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GROWTH AND YIELD VARIABILITY OF GROUNDNUT (*Arachis hypogaea* L.) CULTIVARS INFECTED WITH COWPEA APHID-BORNE MOSAIC VIRUS DISEASE

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ABSTRACT

Groundnut (Arachis hypogaea) is a major legume crop with diverse uses in Nigeria. Its productivity is however threatened by Cowpea aphid-borne mosaic virus (CABMV) in most groundnut producing areas, resulting in huge losses. This study was conducted to determine the resistance of some commercial groundnut cultivars under CABMV disease. The experiment was conducted in Minna, Southern Guinea Savanna agro-ecological zone of Nigeria. Twenty groundnut cultivars were evaluated separately as healthy and CABMV infected trials. The experiment was laid out in randomised complete block design with three replications. Seedlings were infected with the virus by mechanical inoculation at 10 days after sowing. The plants were observed for disease incidence, growth and yield attributes. The data collected were subjected to analysis of variance, principal component and cluster analyses at $p \leq 0.05$. One hundred percent infection was found regardless of the cultivar. The healthy plants exhibited significantly ($p<0.05$) higher morphological and yield parameters than infected plants. Principal component analysis revealed that 100-seed weight accounted for the greatest variability in healthy (eigen vector = 0.6239) and CABMV infected (eigen vector = 0.6005) plants. Cluster analysis showed that 18 (90 %) cultivars formed cluster 1, whereas one cultivar each was found in cluster 2 and 3. The top three cultivars for 100-seed weight: "SAMNUT 23" (56.0 g), "SAMNUT 25" (50.5 g) and "SAMNUT 26" (50.9 g) were the most tolerant to CABMV, whereas "ICG-92267" was identified as the best cultivar for dry matter production (24.0 g/plant). Planting of these tolerant cultivars is recommended in order to mitigate the stresses imposed by CABMV.

Key words: disease incidence, principal components, clusters, groundnut

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important grain legume in tropical cropping systems of Africa which is typically grown in subsistence nature by resource poor farmers (Haussmann *et al*., 2012). Cultivated groundnut originated from South America (Scott and Vikas, 2014). It is an annual oilseed and food legume crop grown in numerous environments all over the world between 40 °N and 40 °S. Groundnut is ranked fifth position among oilseed crops worldwide after oil palm, soyabean, rapeseed and sunflower (FAO, 2014). It serves as an excellent source of plant-based protein and contains high contents of various minerals, vitamins and plant compounds (Muhammad *et al*., 2013). Its haulms are essential animal feed containing 8-15 % protein, 1-3 % lipids, 9-17 % minerals, and 38-45 % carbohydrates (Janila *et al*., 2016). Groundnut is used as therapeutic food in Africa and many developing nations of the world to combat malnutrition in children (UNICEF, 2007). It has been found to produce more oil per hectare than any other food crop hence possibilities are being considered to explore it for bio-diesel production (Prasad *et al*., 2011). Groundnut is commonly grown in intercrops due to its nitrogen fixing ability thereby enriching the soil for other crops (Konlan *et al.,* 2013). Studies have shown that groundnut could fix between 40 and 80 kg N per hectare in one year (Janila *et al*., 2013).

In sub Saharan Africa, 32 viruses induce yield losses in groundnut and the major ones are *Cowpea aphid-borne mosaic virus* (CABMV), *Cucumber mosaic virus* (CMV), *Indian peanut clump virus* (IPCV), *Peanut clump virus* (PCV), *Peanut mottle virus* (PeMoV), *Peanut streak virus* (PStV) and *Cowpea mild mottle virus* (CPMMV-severe strain) (Sastry and Zitter, 2014). All these viruses are transmitted through groundnut seed and are regarded as important quarantine pests. *Cowpea aphid-borne mosaic virus* has been known in Nigeria since 1976 as a devastating virus disease of legume in all the agro-ecological zones (Shoyinka *et al*., 1997). The virus has flexuous filamentous particles raging from 727 to 765 nm in length and

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11 nm wide (Damiri *et al*., 2013). It is a potyvirus whose particles are not affected by Mg ions (Luis *et al*., 2013). Most often, the fecundity of CABMV soars under field conditions through increased aphid populations, availability of susceptible host plants and the presence of initial infection foci (Luis *et al*., 2013). Infection due to CABMV has resulted in yield losses that ranged from 13 to 87 % and sometimes total crop loss could be encountered depending on the level of susceptibility of the cultivars (Alegbejo, 2015). Besides sole infection, CABMV can co-exist with other viruses like *Cowpea mottle virus* (CPMoV) or CMV (Arogundade *et al*., 2010), causing a mixed or combined infections with more damaging effect on farmers' field. Although a lot of studies have been conducted to determine the pathogenicity of CABMV disease on cowpea there is scanty information on the effect of the virus on groundnut in Nigeria. Groundnut cultivars with in-built characteristics of CABMV disease resistance have the potential to produce higher yields on farmers' fields. Knowledge of the resistance status of commercial groundnut cultivars would contribute to Nigeria's food security. Therefore, the objective of this study was to evaluate 20 commercial cultivars of groundnut for CABMV resistance in Southern Guinea Savanna agro-ecological zone.

MATERIALS AND METHODS

Study Location

The study was conducted at the Teaching and Research Farm, Federal University of Technology, Minna during the 2016 cropping season. The coordinates of the site were 9^{O} 51′N, 6^{O} 44′E and 212 m above sea level. The site of the experiment is located in the Southern Guinea Savannah ecological zone of Nigeria. The mean annual rainfall is 1200 mm and is distributed between April and early October of each year. Temperature ranges between 35.0 ^{o}C and 37.5 ^{o}C while relative humidity varies from 40 to 80 %. According to Adeboye *et al*. (2011), soils in Minna are generally classified as Alfisols.

