

RESPONSE OF COWPEA LINES TO INOCULATION WITH FOUR SEED TRANSMITTED VIRUSES OF COWPEA

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ABSTRACT

This study evaluated the performance cowpea genotypes in the field in Ibadan, Nigeria for response to infection induced by four seed transmitted viruses of cowpea. The experiment was laid out in split plot design with three replicates. *Cowpea mottle virus* genus *Carmovirus* (CMeV) produced infection in 14 of the 15 lines, *Bean common mosaic virus* genus *Potyvirus* - blackeye cowpea strain (BCMV – BIC) in 12, *Cowpea aphid-borne mosaic virus* genus *Potyvirus* (CABMV) in 11 and *Southern bean mosaic virus* genus *Sobemovirus* (SBMV) in 6. BCMV – BIC significantly reduced ($p < 0.05$) the grain yield, number of pods per plant, number of seeds per plant and shoot length than CMeV, and CMeV reduced the same traits than CABMV and SBMV. Percentage reduction in the grain yield induced by BCMV – BIC infection ranged from 62.6% in CP-VAR8 to 87.7% in IT86D-371, CMeV from 49.9% in IT90K-284-2 to 91.4% in IT82D-889, CABMV from 20.2% to 87% and SBMV from 31.8% to 69.2%. Similar trend was observed in the reduction of the number of pods per plant, plant height and number of seeds per pod. The four viruses did not affect the number of days from planting to 50% flowering and the number of days from planting to maturity. IT90K-284-2, IT82D-889, TVu 11426 and IT86D-880 were resistant to infection caused by BCMV – BIC, CABMV and SBMV but were tolerant to CMeV infections. CP-VAR8 was resistant to infections induced by CMeV and SBMV. The cultivation of these lines should be encouraged in the areas where the viruses are endemic.

KEY WORDS: Cowpea, *Vigna* species, Virus infections, Cowpea Diseases, Seed Transmitted Viruses

INTRODUCTION

Cowpea (*Vigna unguiculata* (L) Walp) is a tropical legume, which provides affordable protein for humans and animals in Sub-Saharan Africa, Asia and Latin America (Mishra *et al.*, 1985; Singh and N'tare, 1985; Watt *et al.*, 1985; Bashir and Hampton 1993; Tarawali *et al.*, 2002). Cowpea serves also as cover crop, in soil nitrogen fixation and in the control of erosion and weeds (Hutchinson and McGiffen, 2000). FAO (2000) estimated that 3.3 million tonnes of dry cowpea grains were produced from 9.8 million hectare of land worldwide. More than 60% of the world cowpea is produced by Nigeria and Niger Republic (Quin, 1997).

Seeing the value of the crop and in support that its production should be increased, Coulibaly and Lowenberg - DeBoer (2002) stated that cowpea has the potential to contribute to food security and reduce poverty in West Africa, provided that both socio-economic and biological constraints are adequately tackled. Such socio – economic and biological constraints include poor management of resources, poor application of appropriate cultural technologies, infestation by weeds and insect pests, and infection by diseases (Jackai and Adalla, 1997; Quin, 1997). Plant diseases; especially those transmitted by the seeds, play very important role in loss of valuable food crop throughout the world (De Wolf and Isard, 2007). Virus infections are the cause of numerous plant disease syndromes that are generally characterized by

(Culver and Padmanabhan 2007). Seed transmitted viruses are important pathogens because the pathogens lodge in seed tissues such as embryo and disease symptoms may manifest in seedlings grown from the seeds (Stace - Smith and Hamilton, 1988). A few infected seedlings may be the source of epidemic infections in the field if vectors (aphids, beetles, etc.) convey the pathogens to healthy plants during feeding. Seed transmitted viruses hiding in seeds in storage retain their ability to cause infection for many years even after the seeds had lost viability (Bennett, 1969).

Seven of the viruses infecting cowpea are seed transmitted and are found in all cowpea growing areas (Hampton, *et al.*, 1997). For example, *Bean common mosaic virus* genus *Potyvirus* - blackeye cowpea strain (BCMV – BIC) was reported in Brazil, India, Kenya, Nigeria, and other parts of the world (Mali, *et al.*, 1983; Taiwo and Shoyinka 1988; Shoyinka *et al.*, 1997; Boxel *et al.*, 2000). Infections caused by seed- borne viruses also reduce seed quality and potential yield of crops. Phatak (1974) observed that cowpea ringspot virus infection distorted cowpea pods and *cowpea aphid – borne mosaic virus* genus *Potyvirus* (CABMV) infection reduced yield in cowpea by between 48 to 87% (Kaiser and Mossahebi, 1975).

