweetpotato cultivars.

Cultivars	Particulars	Disease incidence (%) and vector population (Avg. of 5 plants) at different days after planting					r
		30	45	60	75	90	
Tripty	Disease incidence	1.11	2.76	8.87	14.38	17.70	
	Avg. no. *Aphis gossypii*	6.33	2.6	4.33	7.66	8.33	0.770
	Avg. no. *Myzus persicae*	4	2.33	4	6.66	7.33	0.927**
	Avg. no *Bemisia tabaci*	11.33	14.66	16.66	19.33	19.66	0.906*
BCSP-5	Disease incidence	0	0.55	1.10	2.76	5.54	
	Avg. no. *Aphis gossypii*	1.66	2	3.33	4.66	5.33	0.934**
	Avg. no. *Myzus persicae*	2	2.33	3.66	4.33	6.33	0.983**
	Avg. no *Bemisia tabaci*	11	13.66	14	15.33	16.66	0.956**
WBSP-4	Disease incidence	0	1.10	2.7	4.42	7.75	
	Avg. no. *Aphis gossypii*	1.33	2	2.33	3.66	4.33	0.978**
	Avg. no. *Myzus persicae*	1.6	2	2.33	4.66	5	0.889*
	Avg. no *Bemisia tabaci*	11	11.66	13	15	15.66	0.928**
S-594	Disease incidence	2.21	3.64	10.51	20.48	32.64	
	Avg. no. *Aphis gossypii*	5	2.66	3.33	7.66	8.33	0.711
	Avg. no. *Myzus persicae*	4	2.33	4.66	5.66	7.33	0.908*
	Avg. no *Bemisia tabaci*	11.33	14.33	16.6	18	19.33	0.946**
187017-1	Disease incidence	0	0.55	2.21	5.45	7.03	
	Avg. no. *Aphis gossypii*	3	2	2.33	5	5.33	0.859*
	Avg. no. *Myzus persicae*	3.33	2.66	4	5.33	5.66	0.895*
	Avg. no *Bemisia tabaci*	10.33	12.33	14.66	16.6	17	0.952**
ST-14	Disease incidence	0	2.21	4.34	9.96	16.04	
	Avg. no. *Aphis gossypii*	2	2.33	2.66	3	4.33	0.961**
	Avg. no. *Myzus persicae*	2	2	2.33	4.66	5.33	0.945**
	Avg. no *Bemisia tabaci*	10.33	11	12.66	14.33	15	0.915*

* Significant at P=0.05, **Significant at P=0.01

Table 2: Correlation between disease incidence and vector population during rabi season of 2006-2007 in six sweetpotato cultivars.

Cultivars	Particulars	Disease incidence (%) and vector population (Avg. of 5 plants) at different days after planting					r
		30	45	60	75	90	
Tripty	Disease incidence	1.10	2.21	7.75	16.04	24.34	
	Avg. no. *Aphis gossypii*	6.33	2.66	4	7.33	8.66	0.761
	Avg. no. *Myzus persicae*	3.6	2	4.33	6.33	7	0.926**
	Avg. no *Bemisia tabaci*	11.66	15	16.33	19.33	19.66	0.900*
BCSP-5	Disease incidence	0	0.55	2.76	4.98	7.23	
	Avg. no. *Aphis gossypii*	2	1.33	4.66	5.33	6	0.992**
	Avg. no. *Myzus persicae*	1.33	2.66	3.33	5	6.66	0.987**
	Avg. no *Bemisia tabaci*	11.33	13	14.33	15.66	16.33	0.921**
WBSP-4	Disease incidence	0	0.55	3.32	7.20	9.41	
	Avg. no. *Aphis gossypii*	1.33	1.66	2	4.66	5.33	0.986**
	Avg. no. *Myzus persicae*	2	2.66	2.66	3	4.33	0.976**
	Avg. no *Bemisia tabaci*	11.33	12	14.	15.33	15.66	0.994**
S-594	Disease incidence	1.11	4.42	44.62	21.58	33.20	
	Avg. no. *Aphis gossypii*	6.33	1.66	4	7.33	8.66	0.825*
	Avg. no. *Myzus persicae*	3.66	2	4.33	6.33	7	0.913*
	Avg. no *Bemisia tabaci*	12.6	14	16.33	18.66	19	0.927**
187017-1	Disease incidence	0	0.55	2.21	5.92	7.6	
	Avg. no. *Aphis gossypii*	3.33	1.33	2.66	4.66	5.33	0.913*
	Avg. no. *Myzus persicae*	3.66	2	3	5.6	6	0.962**
	Avg. no *Bemisia tabaci*	11	12.66	14	16.33	16.33	0.937**
ST-14	Disease incidence	0	1.66	4.34	9.40	17.70	
	Avg. no. *Aphis gossypii*	1.33	2	2.66	4	4.66	0.989**
	Avg. no. *Myzus persicae*	3	2.33	2.66	4	5.66	0.950**
	Avg. no *Bemisia tabaci*	10	11.33	13	15.66	16.00	0.935**