Source of Groundnut Seeds

The groundnut cultivars ("FDRF7-61", "FDRF7-67", "ICG-01276", "ICG-02189", "ICG-5159", "ICG-6654", "ICG-92267", "ICG-94169", "ICG-IS-13003", "ICG-IS-13986", "ICGV-91317", "ICGV-IS-76855", "SAMNUT 10", "SAMNUT 14", "SAMNUT 21", " SAMNUT 22", "SAMNUT 23", "SAMNUT 24", "SAMNUT 25", and "SAMNUT 26") used for the experiment were collected from the Institute for Agricultural Research (IAR), Samaru, Zaria, Kaduna State, Nigeria. These are commercial varieties of groundnut which are already being grown by farmers across the country especially in Minna, Southern Guinea Savanna agro-ecological zone where the study was conducted. They are early to medium maturing, dual purpose (kernel and haulm) with 45-50 % oil content.

Treatments, Experimental Design and Field Layout

The twenty groundnut cultivars served as the treatments. Each cultivar was evaluated separately as infected and control (healthy). The experiment was laid out in randomised complete block design with three replications. The overall plot size was 40 m × 12 m (480 m^2). The plots containing the infected plants had a total size of 15 m × 2 m (30 m^2) containing 20 rows of 2 m long each with an alley of 3 m between the replicates. Uninfected (control) plots of each cultivar also had a total size of 15 m × 2 m (30 m^2) containing 20 rows of 2 m long each with an alley of 3 m between the replicates. The infected and control plots were established side by side with an isolation distance of 10 m in order to prevent virus contaminations.

Source and Multiplication of Virus Inoculum

The CABMV isolate used was obtained from the stock in the Department of Crop Production, Federal University of Technology, Minna. The inoculum was multiplied in the screen house to obtain enough quantity required for the field work. This was accomplished by planting susceptible cowpea cultivar (Ife Brown) into 20 pots at 5 plants per pot. The plants were infected with CABMV extract at 10 days after sowing. Inoculation of the cowpea seedlings was carried out after grinding the inoculum (1 g of CABMV infected leaf) in inoculation buffer (0.1 M sodium phosphate dibasic, 0.1 M potassium phosphate monobasic, 0.01 M ethylene diamine tetra acetic acid and 0.001 M L-cystine per litre of distilled water, adjusted to pH 7.2) using a pre-cooled sterilized mortar and pestle (Adamu *et al*., 2015). Two microlitres of β-mercapto-ethanol was added to the extract prior to application. The upper leaf surface of the target plants were dusted with 600-mesh carborundum (Fisher Scientific, Fair Lawn, NJ) powder before the inoculum extract was applied. The inoculated leaves were then rinsed with cold distilled water and observed for disease symptoms. The infected leaves were harvested at three weeks after inoculation (WAI). Leaf tissues infected with CABMV were preserved in vials (1 g of the leaf/vial) at room temperature. Each vial contained 5 g silica gel as moisture absorber covered with 1 g of non-absorbent cotton wool.

Field Establishment, Inoculation and Crop Management

The experimental site was ploughed with tractor in the first week of May, 2016. Manual ridging was then carried out at one week after ploughing. Groundnut seeds were sown in the second week of

May, 2016 on the ridges at the rate of two seeds per hole, using 75 cm × 25 cm inter- and intra row spacing. Seedlings were thinned to one plant per stand at one week after emergence. Manual weeding was carried out at 3, 5 and 8 weeks after planting. The earlier preserved virus isolates (CABMV infected leaves) were used to inoculate the treatment plots on the field. Inoculation was carried out following the same procedure as described above. Lambda cyhalothrin 30 % EC insecticide was sprayed (Badii *et al.*, 2013) at the rate of 2.5 litres/ha in three applications to control aphids and other insects. Insecticide was applied weekly starting from 2 weeks after sowing (WAS) until the fourth week.

Data Collection and Statistical Analysis

Disease incidence was recorded at 1 and 2 weeks after inoculation (WAI). It was taken as percentage of the total plants that exhibited symptoms of CABMV disease. Disease symptoms were scored using a scale of 1-5 (Adamu *et al.*, 2015) as follows:

1 = no symptoms (apparently healthy plant)
2 = mild mosaic (10-30 % infection)
3 = moderate mosaic (31-50 % infection)
4 = severe mosaic, chlorosis and stunting (51-70 % infection)
5 = very severe mosaic, chlorosis, stunting and plant dead (>70 % infection)

The growth and yield parameters observed were plant height (cm), leaf diameter (cm), number of branches per plant, number of days to 50% flowering, number of pod per plant, pod weight per plant (g), fresh haulm weight per plant (g), dry haulm weight per plant (g), 100-seed weight (g) and pod yield (kg ha^{-1}). The data were subjected to analysis of variance, principal component and cluster analyses, using Statistical Analysis System (SAS, 2008). The cultivars were classified into three clusters based on the reductions in their growth and yield parameters using Unweighted Pair Group Method with Arithmetic (UPGMA) mean (Adama *et al.*, 2015).

$$\text{Reduction (\%)} = \frac{(X_1 - X_2)}{X_1} \times 100;$$

where X_1 is mean of healthy plants and X_2 is mean of infected plants.

RESULTS

CABMV Disease Incidence and Effects on Growth Characters

All the inoculated plants showed disease symptoms at 1 WAI. The symptoms observed varied from mild to severe mosaic. Generally, the healthy plants were significantly ($p < 0.05$) taller than infected plants with the exception of "SAMNUT 14" (Table 1). The highest height reduction was observed in "ICG-94169" (59.1 %) followed by "SAMNUT 21" and "ICG-01276" which showed 45 and 44.3 % height reduction, respectively. The groundnut cultivars "FDRF7-61", "ICG-02189", "ICG-5195", "ICG-IS-13986", "ICGV-91317", "ICGV-IS-76855", "SAMNUT 22", and "SAMNUT 24" exhibited height reduction between 30 and 39 %. Other cultivars such as "FDRF7-67", "ICG-92267", "ICG-IS-13003", "SAMNUT 10", "SAMNUT 23" and "SAMNUT 26" suffered between 22.2 and 29.6 % height reduction. Height reduction of 14.8 % was observed in "ICG-6654", whereas the height of "SAMNUT 14" and "SAMNUT 25" was reduced by 7.8 and 10.8 %, respectively.