Considering the damage that cowpea seed transmitted viruses can bring about in susceptible

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the induction of disease symptoms such as developmental abnormalities, chlorosis and necrosis

knowledge will enable farmers make informed judgement when choosing planting materials in virus

endemic regions. Also, the information on resistance and susceptibility status of genotypes can be used in genetic studies and in breeding elite cowpea genotypes.

Studies of this sort should be routinely conducted to identify possible variation in the interaction between virus strains and cowpea genotypes. The objective of this study was to evaluate the effect of four seed-borne viruses on the performance of some cowpea lines.

Materials and Methods

Fifteen cowpea genotypes were chosen from a screen – house study reported by Ittiah (2004) and evaluated in the field for their responses to infection caused by four seed-borne viruses. Isolates of *Bean common mosaic virus* genus *Potyvirus* - blackeye cowpea strain (BCMV – BIC), *Cowpea aphid-borne mosaic virus* genus *Potyvirus* (CABMV), *Cowpea mottle virus* genus *Carmovirus* (CMeV) and *Southern bean mosaic virus* genus *Sobemovirus* (SBMV) were obtained from the Virology unit of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria and maintained in life plant (Ife brown) culture in an insect free screen – house in the unit.

The cowpea genotypes were Ife Brown, IT82D-716, IT82D-889, IT84S-2246-4, IT86D-371, IT86D-880, IT96D-774, TVu 12349, CP-VAR8, IT83D-442, IT90K-284-2, TVu 66, TVu 11426, TVu 1190, and TVu 13686. These genotypes were chosen based on their infection status, to determine their responses under field conditions. The field was laid out in a split - plot design with three replicates. The four viruses and control were the 5 main-plot treatments and the cowpea genotypes were the sub-plot treatments. Plot size was 486.75m², a ridge (sub-plot) was 10 x1 m, plant spacing was 60 cm, inter-ridge spacing was 100 cm and inter-block spacing was 2.0 m. Weeds were removed first by slashing and ploughing, then with the pre – emergence herbicide; Gramoxone, which was applied with knapsack sprayer after seeds were planted at the rate of 5 litres per hectare. Subsequent weeding was done manually and Karate was sprayed fortnightly to control insects and prevent cross contamination of viruses through vectors.

Cowpea plants were mechanically inoculated with inoculum of each virus. Inoculum was prepared by picking young virus infected leaves (3 – 5) from Ife brown cowpea plants maintained in the screenhouse and ground in ice-cooled mortars and pestles in inoculation buffer. The buffer was made up of 1 g of dibasic potassium phosphate (K₂HPO₄), 1 g monobasic potassium phosphate (KH₂PO₄), 0.1 g of sodium sulphite (Na₂SO₃) in 100 ml distilled water at pH 7.5. It was stored in the refrigerator until required (Walkey, 1985). Carborundum powder (600 mesh) was sprinkled on the leaf surface at the emergence of the first trifoliolate leaf (5 - 8 days after planting) before rubbing the inoculum into the lines. The fingers were protected with rubber gloves to prevent cross infection. Excess inoculum was rinsed off with distilled water. Plants in control plots were not inoculated.

Virus expressions on the cowpea plants were confirmed with Protein-A sandwich enzyme linked immunosorbent assay (PAS – ELISA), a serological test (Hughes and Thomas, 1988). Polyclonal antisera to the viruses were obtained from Virology Unit of IITA, Ibadan. Five

randomly selected plants from plots without symptoms were similarly tested to find out if there were viruses latently hiding in the leaf tissues. Plants in the control plots were tested regularly to ensure that there were no cross infections. Plants with other viruses or contaminated with non-specified viruses were removed. The disease symptom expression was visually scored using a 5-point scale (Thottappilly, *et al.*, 1994) as follows;

1 = Highly resistant (disease symptoms were not observed on the leaves and ELISA results were negative).

2 = Resistant (less than 20% of the leaves on each plant expressed symptoms of the specified virus or ELISA results of symptomless plants were positive).

3 = Moderately resistant (symptoms of the specified virus appeared on 21 – 40% of the leaves).

4 = Susceptible (symptoms of the specified virus appeared on 41 – 60% of the leaves).

5 = Highly susceptible (symptoms of the specified virus appeared on more than 60% of the leaves).

Means were compared using Least Square Means (LSMeans) and associated standard errors, using pairwise differences (pdiff) of means option in statistical analysis system (SAS) (SAS Institute, 1995). The disease severity means were logarithmically transformed because data were taken by count, which would not fit into the law of normality (Gomez and Gomez, 1984).

