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## Evaluation of Yield Losses Caused by Cowpea *Aphid-borne mosaic virus* (CABMV) in 21 Cowpea (*Vigna unguiculata* (L.) Walp.) Varieties in Burkina Faso

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### ABSTRACT

Cowpea (*Vigna unguiculata* (L.) Walp.) is one the main leguminous crop plants world wide, particularly in sub-Saharan Africa where the rainfall is low and often unevenly distributed. However, its production is limited by insect attacks and numerous diseases including those caused by viruses. In Burkina Faso, the Cowpea Aphid-Borne Mosaic Virus (CABMV) is one of the viruses capable of causing 7-60% of yield losses. The aim of this study is to assess the susceptibility of 21 cowpea varieties against CABMV and to also assess the yield losses caused by this virus on each of the varieties. In this context trial was conducted on INERA research stations at Kamboinsé and Farako-Bâ in 2012 and 2013. Twenty one varieties were used for this study. The experimental design used is a split-plot with 4 repetitions for which the first 2 repetitions were inoculated with the CABMV. Symptoms caused by the CABMV on the 21 varieties of cowpea were of a great diversity. The assessment of the virus in infected plant samples from these varieties by ELISA test allowed detecting the mosaic virus in all samples that presented mosaic symptoms. The number of flowers and pods strongly varied depending to the type of plant (inoculated or non-inoculated plant) and the variety. Yields from the different varieties, comprised between 187 and 6250 kg ha<sup>-1</sup>, were influenced by the site, the year, the variety and the type of plant. Yields losses were ranged from 3-64% depending to the variety.

**Key words:** Cowpea (*Vigna unguiculata* (L.) Walp), virus (CABMV), aphid, assessment losses, yield

### INTRODUCTION

Cowpea plays a major as role food and feed, especially in developing countries because of its high protein content. Cowpea contains 20-25% proteins, 64% carbohydrates (Modu *et al.*, 2010) and some nutritive elements such as thiamin, niacin and riboflavin. One of the most important aspects of cowpea contribution in human food is the richness of its proteins in essential amino acids including lysine, tryptophan, phenylalanine, valine, threonine, methionine etc. (USDA., 2004). Therefore, cowpea contributes to the

reduction of protein deficiencies in human diets, particularly in rural area, where it is considered as «poor's meat» (Modu *et al.*, 2010). According to a previous study cowpea is consumed by up to 200 million people in tropical Africa. It provides livestock with quality fodder for feed. The fodder value is estimated at 0.45 Fodder Units (FU) kg<sup>-1</sup> and 100-200 g of Digestible Nitrogen Matter (DNM) per kilogram (Mazzela-Second *et al.*, 2002).

As a leguminous plant, cowpea also contributes to soil fertilization through nitrogen fixation. Bado (2002) and Husson *et al.* (2010) indicated that in monoculture, cowpea

can fix between 50 and 115 kg of nitrogen per hectare. Cowpea also improves soil physical and biological properties and makes calcium phosphates and phosphorous soluble with the help of root exudation (Hoshikawa, 1990; Gardner *et al.*, 1981).

The overall world cowpea grain production was estimated at 5.7 million tons in 2012 by the food and agriculture organization. With a production of 450,000 t, Burkina Faso was the third producer after Nigeria and Niger. Cowpea grains and fodder are sold in local markets within the country, but substantial amounts of grains are exported into neighbouring countries. Langyintuo *et al.* (2003) reported that Burkina Faso exported 140,000 tons of cowpea grains, which generated 400 million USD of income.

Cowpea production is characterized by very low yields varying between 250-300 kg ha<sup>-1</sup> (Singh *et al.*, 1987). Yields are affected by biotic constraints (mainly insufficient or unevenly distributed rainfall and poor soils) and biotic constraints (insect pests, weeds and diseases). Viral diseases are the most devastating and the most difficult to manage because of the absence of curative control methods applicable to this type of diseases. Cowpea Aphid-Borne Mosaic Virus (CABMV) is by far considered as the most important viral disease of cowpea in Burkina Faso (Neya *et al.*, 2007). The CABMV is responsible of important crop losses ranging from 15-87% depending on cowpea varieties and the plant age at infection (Aboul Ata *et al.*, 1982; Thottappilly and Rossel, 1992). The virus is readily transmitted by mechanical inoculation and through seeds. Seed transmission rates of 0-55% were reported by Bashir and Hampton (1994) and depended on cowpea genotypes.

The grain legume programme recently developed new cowpea varieties to tackle several cowpea production constraints and meet the market demand. The objective of this work was to assess the impact of CABMV on the yield in the developed improved varieties for better control of the virus.

## MATERIALS AND METHODS

**Plant material:** During two consecutive years (2012-2013), 21 cowpea varieties were tested at two locations i.e., Kamboinsé (12.44667 latitude and -1.5625 longitude) and Farako-Bâ (11.0949200 latitude and -4.3334900 longitude). Cowpea varieties were showed in Table 1.

**Field experiment:** The experimental design was a split-plot of random blocs completely randomized with 4 replications. The elementary plots corresponding to the cowpea varieties comprised two rows of four meters long in 4 repetitions, that is to say 84 elementary plots. The soil was previously ploughed and ridged after mineral fertilization consisting of nitrogen, phosphate and potassium (NPK: 14-23-14) was applied at 100 kg ha<sup>-1</sup>. Two seeds were sown per hole at distances of 0.40 m between holes in the same row and 0.80 m between rows.