The leaf diameter of healthy plants was significantly ($p < 0.05$) wider than their infected counterparts (Table 1). The cultivar "SAMNUT 25" had the highest reduction in leaf diameter (35.9 %). In seven other cultivars ("ICG-02189", "ICG-5195", "ICG-92267", "ICGV-91317", "SAMNUT 21", "SAMNUT 22" and "SAMNUT 24") leaf diameter reduction was greater than 30 %. Reduction between 20.4 and 29.7 % in leaf diameter was observed in "FDRF7-61", "ICG-01276", "ICG-IS- 13003", "ICG-IS-13986", "ICGV-IS-76855", "SAMNUT 10", "SAMNUT 23" and "SAMNUT 26". On the other hand, the cultivars "FDRF7-67", "ICG-6654", "ICG-94169" and "SAMNUT 14" suffered between 13.4 and 17.9 % reduction in leaf diameter. All the healthy plants except in "FDRF7-67", "ICG-6654" and "SAMNUT 23" produced significantly ($p<0.05$) higher number of branches compared to the infected ones (Table 1). The highest reduction in number of branches per plant was observed in "ICG-92267" (68.0 %) followed by "ICGV-91317" (66.7 %), "SAMNUT 21" (60.9 %) and "SAMNUT 25" (60.0 %). In "ICG-02189", "ICG-5195", "ICG-94169", "ICGV-IS-76855", "SAMNUT 10", "SAMNUT 14", "SAMNUT 23" and "SAMNUT 23" reduction in number of branches per plant ranged between 50 and 58.8 %. Five cultivars ("FDRF7-61", "ICG-01276", "ICG-IS-13986", "SAMNUT 22" and "SAMNUT 26") showed reduction which varied from 40 to 47.6 %. Number of branches per plant was reduced by 33.3 % in "FDRF7-67" and "ICG-6654", whereas the lowest reduction in number of branches was observed in "ICG-IS-13003" (30.8 %)

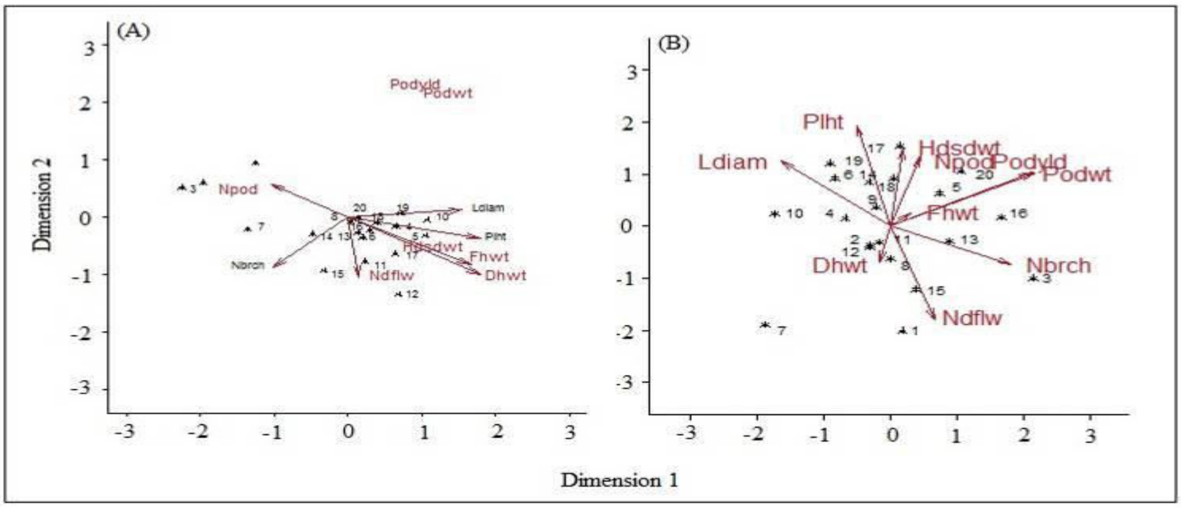

Figure 1: Biplot of the first two principal components from (A) Healthy and (B) *Cowpea aphid-borne mosaic virus* infected groundnut plants

Table 1: Mean plant height (cm), leaf diameter (cm) and number of branches per plant in *Cowpea aphid-borne mosaic virus* infected compared with healthy groundnut plants