RESULTS

Disease expression and Growth Manifestations

Table 1 shows cowpea lines response to infection, and severity and incidence of infection induced by the seed transmitted viruses on the cowpea lines. All the cowpea genotypes expressed symptoms of one virus or the other. The severity of BCMV – BIC infection ranged from 1.0 in IT90K-284-2 to 4.8 in IT96D-774, that of CABMV from 1.0 in IT86D-880 and IT90K-284-2 to 4.3 in IT96D-774, CMeV from 1.2 in CP-VAR8 to 4.7 in IT82D-716 and IT84S-2246-4, and SBMV from 1.0 in 8 cowpea lines to 4.2 in IT96D-774 and TVu 66. The incidence of infection measured the spread of the diseases in the plots; all the plants in the Ife brown, IT82D-716, IT84S-2246-4, IT96D-774, TVu 1190 and TVu 13686 plots inoculated with the BCMV – BIC virus were infected, all the plants in IT84S-2246-4 plot inoculated with CABMV were infected. Similarly, all of the plants in 8 plots (Ife brown, IT82D-716, IT82D-889, IT84S-2246-4, IT86D-880, IT96D774, TVu 66 and TVu 13686) inoculated with the CMeV virus were diseased, however, the trend that all the plants in the plot expressed symptoms of infection of the virus was not recorded in the plots where SBMV was inoculated. The highest incidence of infection in SBMV inoculated plots was 60% of the plants in IT84S-2246-4, IT96D-774 and TVu 66.

IT86D-880 and IT90K-284-2 were highly resistant to BCMV – BIC, CABMV and SBMV. IT86D-371, IT86D-880 and TVu 11426 were tolerant to the infections caused by all the four viruses because the severity of infection scored between 1.0 and 3.5, and incidence of infection was less than 40%. Similarly, IT82D-889, IT90K-284-2, IT83D-442 and TVu 12349 were tolerant to infection induced by three of the four viruses (BCMV –

BIC, CABMV and SBMV). CP-VAR8 was the only line that was highly resistant to the infections caused by CMeV.

Days to 50% flowering and days to maturity

Infection caused by the seed transmitted viruses did not significantly ($p < 0.05$) influence the number of days from planting to when 50% of the plants on the plots flowered (Table 3) and the number of days from planting to maturity in any cowpea lines (Table 4).

Plant height/length of shoot

The mean length of shoot of the cowpea lines at maturity under the 5 virus treatment is shown in Table 4. The length of shoot of the uninoculated lfe brown variety was 109.6 cm, the mean length was significantly longer ($p < 0.05$) than the lfe brown plants infected by BCMV – BIC (38.9 cm), CMeV (73.2 cm) and SBMV (73.7 cm). The mean length of TVu 66 variety in the control plot was 70.8cm; it was also, significantly longer ($p < 0.05$) than the same variety inoculated with all the viruses except SBMV. Similar trend was observed in the other susceptible varieties. BCMV – BIC significantly reduced the length of shoot in 12 genotypes, the percentage reduction ranged from 19.6% to 64.5%; CMeV significantly reduced the length in 9 lines between 11.4% in IT90K-284-2 and 41.8% in TVu 13686; CABMV in 3 and SBMV in 5 lines ($p < 0.05$). There were no significant differences in the length of shoot in three lines (IT82D-889, IT86D-880 and IT90K-284-2) infected with any of the four viruses ($p < 0.05$); these genotypes were the highly resistant genotypes, whereas, highly susceptible genotypes infected by CMeV and BCMV – BIC were stunted.

Number of pods per plant

Table 5 compares the number of pods per plant in the cowpea lines infected with the seed transmitted viruses. In lfe brown line, the control plot had an average of 27.1 pods per plant whereas the plots infected with the viruses had significantly ($p < 0.05$) less number of pods per plant, the trend was observed in the other susceptible lines; IT82D-716, IT84S-2246-4, IT96D-774 and TVu 66. Infection by BCMV – BIC significantly ($p < 0.05$) reduced the number of pods per plant in 12 lines. The most severely affected lines were lfe Brown (69.1%), TVu 1190 (66.4%), IT84S-2246-4 (58.7%) and IT96D-774 (56.2%). CMeV significantly reduced the number of pods per plant in 14 lines, percentage reduction in the number of pods per plant ranged from 16.5% in IT82D-889 to 57.4% in IT84S-2246-4. CABMV infection significantly reduced the number of pods per plant in 9 lines, percentage reduction ranged from 10.1 to 33% while SBMV

decreased the number of pods per plant in 6 lines between 11.8 and 30.3% ($p < 0.05$).