* Significant at P=0.05, **Significant at P=0.01

Table 3: Meteorological data and vector population in the year 2005-2006

Month	Temperature (°C)		Relative humidity (%)		Total rainfall (mm)	Rainy days	*Aphis gossypii*/ five plant pplantplant	*Myzus persicae*/ five plant	*Bemisia tabaci*/ five plant
	Min	Max	Min	Max					
April	26.5	35.9	51.8	93.2	8.4	3	8.66	8.33	17.66
May	25.6	37.1	56.8	92.1	37.6	9	7	8.66	15.33
June	25.6	34.2	70.1	94.1	67.3	13	5.33	7.33	12.33
July	25.7	32.3	78.8	98.8	307.2	21	5	5.33	10
August	25.9	33.4	78.3	97.1	173.5	17	4.66	6	13.33
September	25.5	33.7	77.4	97.7	147.1	16	5.33	5.66	14.66
October	23.5	31.2	76.8	98.2	351.1	15	4.66	5	15.66
November	15.8	30.3	51.5	98.1	0	0	6	5.66	17
December	11.8	27.5	48.0	98.3	1.2	2	5	5.33	15.33
January	9.6	27.1	42.2	98.2	0	0	7.66	6.66	16
February	15.8	33.5	36.1	97.0	0	0	8.33	8.33	16.66

monthly average of maximum, minimum temperature, maximum and minimum relative humidity, total rainfall and total rainy days during the period from 2005-2006 and 2006-2007 are presented in Table 3 and 4. Data presented in the Table 3 indicated that the vector population varied in different months of the observation. In the year 2006-2007 (Table 4), the appearances of insect vector population are almost similar as previous year.

The peak population in March for both the years (*A. gossypi*, *M. persicae* and *B. tabaci*) may be due to prevalence increasing temperature and low rainfall. These findings are in conformity of previous worked by Singh *et al.* (1979). According to them, the high population of vector (*Bemisia tabaci*) during summer months was mainly due to prevalence of high temperature. The individual effects of different weather factors relating to vector population are follows.

Maximum temperature

Correlation studies showed that negative insignificant with *Aphis gossypii*, *Myzus persicae* and *Bemisia tabaci* population during the year 2005-2006 and 2006-2007 (Table 5 and 6). Maximum number of vector population was observed during the month of March in both the year with an average temperature of 32.4 °C during the year 2005-2006 and 32.1ÚC of the year 2006-2007. It was 9, 10 and 18.66 of *Aphis gosypii*, *Myzus persicae* and *Bemisia tabaci* respectively for the year 2005-2006 and for the year 2006-2007 it was 9.33, 9.66 and 18.33 respectively (Table 3 and 4).

Minimum temperature

Statistical analysis showed (Table 5 and 6) positive but

Table 4: Meteorological data and vector population in the year 2006- 2007.