	Plant height (cm)				Leaf diameter (cm)				Number of branches per plant			
Cultivar	Healthy	Infected	LSD	% Reduction	Healthy	Infected	LSD	% Reduction	Healthy	Infected	LSD	% Reduction
FDRF7-61	32.8	21.2	4.5	35.5	2.6	1.8	0.3	28.8	16	9	1.9	43.8
FDRF7-67	36.4	28.1	2.7	22.8	2.5	2.2	0.3	14.2	12	8	1.0	33.3
ICG-01276	37.1	20.7	4.8	44.3	2.4	1.7	0.3	28.8	21	11	3.3	47.6
ICG-02189	40.1	27.4	2.7	31.7	3.2	2.1	0.3	34.1	16	8	1.4	50.0
ICG-5195	51.4	32.2	3.3	37.3	3.2	2.2	0.3	32.8	19	9	2.0	52.6
ICG-6654	38.8	33.0	3.0	14.8	2.8	2.4	0.0	13.4	12	8	2.6	33.3
ICG-92267	31.4	23.2	1.2	26.2	3.3	2.2	0.3	31.8	25	8	4.5	68.0
ICG-94169	39.2	16.0	2.7	59.1	2.8	2.3	0.3	17.9	17	8	2.5	52.9
ICG-IS- 13003	38.8	27.3	2.1	29.6	3.1	2.2	0.3	29.7	13	9	2.6	30.8
ICG-IS- 13986	46.0	28.1	2.1	39.0	3.1	2.4	0.3	24.3	10	6	1.4	40.0
ICGV-91317	41.5	28.3	2.4	31.8	3.1	2.0	0.3	33.9	18	6	3.9	66.7
ICGV-IS-76855	40.5	25.8	2.4	36.3	2.7	2.1	0.3	20.4	17	7	1.7	58.8
SAMNUT 10	38.5	27.7	2.7	28.0	3.0	2.1	0.6	29.0	18	9	2.0	50.0
SAMNUT 14	38.1	35.1	3.0	7.8	2.6	2.2	0.6	16.4	18	9	2.6	50.0
SAMNUT 21	35.5	19.5	3.9	45.0	2.7	1.9	0.3	31.5	23	9	5.6	60.9
SAMNUT 22	40.9	27.0	4.2	34.1	3.1	2.0	0.3	35.1	20	11	2.2	45.0
SAMNUT 23	40.2	29.1	2.4	27.6	2.8	2.2	0.6	21.4	14	7	2.0	50.0
SAMNUT 24	43.0	28.4	5.1	33.8	3.2	2.1	0.3	32.8	14	7	3.7	50.0
SAMNUT 25	42.4	37.8	2.4	10.8	3.4	2.2	0.3	35.9	15	6	3.7	60.0
SAMNUT 26	37.9	29.5	6.6	22.2	2.9	2.1	0.3	27.9	15	9	1.0	40.0

For each cultivar, means of healthy and infected plants were compared along the row using the Least Significant Difference (LSD) at $p \leq 0.05$

Effects of CABMV Infection on Reproductive Characters

Cowpea aphid-borne mosaic virus disease delayed the number of days to 50 % flowering in almost all the infected groundnut cultivars even though the effect was in most cases not significant ($p > 0.05$) (Table 2). Majority of the infected plants attained 50 % flowering at 1 or 2 days later than their healthy counterparts. “SAMNUT 10” was most affected with 50 % flowering being delayed for 5 days. Next to it were “ICG-92267” and “SAMNUT 21” in which 50 % flowering was delayed for 3 days. Conversely, the infected plants of “ICG-IS-13986”, “SAMNUT 23” and “SAMNUT 26” attained 50 % flowering concurrently with their healthy plants. The healthy plants produced significantly ($p < 0.05$) higher number of pods per plant than the infected plants (Table 2). Reduction in pod number was highest in “ICG-94169” (78.6 %), followed by “ICG-92267” (60.9 %). The lowest reduction in number of pods per plant was found in “SAMNUT 23” (4.3 %). However, relatively low reduction was also observed in “ICG-6654” (8.7 %), “ICGV-91317” (13 %), “ICGV-IS-76855” (5 %) and “SAMNUT 24” (6.9 %). In the remaining cultivars, pod number was reduced by a range of 25 to 54.8 %. Generally, pod weight per plant was significantly ($p < 0.05$) higher in the healthy plants than their infected counterparts (Table 2). The healthy plants exhibited pod weight that varied between 14.3 in “ICG-92267” and 22.3 g in “ICG-IS-13003” per plant. Conversely, a range of 5 (“ICG-92267”) to 6.2 g (“SAMNUT26”) was observed in the infected plants. Also, most of the infected plants suffered more than 60.0 % reduction in pod weight. The highest pod weight reduction was observed in “ICG-IS- 13003” (74.6 %) while the lowest was found in "SAMNUT 23" (59.1 %). Other cultivars such as "ICG-01276", "SAMNUT 10", "SAMNUT 22" and "SAMNUT 26" had between 59.2 and 59.7 % reduction in pod weight per plant. Fresh haulm weight per plant varied between 75.8 ("ICG-92267") and 153.2 g ("ICG-02189") per plant in the healthy plants, whereas a range of 26.2 ("ICGV-91317") to 48.7 g ("FDR7-67") was found in the infected plants (Table 3). Fresh haulm weight per plant of most infected plants was significantly ($p < 0.05$) reduced by CABMV disease. "ICG-02189" with 80.7 % suffered the highest reduction among the infected plants while only "FDRF7-67" (46.4 %) exhibited less than 50 % reduction in fresh haulm weight per plant. The healthy plants produced dry haulm weight varying between 25.2 ("ICG-01276") and 60.3 g ("SAMNUT21") per plant (Table 3). On the other hand, the infected plants had dry haulm weight between 13.6 ("ICG-02189") and 24 g ("ICG-92267") per plant. Majority of the infected plants suffered between 60.2 ("SAMNUT 23") and 74.9 % ("ICG-02189") reduction in dry weight per plant. The cultivars "FDR7-61", "ICG-92267", "ICG-IS-13986", "ICGV-91317" and "SAMNUT 22" exhibited between 49.5 and 59.5 % reduction in dry haulm weight per plant. FDR7-67 had 36.4 % reduction in dry haulm weight while **"**ICG-01276" exhibited the lowest (17.5 %).