BCMV – BIC, CABMV and SBMV infections did not significantly reduce the number of pods per plant in four lines; IT82D-889, IT86D-880, IT90K-284-2 and TVu 11426. The highly resistant and resistant lines experienced no significant reduction in the number of pods, while susceptible and highly susceptible lines suffered the highest reduction in the number of pods per plant.

Number of seeds per pod

The effects of the infection induced by the seed transmitted viruses on the number of seeds per pod are shown in Table 6. Infection by BCMV - BIC significantly reduced number of seeds per pod ($p < 0.05$) in 9 lines (lfe brown, IT82D-716, IT82D-889, IT84S2246-4, IT96D-774, CP-VAR8, TVu 66 TVu 1190 and TVu 13686); the percentage reduction ranged from 9.1% in TVu 12349 to 46.2% in lfe Brown. CMeV infection significantly reduced number of seeds per pod in 11 cowpea lines, between 11.7% in IT82D-889 to 35.9% in IT96D-774 ($p < 0.05$), CABMV in 7 lines between 9.0% and 23.1%, while SBMV reduced the number of seeds per pod in four lines ranging from 8.5% in TVu 1190 to 16.8% in lfe Brown ($p < 0.05$). Susceptible and highly susceptible genotypes were the most severely affected by each of the viruses, and they had the highest percentage reduction in the number of seeds per pod.

Grain yield per hectare

Table 7 shows the grain yield (in Kg/Ha) of the cowpea lines after infection of the four seed transmitted viruses and the uninoculated plot in the field. The average yield of lfe brown variety in the control plot was 1058.4 Kg/Ha; this yield was significantly higher ($p < 0.05$) than the yield observed after the infection of BCMV – BIC (245.5 Kg/Ha), CABMV (260.6 Kg/Ha), CMeV (224.8 Kg/Ha) and SBMV (721.6 Kg/Ha). The trend was the same in all the susceptible lines infected with the viruses; CMeV infections caused significant reduction ($p < 0.05$) of the grain yield of 14 cowpea lines, the percentage decrease ranged from 49.9% in IT90K-284-2 to 91.4% in IT82D-889, and BCMV – BIC in 12 lines ranging from 62.6% in CP-VAR8 to 87.7% in IT86D-371 ($p < 0.05$). CABMV also caused significant reduction ($p < 0.05$) in the grain yield of 10 lines; from 20.2% in TVu 13686 to 87% in IT86D-371 and SBMV in 8 lines from 31.8% to 69.2%. Very severely infected genotypes had the highest reductions in grain yield, while the highly resistant genotypes were not infected despite that they were inoculated with the viruses; their grain yield were not significantly different from the plants that were not inoculated (i.e. control).

Table 1. Response to infection, Infection severity and incidence of infection of four seed transmitted viruses on cowpea lines at 90% maturity

Lines	BCMV-BIC			CABMV			CMeV			SBMV		
	RES	SEV	INC	RES	SEV	INC	RES	SEV	INC	RES	SEV	INC

Ife Brown	HS	4.2	100	S	3.8	90	HS	4.4	100	MR	2.7	40
IT82D-716	S	3.4	100	S	3.6	60	HS	4.7	100	MR	2.6	40
IT82D-889	R	1.8	20	HR	1.2	0	S	3.5	100	HR	1.0	0
IT84S-2246-4	HS	4.8	100	S	3.6	100	HS	4.7	100	S	3.6	60
IT86D-371	MR	2.3	80	R	1.4	40	MR	2.6	60	HR	1.0	0
IT86D-880	HR	1.2	0	HR	1.0	0	MR	3.0	60	HR	1.0	0
IT96D-774	HS	4.8	100	HS	4.3	80	HS	4.6	100	HS	4.2	60
TVu 12349	MR	3.2	60	MR	2.8	60	S	3.9	80	R	1.9	40
CP-VAR8	S	4.4	80	S	4.0	60	HR	1.2	0	HR	1.0	0
IT83D-442	MR	3.2	50	MR	2.8	40	S	3.9	60	HR	1.0	0
IT90K-284-2	HR	1.0	0	HR	1.0	0	S	3.5	40	HR	1.0	0
TVu 66	S	4.2	60	S	3.8	60	HS	4.6	100	S	4.2	60
TVu 11426	MR	3.2	40	R	3.6	20	MR	3.0	70	HR	1.0	0
TVu 1190	S	3.8	100	R	2.2	20	MR	3.2	80	HR	1.0	0
TVu 13686	S	4.2	100	MR	3.2	40	S	4.2	100	MR	2.8	40

Key: RES = Response to infection; SEV = Disease severity; INC = Incidence of infection (%); HR = highly resistant; R = resistant; MR = moderately resistant; S = susceptible; HS = highly susceptible. BCMV-BIC = Bean common mosaic virus – blackeye cowpea strain; CABMV = Cowpea aphid – borne mosaic virus; CMeV = cowpea mottle virus; SBMV = Southern bean mosaic virus.