Month	Temperature (°C)		Relative humidity (%)		Total rainfall (mm)	Rainy days	*Aphis gossypii*/ five plant	*Myzus persicae*/ five plant	*Bemisia tabaci*/ five plant
	Min	Max	Min	Max					
April	23.4	36.4	50	92	37.3	3	8.33	9.33	17.66
May	24.4	36.7	59	93	103.1	9	7	7	14.66
June	26.2	35.3	70	96	87.1	10	5.33	6.66	12.66
July	26.2	33.1	82	97	409.3	16	4	5	10.33
August	25.7	32.4	82	98	252.8	18	4.33	5.33	12
September	25.3	33.1	78	98	421.8	10	5	5.33	13.33
October	23.1	33.3	72	98	97.9	5	4.66	7.66	13.66
November	18	30.5	55	97	1.8	3	6	8.33	15
December	13	27.8	49	96	0	3	5.33	6.66	13
January	10.8	26.1	47	99	0	3	7.33	7.66	14.66
February	15.8	38.3	65	99	48.5	3	8.33	9.33	16.33

Table 5: Correlation between vector population and meteorological factors during 2005-2006

	Avg. no. of *Aphis gossypii* (Y_1)	Avg. no. of *Myzus persicae* (Y_2)	Avg. no. of *Bemisia tabaci* (Y_3)	Maximum temperature (X_1)	Minimum temperature (X_2)	Maximum humidity (X_3)	Minimum humidity (X_4)	Total rainfall(X_5)	Rainy days(X_6)
X1	0.249	0.571*	-0.028	1.000					
X2	-0.326	-0.022	-0.474	0.585*	1.000				
X3	-0.559	-0.841**	-0.197	0.038	0.729**	1.000			
X4	-0.738**	-0.520	-0.694*	-0.358	-0.291	0.388	1.000		
X5	-0.651*	-0.594*	-0.609*	0.166	0.667*	0.831**	0.221	1.000	
X6	-0.720**	-0.483	-0.819**	0.167	0.728**	0.836**	0.126	0.797**	1.000

* Significant at P=0.05, **Significant at P=0.01

Table 6: Correlation between vector population and meteorological factors during 2006-2007.

	Avg. no. of *Aphis gossypii* (Y_1)	Avg. no. of *Myzus persicae* (Y_2)	Avg. no. of *Bemisia tabaci* (Y_3)	Maximum temperature (X_1)	Minimum temperature (X_2)	Maximum humidity(X_3)	Minimum humidity (X_4)	Total rainfall (X_5)	Rainy days (X_6)
X1	0.214	0.166	0.204	1.000					
X2	-0.468	-0.493	-0.383	0.773**	1.000				
X3	-0.347	-0.250	-0.367	0.244	0.756**	1.000			
X4	-0.744**	-0.728**	-0.720**	-0.754*	-0.370	0.108	1.000		
X5	-0.613*	-0.749**	-0.614**	0.036	0.543	0.836**	0.312	1.000	
X6	-0.686*	-0.820**	-0.741**	0.288	0.771**	0.950**	0.108	0.854**	1.000

* Significant at P=0.05, **Significant at P=0.01

insignificant results on the vectors population (*A. gossypii and M. Persicae*) in both the year excepting for whitefly. It was further observed that vector population from June to September was lower as compared to other months, which might be due to high rainfall. High rainfall may suppresses the other meteorological factors and based on the study we may say that there was positive relationship between *Myzus persicae* and temperature but temperature was not the only factor to build up the population.

Maximum and minimum relative humidity

From the Table 5 and 6 it was observed a negative but significant correlation of all the vector population with relative humidity in both the year except *Myzus persicae* (negative insignificant during the year 2005-2006). It was also observed that maximum number of vector population expected at a relative humidity of 96.2 and 95.4 during the year 2005-2006 and 2006-2007 respectively (Table 3 and 4). No positive relationship was observed in respect to minimum relative humidity except *M. persicae*.

Total rainfall and rainy days

After statistical analysis of the vectors population and total rainfall, it was observed that negative but significant correlation in both the year. So it can be predicted to say that all the three vector population depends on the availability of the rainfall.

Statistical analysis of the data of average total rainy days and vector population was observed negative but significant correlation except *Myzus persicae* (negative but insignificant during the year 2005-2006).

Multiple regression equation

The multiple regression equation of vectors population due to meteorological factors are expressed by corresponding regression coefficient along with R, R^2, adjusted R^2 and standard error estimates are presented in the Table 7. From the data, it

Table 7 : Multiple regression equations between vector population and meteorological factors of the year 2005-2007.