Table 2: Mean number of days to 50 % flowering, pods per plant (no.), and pod weight per plant (g) in *Cowpea aphid-borne mosaic virus* infected compared with healthy groundnut plants

	Days to 50 % flowering (no.)				Pods per plant (no.)%				Pod weight per plant (g)%			
Cultivar	Healthy	Infected	LSD	Increase	Healthy	Infected	LSD	Reduction	Healthy	Infected	LSD	Reduction
FDRF7-61	31	33	2.4	2	29	15	5.1	48.3	14.6	5.4	0.9	62.8
FDRF7-67	29	31	1.5	2	27	14	3.3	48.1	15.1	5.6	0.6	62.8
ICG-01276	32	34	1.8	2	30	20	5.2	33.3	15	6.1	0.3	59.6
ICG-02189	29	31	0.9	2	31	14	10.7	54.8	14.9	5.5	0.4	62.9
ICG-5195	30	32	0.9	2	25	18	3.7	28.0	15.3	6.1	0.3	60.1
ICG-6654	30	32	1.5	2	23	21	8.1	8.7	14.4	5.5	0.5	61.7
ICG-92267	30	33	0.9	3	23	9	3.3	60.9	14.3	5.0	0.4	65.1
ICG-94169	31	33	1.5	2	28	6	1.0	78.6	15.1	5.9	0.8	61.1
ICG-IS- 13003	30	31	0.9	1	24	17	14.8	29.2	22.3	5.7	1.6	74.6
ICG-IS- 13986	31	31	0.9	0	24	18	2.3	25.0	15	5.3	0.6	64.7
ICGV-91317	34	35	0.9	1	23	20	9.6	13.0	14.9	5.8	0.3	61.2
ICGV-IS-76855	35	36	0.9	1	20	19	4.4	5.0	14.7	5.5	0.5	62.5
SAMNUT 10	30	35	0.9	5	27	15	6.1	44.4	14.8	6.0	0.6	59.7
SAMNUT 14	30	31	1.5	1	29	21	3.9	27.6	14.6	5.8	0.5	60.4
SAMNUT 21	32	35	0.6	3	26	16	2.7	38.5	14.7	5.5	0.5	62.5
SAMNUT 22	30	33	1.2	2	25	18	6.2	28.0	15	6.1	0.3	59.2
SAMNUT 23	31	31	1.2	0	23	22	5.7	4.3	14.5	5.9	0.6	59.1
SAMNUT 24	30	31	0.9	1	29	27	12.4	6.9	14.7	5.6	0.8	61.7
SAMNUT 25	30	31	0.9	1	26	16	5.1	38.5	15.1	5.6	0.4	62.9
SAMNUT 26	31	31	1.5	0		16	4.2	38.5	15.3	6.2	0.4	59.6

For each cultivar, means of healthy and infected plants were compared along the row using the Least Significant Difference (LSD) at $p \leq 0.05$

Table 3: Mean fresh and dry haulm weight per plant (g) of *Cowpea aphid-borne mosaic virus* infected compared with healthy groundnut plants

	Fresh haulm weight per plant (g)				Dry haulm weight per plant (g)			
Cultivar	Healthy	Infected	LSD	% Reduction	Healthy	Infected	LSD	% Reduction
FDR7-61	87.3	38.9	10.2	55.5	40	20.2	6.9	49.5
FDR7-67	90.9	48.7	15.3	46.4	35.2	22.4	7.3	36.4
ICG-01276	91.1	40.9	10.5	55.1	25.2	20.8	8.6	17.5
ICG-02189	153.2	29.5	44.1	80.7	54.2	13.6	5.7	74.9
ICG-5195	124.6	43.7	21.0	64.9	55.3	21.1	13.0	61.9
ICG-6654	117.7	35.3	21.0	70.0	53.8	14.9	13.0	72.2
ICG-92267	75.8	33.2	72.3	56.2	50.7	24.0	14.2	52.7
ICG-94169	111.7	36.8	6.0	67.1	50.7	17.2	2.3	66.1
ICG-IS- 13003	104.3	37.8	10.5	63.7	51.4	19.8	5.6	61.4
ICG-IS- 13986	116.4	41.9	21.0	64.0	54.2	23.3	11.6	57.1
ICGV-91317	110.4	26.2	20.1	76.2	53.4	23.0	20.5	56.8
ICGV-IS-76855	122.3	39.9	18.0	67.4	60.3	20.2	8.3	66.6
SAMNUT10	119.9	35.5	11.1	70.4	59.5	18.5	3.3	68.9
SAMNUT14	114.8	40.7	15.9	64.5	59.3	20.0	6.1	66.2
SAMNUT21	117.2	38.4	10.5	67.2	60.3	20.0	5.4	66.8
SAMNUT22	109.3	40.9	13.5	62.6	55.4	22.4	6.3	59.5
SAMNUT23	118.8	41.9	21.9	64.7	53.5	21.3	3.3	60.2
SAMNUT24	109.9	36.8	8.7	66.5	59.3	19.2	8.7	67.6
SAMNUT25	102.7	41.4	7.8	59.7	53.1	20.0	6.5	62.3
SAMNUT26	107.9	31.5	6.9	70.8	55.3	17.1	4.7	69.0

For each cultivar, means of healthy and infected plants were compared along the row using the Least Significant Difference (LSD) at $p \leq 0.05$

One hundred-seed weight of the healthy plants significantly ($p < 0.05$) outweighed their infected counterparts particularly in "FDRF7-67", "ICG-02189", "ICG-94169", "ICG-IS-13003", " ICGV-IS-13986", "ICGV-IS-76855", "SAMNUT 10", "SAMNUT 14", "SAMNUT 21", "SAMNUT 22", "SAMNUT 23", "SAMNUT 25" and "SAMNUT 26" (Table 4). The lowest reduction in 100-seed weight was found in "ICG-5195" (8.1 %). Other cultivars which exhibited relatively low reduction in 100-seed weight were "ICG-6654" (9.5 %), "SAMNUT 24" (12 %), "SAMNUT 26" (13.1 %), "SAMNUT 21" (13.4 %), "SAMNUT 25" (13.6 %), "ICGV-IS-76855" (14.7 %), "ICG-IS-13986" (16 %), "ICG-IS-13003" (16.4 %), "SAMNUT 14" (16.8 %), "ICGV-91317" (17.1 %), "SAMNUT 23" (17.3 %), "SAMNUT 22" (17.6 %), "ICG-92267" (18.1 %) and "ICG-01276" (18.5 %). The remaining cultivars had between 20.3 ("SAMNUT10") and 50.9 % ("FDR7-67") reduction in 100-seed weight. All uninoculated plants produced significantly ($p < 0.05$) higher pod yield compared to the diseased plants. The healthy plants of "ICG-IS-13003" produced 1, 490 kg of pods per hectare while other cultivars produced a range of 970-1, 020 kg ha^{-1}. On the other hand, the infected plants produced between 330 and 410 kg of pods per hectare. The highest reduction in pod yield (74.5 %) was observed in "ICG-IS-13003", whereas "SAMNUT 23" had the lowest (58.8 %) reduction in pod yield. The remaining cultivars exhibited between 59.0 and 65.6 % reduction in pod yield.