Table 2. Comparison of the number of days after planting to 50% flowering of cowpea lines infected with four seed transmitted viruses.

Lines	BCMV-BIC	CABMV	CMeV	SBMV	CONTROL
Ife Brown	46.3 ^a	45.6 ^a	45.5 ^a	46.3 ^a	45.7 ^a
IT82D-716	36.4 ^a	36.4 ^a	36.1 ^a	36.4 ^a	36.2 ^a
IT82D-889	34.4 ^a	34.5 ^a	34.6 ^a	34.0 ^a	34.4 ^a
IT84S-2246-4	41.9 ^a	42.1 ^a	41.4 ^a	41.6 ^a	42.2 ^a
IT86D-371	35.8 ^a	36.0 ^a	35.6 ^a	36.0 ^a	35.5 ^a
IT86D-880	35.1 ^a	35.5 ^a	34.9 ^a	35.4 ^a	34.0 ^a
IT96D-774	36.0 ^a	36.1 ^a	35.8 ^a	36.4 ^a	35.5 ^a
TVu 12349	48.1 ^a	47.6 ^a	48.0 ^a	46.6 ^a	47.2 ^a
CP-VAR8	40.1 ^a	40.6 ^a	41.0 ^a	40.6 ^a	39.9 ^a
IT83D-442	36.5 ^a	36.3 ^a	34.6 ^a	34.0 ^a	34.4 ^a
IT90K-284-2	34.4 ^a	35.0 ^a	35.0 ^a	34.6 ^a	34.2 ^a
TVu 66	48.3 ^a	49.1 ^a	48.0 ^a	49.0 ^a	47.0 ^a
TVu 11426	35.8 ^a	36.0 ^a	35.9 ^a	35.8 ^a	35.1 ^a
TVu 1190	45.5 ^a	45.8 ^a	46.4 ^a	45.9 ^a	46.1 ^a
TVu 13686	51.7 ^a	51.2 ^a	50.8 ^a	49.8 ^a	50.3 ^a

Key: BCMV-BIC = Bean common mosaic virus – blackeye cowpea strain; CABMV = Cowpea aphid – borne mosaic virus; CMeV = cowpea mottle virus; SBMV = Southern bean mosaic virus; ^a Number with the same letters across the rows are not significantly different at 5% probability (LSMeans)

Table 3. Comparison of the number of days from planting to maturity of cowpea lines with four seed transmitted viruses.

Lines	BCMV-BIC	CABMV	CMeV	SBMV	CONTROL
Ife Brown	76.0 ^a	74.9 ^a	75.7 ^a	76.1 ^a	76.1 ^a
IT82D-716	66.2 ^a	66.5 ^a	66.1 ^a	66.6 ^a	66.7 ^a
IT82D-889	64.6 ^a	64.9 ^a	64.6 ^a	64.4 ^a	64.8 ^a
IT84S-2246-4	70.1 ^a	69.8 ^a	70.4 ^a	71.5 ^a	72.3 ^a
IT86D-371	65.8 ^a	65.7 ^a	65.9 ^a	66.6 ^a	65.9 ^a
IT86D-880	65.9 ^a	65.6 ^a	65.4 ^a	64.4 ^a	65.2 ^a
IT96D-774	67.2 ^a	66.1 ^a	66.6 ^a	66.8 ^a	66.4 ^a
TVu 12349	84.2 ^a	83.2 ^a	82.5 ^a	82.2 ^a	83.4 ^a
CP-VAR8	69.9 ^a	70.5 ^a	70.9 ^a	70.7 ^a	70.4 ^a
IT83D-442	70.7 ^a	72.7 ^a	69.7 ^a	69.3 ^a	70.4 ^a
IT90K-284-2	65.1 ^a	65.3 ^a	65.3 ^a	65.3 ^a	65.0 ^a
TVu 66	64.0 ^a	62.7 ^a	62.0 ^a	64.4 ^a	62.0 ^a

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TVu 1190	80.3 ^a	79.9 ^a	81.7 ^a	80.6 ^a	80.8 ^a
TVu 13686	95.4 ^a	92.0 ^a	94.4 ^a	94.5 ^a	95.3 ^a