Year	Dependent variable	Max. temp (X_1)	Min. temp (X_{-2})	Max. R.H. (X_3)	Min. R.H. (X_4)	Total rainfall (X_5)	Total RainyDays (X_6)	Intercept	R values (%)	R^2Values (%)	Adi R^2 Values (%)	S.E of estimate
2005-2006	Y_1	-0.107	0.296	-0.040	-0.236	0.005	-0.110	24.471	0.914	0.833	0.631	1.220
	Y_2	-0.210	0.427	-0.177	0.356	0.001	0.020	32.343	0.971	0.952	0.893	0.551
	Y_3	-0.103	0.599*	0.179	0.243	0.009	-0.711	-31.341	0.952	0.911	0.804	1.042
2006-2007	Y_1	0.152	0.493	-0.334	0.797**	0.005	0.164	-71.212	0.981	0.974	0.942	0.393
	Y_2	0.200	0.290	-.0187	0.596*	-0.001	0.056	-51.031	0.932	0.802	0.733	0.865
	Y_3	0.436	0.489	-0.417	1.118	0.005	0.087	-93.120	0.944	0.894	0.761	1.143

* Significant at P=0.05, **Significant at P=0.01

can be concluded that maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity, total rainfall and rainy days are collectively responsible for build up of vector population in the field. Both significant and nonsignificant results were noted on built up of vector population in respect to meteorological parameters. From the adjusted R^2 value it can be said that, these meteorological factors responsible up to 63%, 89% and 80% for the year 2005-2006 and also 94%, 73% and 76% for the year 2006-2007 to build up of *Aphis gossypii*, *Myzus persicae* and *Bemisia tabaci* respectively.

The above findings are closely related with the findings of Singh *et al.* (1979) worked with leaf curl virus of chilli. The increase or decrease in the incidence and spread of chili leaf curl virus was found to be directly with the increase or decrease of vector population (De *et al.*, 2005). Bryan *et al.* (2002) also reported that increase of aphid vector population in sweetpotato from 4 to 8 week after planting (WAP). Both SPCSV and SPMMV (Wisler *et al.*, 1998; Hollings *et al.*, 1976) are transmitted by whiteflies which are relatively abundant in sweetpotato fields than aphids that transmit two viruses SPCFV and SPFMV without necessary colonizing the crop (Aritua *et al.*, 1998). In this study whitefly recorded relatively more than the aphid in all the sweetpotato growing months as well as days. However, there was clear correlation observed between virus occurrence and whitefly and aphid abundance. This could be because aphids which transmit it do not necessary have to colonize on sweetpotato plants. Transmission is done semi-persistently by aphids carrying sweetpotato viruses when they briefly fed on sweetpotato without colonizing the plants. Presumably, the alates of these and other non colonizing aphid species spread SPFMV while making test visits to crops, as occur for dissemination of potyviruses in some other crops (Halbert *et al.*, 1981). Similarly aphids are rarely observed on sweetpotato in America as well as Uganda (Karyeija *et al.*, 1998) and in North Western Tanzania (Ndunguru and Rajabu, 2007).

This survey of viruses in sweetpotato in West Bengal was for the first time covered crops in all major sweetpotato-producing districts. A prominent feature was observed that the high incidence of the viruses recorded in the areas of experiment farm, where plants are maintained throughout the year. The rainfall trends to be unimodally distributed, alternating with a prolonged, hot and intense dry season, the latter providing a natural break in virus transfer between old and young crops and in food supply for aphid and whitefly vectors. In some areas of West Bengal, sweetpotato is often grown commercially in large field plots. In contrast, in the high-infection areas of the farm, sweetpotato is commonly grown near in small fields grouped close together and with new and mature crops overlapping (Bashaasha *et al.*, 1995). The year-round planting, facilitated by the bimodal rainfall distribution, favors the infection cycle of SPVD by continuously maintaining some plants as reservoirs for the viruses and their insect vectors.