Principal Component Analysis Based on Growth and Yield Traits

The first five principal components of healthy plants accounted for 83.8 % of the total variation (Table 5). The PC 1 was strongly correlated with dry haulm weight per plant (eigen vector = 0.4388), plant height (eigen vector = 0.4386) and fresh haulm weight per plant (eigen vector = 0.4089). The PC 2 was loaded with pod yield (eigen vector = 0.5899) and pod weight per plant (eigen vector = 0.5894). The third principal component was mainly loaded with number of days to 50 % flowering (eigen vector = 0.6094) while variability in PC 4 was mainly due to the number of branches per plant (eigen vector = 0.5861) and leaf diameter (eigen vector = 0.5599. The fifth principal component was positively correlated with 100-seed weight (eigen vector = 0.6329). Leaf diameter, number of pods per plant, pod weight per plant and pod yield contributed positively to the variability among "ICG-01276", "ICG-92267", "ICG-IS-13986", "SAMNUT 25" and "SAMNUT 26" (Figure 1 A).

The first five principal components of the infected groundnut plants accounted for 85.4 % of the total variation (Table 5). The PC 1 was loaded with pod yield (eigen vector = 0.5358), pod weight per plant (eigen vector = 0.5304) and number of branches per plant (eigen vector = 0.4502). Variability in the PC 2 was induced by plant height (eigen vector = 0.4883) while in PC 3, fresh haulm weight per plant (eigen vector = 0.6555) and dry haulm weight per plant (eigen vector = 0.6270) were responsible for the observed variability.

Table 4: Mean 100-seed weight per plant and pod yield (kg ha^{-1}) of *Cowpea aphid-borne mosaic virus* infected compared with healthy groundnut plants

	100-seed weight per plant (g)				Pod yield (kg ha^{-1}) %			
Cultivar	Healthy	Infected	LSD	% Reduction	Healthy	Infected	LSD	Reduction
FDR7-61	34.7	27.4	5.1	21.1	970	360	0.057	62.9
FDR7-67	51.1	25.1	11.9	50.9	1010	380	0.040	62.4
ICG-01276	41.7	34.0	4.0	18.5	1000	400	0.019	60.0
ICG-02189	48.4	37.9	4.3	21.7	990	370	0.031	62.6
ICG-5195	40.3	37.0	4.5	8.1	1020	400	0.020	60.8
ICG-6654	46.1	41.7	6.9	9.5	960	370	0.032	61.5
ICG-92267	38.8	31.8	5.8	18.1	960	330	0.023	65.6
ICG-94169	65.0	42.7	7.7	34.3	1000	390	0.051	61.0
ICG-IS- 13003	50.5	42.2	5.6	16.4	1490	380	1.043	74.5
ICG-IS- 13986	50.4	42.4	2.2	16.0	1000	350	0.044	65.0
ICGV-91317	43.1	35.7	8.4	17.1	990	390	0.020	60.6
ICGV-IS-76855	54.9	46.8	6.6	14.7	980	360	0.038	63.3
SAMNUT10	49.6	39.6	9.9	20.3	990	400	0.042	59.6
SAMNUT14	43.6	36.3	4.0	16.8	980	390	0.038	60.2
SAMNUT21	54.2	46.9	6.3	13.4	980	370	0.035	62.2
SAMNUT22	55.1	45.4	7.4	17.6	1000	410	0.019	59.0
SAMNUT23	67.7	56.0	5.1	17.3	970	400	0.044	58.8
SAMNUT24	46.0	40.5	3.9	12.0	980	380	0.053	61.2
SAMNUT25	58.4	50.5	4.2	13.6	1010	370	0.029	63.4
SAMNUT26	58.6	50.9	4.4	13.1	1020	410	0.027	59.8

For each cultivar, means of healthy and infected plants were compared along the row using the Least Significant Difference (LSD) at $p \leq 0.05$

Table 5: Eigen vectors from the principal components (PCs) of growth and yield attributes in healthy and *Cowpea aphid-borne mosaic virus* infected groundnut plants

	Healthy					Infected				
Plant trait	PC 1	PC 2	PC 3	PC 4	PC 5	PC 1	PC 2	PC 3	PC 4	PC 5
Plant height (cm)	0.4386	-0.1009	-0.2133	-0.0046	-0.5350	-0.1250	0.4883	0.1922	0.0235	-0.3281
Leaf diameter (cm)	0.3792	0.0324	-0.2043	0.5599	0.0984	-0.4047	0.3137	-0.0524	-0.3272	0.2194
Number of branches per plant	-0.2514	-0.2388	0.1745	0.5861	0.3120	0.4502	-0.1842	0.0737	-0.3830	-0.2279
Number of days to flowering	0.0359	-0.2839	0.6094	-0.0113	-0.3293	0.1636	-0.4522	-0.0854	0.4099	0.1285
Fresh haulm weight per plant (g)	0.4089	-0.2256	-0.2510	-0.1570	-0.0069	0.0790	0.0655	0.6555	-0.2969	0.2971
Dry haulm weight per plant (g)	0.4388	-0.2723	0.0303	0.2291	0.2900	-0.0382	-0.1736	0.6270	0.2891	0.2865
Number of pods per plant	-0.2576	0.1541	-0.5788	-0.0086	0.1076	0.1123	0.3385	0.2456	0.5307	-0.4591
Pod weight per plant (g)	0.2181	0.5894	0.2147	0.0865	0.0326	0.5304	0.2640	-0.0508	-0.0732	0.1382
Pod yield (kg ha^{-1})	0.2176	0.5899	0.2135	0.0912	0.0309	0.5358	0.2546	-0.0614	-0.0510	0.1220
100-seed weight (g)	0.2798	-0.0834	0.1428	-0.4998	0.6329	0.0495	0.3758	-0.2411	0.3413	0.6005
% variation	26.6	21.8	15.4	11.6	8.4	26.3	25.2	14.8	10.9	8.2
Cumulative variation	26.6	48.4	63.8	75.4	83.8	26.3	51.5	66.3	77.2	85.4