Key: BCMV-BIC = Bean common mosaic virus – blackeye cowpea strain; CABMV = Cowpea aphid – borne mosaic virus; CMeV = cowpea mottle virus; SBMV = Southern bean mosaic virus; ^a Number with the same letters across the rows are not significantly different at 5% probability (LSMeans)

Table 4. Comparison of the mean mature plant height of cowpea lines infected with four seed transmitted viruses

Lines	BCMV-BIC	CABMV	CMeV	SBMV	CONTROL
Ife Brown	38.9 ^c	98.7 ^a	73.2 ^b	73.7 ^b	109.6 ^a
IT82D-716	46.7 ^b	55.2 ^a	44.9 ^b	54.4 ^a	60.7 ^a
IT82D-889	53.8 ^a	59.4 ^a	52.0 ^a	56.9 ^a	59.1 ^a
IT84S-2246-4	46.8 ^{bc}	74.3 ^a	51.2 ^b	65.0 ^{ab}	77.6 ^a
IT86D-371	67.2 ^b	81.6 ^a	70.9 ^{ab}	68.1 ^{ab}	77.6 ^a
IT86D-880	115.6 ^a	118.3 ^a	109.3 ^a	106.3 ^a	116.3 ^a
IT96D-774	47.9 ^b	70.6 ^a	48.3 ^b	74.0 ^a	74.8 ^a
TVu 12349	189.8 ^c	230.7 ^a	211.2 ^b	227.2 ^a	238.4 ^a
CP-VAR8	61.7 ^b	74.3 ^{ab}	78.9 ^a	77.5 ^a	76.8 ^a
IT83D-442	135.3 ^d	139.6 ^d	191.6 ^c	225.6 ^b	277.9 ^a
IT90K-284-2	55.8 ^a	56.3 ^a	45.4 ^a	56.2 ^a	56.4 ^a
TVu 66	50.5 ^{bc}	57.6 ^b	48.1 ^c	64.9 ^a	70.8 ^a
TVu 11426	107.4 ^b	132.8 ^a	91.6 ^c	129.2 ^a	137.0 ^a
TVu 1190	101.0 ^c	261.1 ^a	250.4 ^b	232.1 ^b	274.0 ^a
TVu 13686	170.4 ^d	187.0 ^c	146.2 ^e	228.7 ^b	251.2 ^a

Key: BCMV-BIC = Bean common mosaic virus – blackeye cowpea strain; CABMV = Cowpea aphid – borne mosaic virus; CMeV = cowpea mottle virus; SBMV = Southern bean mosaic virus; ^a Number with the same letters across the rows are not significantly different at 5% probability (LSMeans)

Table 5. Comparison of the number of pods per plant of cowpea lines infected with four seed transmitted viruses

Lines	BCMV-BIC	CABMV	CMeV	SBMV	CONTROL
Ife Brown	8.4 ^c	18.1 ^b	16.1 ^b	18.9 ^b	27.1 ^a
IT82D-716	14.6 ^b	16.3 ^b	9.8 ^c	16.1 ^b	21.8 ^a
IT82D-889	17.4 ^{ab}	18.0 ^{ab}	16.2 ^b	15.5 ^b	19.4 ^a
IT84S-2246-4	16.8 ^c	30.4 ^b	17.3 ^c	31.8 ^b	40.7 ^a
IT86D-371	11.2 ^b	14.4 ^a	10.4 ^b	12.9 ^{ab}	14.7 ^a
IT86D-880	14.7 ^a	14.4 ^a	12.4 ^b	15.3 ^a	15.9 ^a
IT96D-774	8.6 ^d	15.5 ^{bc}	9.0 ^d	13.6 ^c	19.7 ^a
TVu 12349	13.2 ^b	15.6 ^b	15.6 ^b	18.9 ^a	18.9 ^a
CP-VAR8	18.9 ^b	24.1 ^a	25.0 ^a	24.6 ^a	24.5 ^a
IT83D-442	15.9 ^d	19.5 ^c	16.3 ^c	22.0 ^{bc}	25.8 ^a
IT90K-284-2	20.1 ^a	19.6 ^a	13.8 ^b	20.9 ^a	21.0 ^a
TVu 66	9.6 ^c	18.9 ^b	11.0 ^c	19.7 ^b	25.7 ^a
TVu 11426	16.0 ^a	16.0 ^a	12.8 ^b	16.5 ^a	16.9 ^a
TVu 1190	7.3 ^d	15.0 ^b	11.6 ^c	19.7 ^a	21.7 ^a
TVu 13686	8.7 ^c	15.8 ^b	10.5 ^c	17.4 ^{ab}	19.2 ^a

Key: BCMV-BIC = Bean common mosaic virus – blackeye cowpea strain; CABMV = Cowpea aphid – borne mosaic virus; CMeV = cowpea mottle virus; SBMV = Southern bean mosaic virus; ^a Number with the same letters across the rows are not significantly different at 5% probability (LSMeans)

Table 6. Comparison of the number of seeds per pod of cowpea lines infected with four seed transmitted viruses.