REFERENCES

Aritua, V., Adipala, E., Carey, E. E. and Gibson, R. 1998. The incidence of sweet potato virus disease abundance of whiteflies virus resistance and other key characteristics of sweet potato crops grown by Ugandan farmers in largely subsistence systems'. *Ann. Appl. Biol.* **132:** 399-411.

Bashaasha, B., Mwanga, R. O. M., Ocitti Obwoya, C. and Ewell, P.T. 1995. *Sweetpotato in the farming and food systems of Uganda: a farm survey report*. International Potato Center (CIP) and National Agricultural Research Organisation (NARO). p. 63.

Bryan, A. D. 2002. Impact of sweetpotato feathery mottle virus and micro propagation on yield, root quality and virus incidence in commercial sweetpotato production system. *M.Sc.Thesis, North Carolina State University, USA.*

Bireswar Sinha and Tarafdar, J. 2007. A study on the cause of sweetpotato virus disease in West Bengal. *The Bioscan.* **2(2):** 163-166.

Cohen, J., Franck, A., Vetten, H. J., Lesemann, D. E. and Loebenstein, G. 1992. Purification and properties of closterovirus-like particles associated with a whitefly-transmitted disease of sweet potato. *Ann. Appl. Biol.* **121:** 257-268.

De, B. K., Saha, A. K. and Nath, P. S. 2005. Influence of meteorological factors on the build up of whitefly (*Bemisia tabaci*) vector population and incidence of chilli leaf curl virus disease in the plains of West Bengal. *J. Mycopathol. Res.* **43(20):** 195-201.

Draper, N. R. and Smith, H. 1981. *Applied Regression Analysis* (3rd edition). New York: Wiley.

Gibson, R. W., Aritua, V., Byamukama, E., Mpembe, I. and Kayongo, J. 2004. Control strategies for sweetpotato virus disease in Africa. *Virus Res.* **100:** 115-122.

Gibson, R. W., Mpembe, I., Alicai, T., Carey, E. E., Mwanga, R. O. M., Seal, S. E. and Vetten, H. J. 1998. Symptoms, aetiology and serological Analysis of sweet potato virus disease in Uganda. *Pl. Pathol.* **47:** 95-102.

Halbert, S. E., Irwin, M. E. and Goodman, R. M. 1981. Alate aphids (Homoptera: Aphididae) species and their relative importance as field vectors of soybean mosaic virus. *Ann. Appl. Biol.* **97:** 1-9.

Hollings, M., Stone, O. M. and Bock, K. R. 1976. Purification and properties of sweetpotato mild mottle, a whitefly-borne virus from sweetpotato (*Ipomoea batatas*) in East Africa. *Ann. Appl. Biol.* **82:** 511-528.

Karyeija, R. F., Gibson, R. W. and Valkonen, J. P. T. 1998. The significance of sweetpotato feathery mottle virus in subsistence sweetpotato production in Africa. *Plant Dis.* **82:** 4-15.

Ndunguru, J. and Regina, C. A. 2007. Incidence of sweet potato virus disease under different sweet potato cropping systems in the Lake Zone of Tanzania. *African Potato Association (APS) Conference Proc.* **5:** 405-408.

Ramappa, H. K., Muniyappa, V. and Colvin, J. 1998. The contribution of tomato and alternative host plants to tomato leaf curl virus inoculum pressure in different areas of South India. *Ann. Appl. Biol.* **133:** 187-198.

Schaefers, G. A. and Terry, E. R. 1976. Insect transmission of sweetpotato virus disease agents in Nigeria. *Phytopath.* **66:** 642-645.

Singh, S. J., Sastry, K. S. and Sastry, K. S. M. 1979. Combating leaf curl virus in chilli. *Ind. Hort.* **24:** 9-10.

Wisler, G. C., Duffus, J. E., Liu, H. Y. and Li, R. H.1998. Ecology and epidemiology of whitefly-transmitted closteroviruses. *Plant Dis.* **82:** 270-280.

Zeiden, M., Green, S. K., Maxwell, D. D., Nikhala, M. K. and Czonek, H. 1998. Molecular analysis of whitefly transmitted tomato Geminivirus from South-East and East Asia. *Trop. Agric. Res. and Extn.* **1(1):** 207-215.