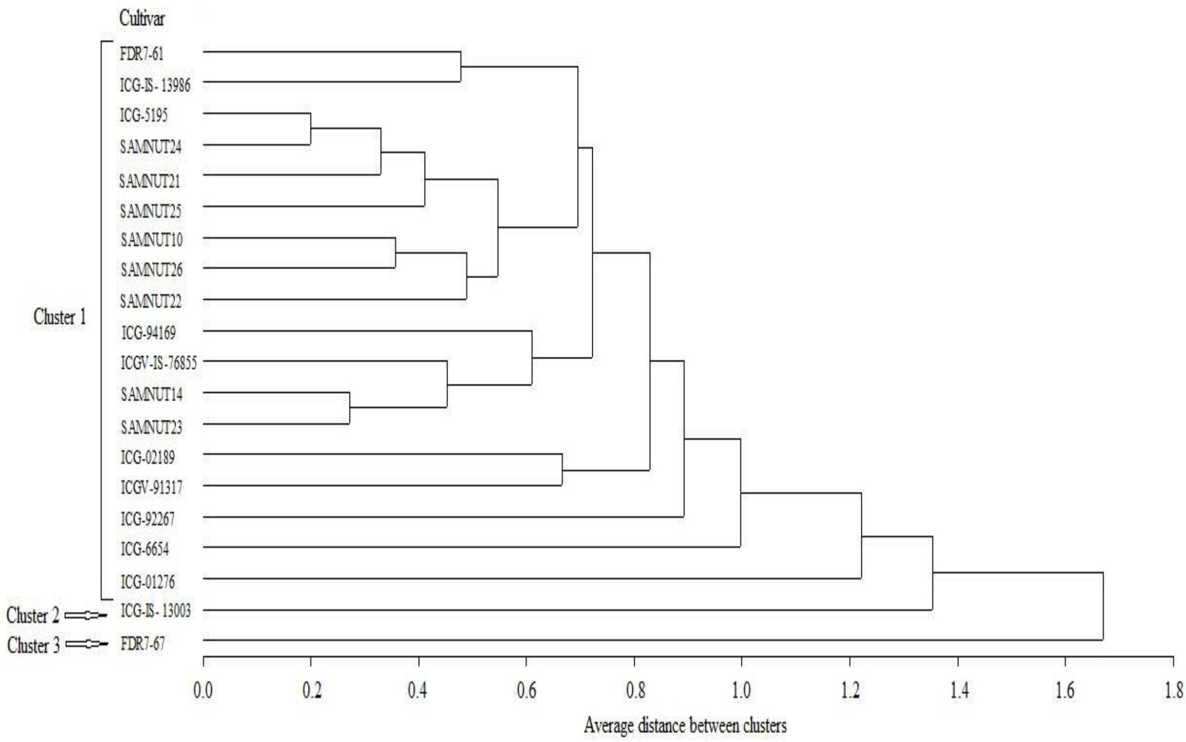

Figure 2: Dendogram of the reduction in growth and yield attributes of groundnut cultivars infected with *Cowpea aphid-borne mosaic virus*, according to Unweighted Pair Group Method with Arithmetic (UPGMA) mean

The fourth principal component was positively correlated with number of pods per plant (eigen vector = 0.5307) and number of days to 50 % flowering (eigen vector = 0.4099). On the other hand, the PC 5 was majorly loaded with 100-seed weight (eigen vector = 0.6005). Plant height, leaf diameter, fresh haulm weight per plant, pod weight per plant, pod yield and 100-seed weight exerted positive contribution to the variability among "ICG-02189", "ICG-5195", "ICG-6654", "ICG-94169", "ICG-IS-13003", "ICG-IS-13986", "SAMNUT 14", "SAMNUT 22", "SAMNUT 23", "SAMNUT 25" and "SAMNUT 26" (Figure 1 B).

Groundnut cultivar: 1 = "FDRF7-61", 2 = "FDRF7-67", 3 = "ICG-01276", 4 = "ICG-02189", 5 = "ICG-5159", 6 = "ICG-6654", 7 = "ICG-92267", 8 = "ICG-94169", 9 = "ICG-IS-13003", 10 = "ICG-IS-13986", 11 = "ICGV-91317", 12 = "ICGV-IS-76855", 13 = "SAMNUT 10", 14 = "SAMNUT 14", 15 = "SAMNUT 21", 16 = "SAMNUT 22", 17 = "SAMNUT 23", 18 = "SAMNUT 24", 19 = "SAMNUT 25", 20 = "SAMNUT 26"

Plant character: Plht = Plant height, Ldiam = Leaf diameter, Nbrch = Number of branches per plant, Ndflw = Number of days to 50 % flowering, Fhwt