Lines	BCMV-BIC	CABMV	CMeV	SBMV	CONTROL
Ife Brown	5.7 ^c	8.6 ^b	8.5 ^b	8.8 ^b	10.5 ^a
IT82D-716	6.5 ^b	7.9 ^a	6.2 ^b	7.9 ^a	8.6 ^a
IT82D-889	12.6 ^b	12.7 ^b	12.6 ^b	14.2 ^a	14.3 ^a
IT84S-2246-4	8.1 ^{ab}	8.5 ^{ab}	7.4 ^b	8.0 ^{ab}	9.4 ^a
IT86D-371	9.4 ^{ab}	9.2 ^b	9.8 ^{ab}	10.3 ^{ab}	10.7 ^a
IT86D-880	11.1 ^{ab}	11.9 ^a	10.4 ^b	11.8 ^a	12.0 ^a
IT96D-774	7.3 ^{bc}	7.7 ^b	6.5 ^c	8.6 ^b	10.1 ^a
TVu 12349	13.3 ^a	13.2 ^a	13.9 ^a	13.4 ^a	14.6 ^a
CP-VAR8	10.2 ^c	12.5 ^b	13.1 ^a	12.9 ^{ab}	13.7 ^a
IT83D-442	11.2 ^{ab}	11.2 ^{ab}	11.2 ^{ab}	11.2 ^{ab}	11.2 ^{ab}

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TVu 66	8.0 ^c	10.7 ^b	9.6 ^b	11.0 ^b	12.4 ^a
TVu 11426	15.2 ^{ab}	14.7 ^{ab}	13.9 ^{bc}	15.5 ^{ab}	16.0 ^a
TVu 1190	10.0 ^c	11.6 ^{bc}	11.4 ^{bc}	13.6 ^{ab}	14.6 ^a
TVu 13686	12.3 ^c	13.8 ^{ab}	12.8 ^{bc}	13.8 ^a	14.7 ^a

Key: BCMV-BIC = Bean common mosaic virus – blackeye cowpea strain; CABMV = Cowpea aphid – borne mosaic virus; CMeV = cowpea mottle virus; SBMV = Southern bean mosaic virus; ^a Number with the same letters across the rows are not significantly different at 5% probability (LSMeans)

Table 7. Comparison of seed yield (Kg Ha⁻¹) of cowpea lines following infection of four seed transmitted viruses

Lines	BCMV-BIC	CABMV	CMeV	SBMV	CONTROL
Ife Brown	245.5 ^c	260.6 ^c	224.8 ^c	721.6 ^b	1058.4 ^a
IT82D-716	189.9 ^b	177.4 ^b	160.0 ^b	288.5 ^b	892.5 ^a
IT82D-889	630.7 ^b	871.1 ^a	280.3 ^c	835.0 ^a	932.1 ^a
IT84S-2246-4	176.6 ^b	176.8 ^b	158.0 ^b	295.6 ^b	793.9 ^a
IT86D-371	119.7 ^c	126.7 ^c	103.0 ^c	426.0 ^b	974.7 ^a
IT86D-880	937.1 ^a	1033.2 ^a	95.5 ^b	1056.9 ^a	1055.2 ^a
IT96D-774	151.6 ^b	184.1 ^b	159.6 ^b	309.0 ^b	1003.4 ^a
TVu 12349	269.7 ^c	568.6 ^b	264.3 ^c	741.5 ^{ab}	822.5 ^a
CP-VAR8	448.3 ^b	541.0 ^b	1205.9 ^a	1087.3 ^a	1198.4 ^a
IT83D-442	342.2 ^{cd}	210.3 ^d	177.0 ^d	482.0 ^{bc}	1272.2 ^a
IT90K-284-2	1103.9 ^a	1099.4 ^a	552.6 ^b	1123.7 ^a	1103.5 ^a
TVu 66	199.5 ^c	561.7 ^a	115.5 ^c	288.1 ^b	641.0 ^a
TVu 11426	1627.7 ^a	1624.8 ^a	628.5 ^b	1737.0 ^a	1816.9 ^a
TVu 1190	241.5 ^{cd}	390.5 ^c	210.6 ^d	921.8 ^b	1851.1 ^a
TVu 13686	148.5 ^b	435.1 ^a	217.2 ^b	474.9 ^a	545.4 ^a