= Fresh haulm weight per plant, Dhwt = Dry haulm weight per plant, Npod = Number of pods per plant, Podwt = Pod weight per plant, Hdsdwt = 100-seed weight, Podyld = Pod yield Cluster analysis showed that eighteen cultivars (“FDRF7-61”, “ICG-IS-13986”, “ICG-5195”, “SAMNUT 24”, “SAMNUT 21”, “SAMNUT 25”, “SAMNUT 10”, “SAMNUT 26”, “SAMNUT 22”, “ICG-94169”, “ICGV-IS-76855”, “SAMNUT 14”, “SAMNUT 23”, “ICG-02189”, “ICGV-91317”, “ICG-92267”, “ICG-6654” and “ICG-01276”) belonged to cluster 1 (Figure 2). Cultivars in this cluster exhibited variable reduction in height (7.8 to 59.1 %), leaf diameter (13.4 to 35.9 %), number of branches (33.3 to 68.0 %), increased days to 50 % flowering (0 to 5 days), reduction in number of pods per plant (4.3 to 78.6 %), pod weight per plant (59.1 to 65.1%), fresh haulm weight per plant (55.1 to 80.7 %), dry haulm weight per plant (17.5 to 74.9 %), 100-seed weight (8.1 to 34.3 %) and pod yield (58.8 to 65.6 %). However, “ICG-5195” and “SAMNUT 24” formed a sub-cluster within the group. Similarly, “SAMNUT 14” and “SAMNUT 23” were much more genetically identical. Only one cultivar (“ICG-IS-13003”) constituted cluster 2. Its mean reduction in height, leaf diameter, number of branches per plant, increased days to 50 % flowering, reduction in number of pods, pod weight, fresh haulm weight, dry haulm weight, 100-seed weight and pod yield was 29.6 %, 29.7 %, 30.8 %, 1 day, 29.2 %, 74.6 %, 63.7 %, 61.4 %, 16.4 %, and 74.5 %, respectively. Similarly, only one cultivar (“FDRF7-67”) formed cluster 3 with 22.8 % height reduction, 14.2 % reduction in leaf diameter, 33.3 % reduction in number of branches and 50 % flowering was delayed for 2 days. Moreover, the cultivar had reduction in number of pods per plant, pod weight per plant, fresh haulm weight per plant, dry haulm weight per plant, 100-seed weight and pod yield of 48.1, 62.8, 46.4, 36.4, 50.9, and 62.4 %, respectively.

DISCUSSION

All cultivars expressed significant variability in morphological and yield traits between the healthy and CABMV-infected plants. This observation showed that CABMV reduced the potential performance of the entire groundnut cultivars evaluated. This supported the findings of Kaitisha (2001) who identified CABMV as a major biotic constraint to groundnut productivity in sub Saharan Africa. Over the years, researchers have intensified efforts aiming at providing adequate protection for plants and obtaining maximum yield. The fact that 100 % disease incidence was found on the inoculated plants indicated that none of the groundnut cultivars exhibited immunity to the virus. Cultivation of tolerant varieties is an alternative and effective control strategy in the absence of immune varieties. The cultivars “ICG-5195” and “ICG-6654” which exhibited less than 10 % reduction in 100-seed weight probably contained CABMV tolerant genes.

Seed weight is an important trait because of its direct relationship with seed size (Biçer, 2009), overall yield and economic return. For instance, Upadhyaya *et al.* (2006) reported seed size as an important trait for trade and component of yield and adaptation in chickpea (*Cicer arietinum*). In developing countries, including Nigeria most farmers rely on the seeds from previous harvest for field establishment at the next cropping season. Farmers generally prefer varieties with large seeds because such seeds would contain more food for early germination and seedling emergence, vigorous plants and are more likely to produce higher yields. However, since none of the cultivars attained its potential seed weight under infected condition, the top three cultivars “SAMNUT 23”, “SAMNUT 25” and “SAMNUT 26” which gave high 100-seed weight among the infected plants could be described as the most tolerant to CABMV disease. Dry matter was least affected in “ICG-01276” (less than 20 % reduction) among the infected plants, which revealed some level of tolerance to infection. However, in absolute term, “ICG-92267” which exhibited the highest dry matter among the infected plants could be a choice cultivar for the production of hay in CABMV prone areas. The result of principal components which showed that 100-seed weight was responsible for the greatest variability observed in the growth and yield parameters of both healthy and infected plants. This revealed the importance of seed weight in groundnut breeding.

Cultivars’ potential for this parameter was not realized in the CABMV infected plants, thereby revealing the deleterious impact of the virus in susceptible cultivars. The result of cluster analysis was an indication of the variability among the evaluated groundnut cultivars. Cluster 1 consisted of cultivars which could be explored for various purposes. For instance, the cultivars in cluster 1 could be utilized for fresh forage production; “ICG-IS-13003” which is the only member of cluster 2 would be suitable for hay (dry haulm), whereas the cultivar FDRF7-67 that formed cluster 3 would be best for seed production. The inconsistent responses of the cultivars under CABMV disease was partly due to the fact that growth and yield characters were under the influence of different genes. Therefore, it was possibly because the genes conferring disease resistance did not interact synergistically with those controlling growth and yield attributes. This supported the view of Vanhaeren *et al.* (2016) who reported that growth processes are governed by complex genetic networks. Similarly, studies have shown that in diseased plant, plant-virus interactions interfere with a broad range of cellular processes, such as hormonal regulation, cell cycle control and endogenous transport of macromolecules, among others (Pallas and Garcia, 2011). Therefore, the physiology of infected plants was destabilized, resulting in lack of co-ordination among the various organs.

CONCLUSION AND RECOMMENDATIONS

This study has revealed the vulnerability of some commercial groundnut cultivars and variability in their response to CABMV disease. The infected groundnut cultivars expressed significant reduction for most of the growth and yield traits due to their susceptibility to the pathogen. Although none of the groundnut cultivars exhibited immunity to CABMV disease, some cultivars showed certain levels of tolerance and consequently gave appreciable yield. **"**SAMNUT 23", **"**SAMNUT 25" and **"**SAMNUT 26" were the top three cultivars for 100-seed weight while **"**ICG-92267" was identified as the best for dry matter production. Planting of these tolerant cultivars is recommended in order to mitigate the stresses imposed by CABMV disease.

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