Key: BCMV-BIC = Bean common mosaic virus – blackeye cowpea strain; CABMV = Cowpea aphid – borne mosaic virus; CMeV = cowpea mottle virus; SBMV = Southern bean mosaic virus; ^a Number with the same letters across the rows are not significantly different at 5% probability (LSMeans)

DISCUSSION

This study has compared the responses of cowpea cultivars to very destructive pathogens of the plant namely; *Bean common mosaic virus* genus *Potyvirus* - blackeye cowpea strain (BCMV – BIC), *Cowpea aphid-borne mosaic virus* genus *Potyvirus* (CABMV), *Cowpea mottle virus* genus *Carmovirus* (CMeV) and *Southern bean mosaic virus* genus *Sobemovirus* (SBMV). The symptoms expressed by the lines were similar to those reported by Itah (2004); both the severity and incidences of infection were low in the highly resistant and resistant genotypes, and high in the susceptible and highly susceptible lines. But the incidence of BCMV – BIC and CMeV on TVu 13686, TVu 66 and IT82D-889 lines were higher in the field than in the screenhouse probably due to the differences in ambient conditions in the two environments. From PAS – ELISA study of symptomless plots, one in each of the five randomly selected plant samples, IT86D-880 infected with BCMV – BIC and CP-VAR8 infected with CMeV had infection. This may be due to latent infection, or to mutation in the cowpea lines or strain of virus leading to breakdown of resistance, or due to seed - lot bearing similar seeds from other varieties. The last option is the most probable; therefore, utmost care should be exercised in the handling of seeds to avoid contamination of seed - lots.

The seed – borne viruses induced very severe infection symptoms in some cowpea genotypes, whereas, in others the effect varied from moderate to no infection at all. With PAS – ELISA analysis, genotypes with no infection are highly resistant to the virus whereas the genotypes with very severe infections are highly susceptible. As such, IT90K-284-2 and IT86D-880 were highly resistant to BCMV – BIC, these lines and IT82D-889 were highly resistant to CABMV and SBMV. IITA (1997) had reported IT90K-284-2 was resistant to CABMV, SBMV and BCMV – BIC infection syndrome. The varieties IT82D-889 and IT86D-880 are hereby recommended to the listing. CP-VAR8 was the only variety highly resistant to infections caused CMeV, it is also recommended for breeding purposes. The resistant

lines (CP-VAR8, IT90K-284-2, IT82D-889 and IT86D-880) have potentials to be useful in breeding programme to develop elite cowpea lines, in particular CP-VAR8, because cowpea lines resistant to CMeV have not been found (Allen *et al.*, 1982; Ogundiwin 2000).

BCMV – BIC and CMeV were more virulent pathogens than CABMV and SBMV because they infected more cowpea lines, and CABMV infected more cowpea genotypes than SBMV. BCMV – BIC and CMeV were so destructive that suggestion is hereby made that, once either or both of these viruses are observed in farmers' fields, very rigorous management strategies must be adopted immediately to destroy them for the future of the crop; such strategies as roguing of infected and volunteer plants, destruction of vectors or most importantly, cultivation of resistant cultivars in the endemic area. CMeV and BCMV – BIC significantly reduced the plant height, number of pods per plant and seed yield than CABMV and SBMV ($p < 0.05$). BCMV – BIC reduced the plant height, number of pods per plant and yield per hectare than CMeV ($p < 0.05$). Earlier studies had reported similar reductions in yield (Kaiser and Mossahebi, 1975; Singh and Singh, 1985), foliar weight (Anderson *et al.*, 1996) and other traits, and

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to 50% flowering and the number of days from planting to maturity in any of the cowpea lines.

None of the 15 cowpea genotypes was highly resistant to all the four seed-borne viruses but TVu 11426, IT86D-371 and IT86D-880 were moderately resistant (tolerant) to BCMV – BIC and CMeV and highly resistant to SBMV. IT82D-889, IT90K-284-2 and TVu 12349 were resistant to BCMV – BIC, CABMV and SBMV. Resistance and moderate resistance to virus infection observed in some genotypes imply that the viruses multiply within the host plant but do not severely change the agronomic and yield component traits (Walkey, 1985), those lines are tolerant. Similar to the highly resistant genotypes, the tolerant genotypes can also be used in programmes to develop improved cowpea lines (Allen *et al.*, 1982), which will provide a

better virus disease management strategy. Combining resistance and tolerance genes from several genotypes means that protection is introduced from multiple sources of identified resistance and that would be a more effective strategy.

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