Table 1: List of varieties used

Codes	Varieties	Origin
V1	KV×745-11P	INERA
V2	KV×442-3-25	INERA
V3	KV×771-10	INERA
V4	Moussa local	INERA
V5	Gorom local	INERA
V6	KV×61-1	INERA
V7	KV×396-4-5-2D	INERA
V8	TZ1 Gourgou	INERA
V9	KV×775-33-2	INERA
V10	[2D×693] BC4F5	INERA
V11	[8-1×693] BC4F5	INERA
V12	[775×693] BC4F5-1	INERA
V13	[775×693] BC4F5-2	INERA
V14	[775×693] BC4F5-3	INERA
V15	[775×693] BC4F5-4	INERA
V16	[775×693] BC4F5-6	INERA
V17	[775×693] BC4F5-7	INERA
V18	[775×693] BC4F5-8	INERA
V19	[771×693] BC4F5-1	INERA
V20	[Moussa×693] Bulk-F6	INERA
V21	TZ1 Donsin	INERA

Plants were mechanically inoculated 14 days after sowing. Inoculum was prepared by grinding the leaves of infected cowpea cv. Gorom local in 0.01 M phosphate buffer pH 7.0 at a ratio of 1:10 (w/v). Leaf extracts were filtered with cheese cloth and carborundum (600 mesh) was added before inoculation. In all cases, serotype II of CABMV which is the most wide spread in Neya (2011) was used.

Inoculated and non-inoculated plants were sprayed with a mixture of two insecticides (deltamethrin and systhoate) every 2 weeks starting from the 15th day after sowing at the dose of 2 mL of each insecticide per liter of water. Delta methrine (C<sub>22</sub>H<sub>19</sub>Br<sub>2</sub>NO<sub>3</sub>, 25 g a.i./l) is a pyrethroid or contact product while systhoate (C<sub>5</sub>H<sub>12</sub>NO<sub>3</sub>PS<sub>2</sub>, 400 g a.i./l) is an organo systemic thiophosphate whose persistence lasts 2-3 weeks.

At 50% flowering, symptomatic plants (n = 30) and asymptomatic plants (n = 30) were randomly chosen to confirm the presence or absence of CABMV. Virus detection was performed by ELISA as described by Neya (2011). Then, flowers from 10 healthy plants and from 10 diseased plants were counted for each variety. Two weeks later, the number of pods from 10 healthy plants and 10 diseased plants were also determined. At harvest, seeds from infected plants were collected and 93 seeds from each cowpea variety were tested by ELISA as described by Konate and Neya (1996) for virus presence.

**Statistical analysis:** All data were analyzed using Statistical Analysis System Software (SAS) version 8/2001. Where analysis of variance indicated significant F ratios, means were separated according to Newman-Keuls multiple comparison tests compared at 5% level.

## RESULTS

**Susceptibility of cowpea varieties to CABMV:** Plant-virus interactions in terms of time for disease appearance were similar for both 2012 and 2013. Data for 2012 at Kamboinsé are presented in Table 2. All inoculated plants showed disease symptoms 21 days post inoculation (dpi), regardless of the cowpea variety. However, as disease incidence was assessed at 4 different dates (i.e., 6, 10, 15 and 21 dpi), marked differences were observed between cowpea varieties in the proportions of infected plants. In cowpea varieties V4 and V5, all inoculated plants were symptomatic at 10 dpi. High proportions of infected plants were observed in V2 (81.8%), V6 (77.4%), V20 (70.6%) and V11 (69.7%). By contrast, no diseased plant was observed in V8 and V3 at 10 dpi. Infection rates in all other varieties were moderate (33.3-56.5%) at 10 dpi.

Plant infection rates in cowpea varieties at Farako-Bâ (Table 3) were similar to data obtained in Kamboinsé. Between 6 and 10 dpi, no symptoms was observed in varieties V8 and V3, while disease incidence was low (18.2%) in V1. On the opposite side, disease incidence was high in varieties V11 (70.6%), V2 (72.4%), V20 (92.3%) and even reached 100% in V4, V5 and V6.

**Virus detection in symptomatic inoculated plants:** Results from CABMV checking by ELISA test realized on plant leaves presenting symptoms three weeks after inoculation indicate that all plants presenting symptoms effectively contained the Cowpea aphid-borne mosaic virus by giving  $A_{405}$  markedly higher than  $A_{405}$  of the healthy control which is 0.082. In effect, all the tested samples replied positively to ELISA test with  $A_{405}$  comprised between 210 and 2500 attesting the effective presence of the CABMV. This  $A_{405}$  variation also indicates the difference in viral particles intensity according to variety susceptibility.

**Diversity of symptoms:** Very various symptoms were observed on tested varieties as well at Farako-Bâ as at Kamboinsé during the two years study. The infected plants thus presented in most of the cases, heavy green ranges alternating with light green or yellow zones on the leaves. Sometimes, foliar distortions with often stunted plants or defoliation were observed. Symptoms severity varied according to the variety. The different types of observed symptoms are recapitulated in the Fig. 1. We can distinguish six types of symptoms. If yellow mosaic symptoms, yellow mosaic with foliar distortion, green mosaic and green mosaic with foliar distortion were frequently encountered on infected plants, severe green mosaic was only observed on V4, V14, V5, V20 varieties and V6 variety, for which yellow mosaic is associated with defoliation. These observed symptoms are illustrated by the Fig. 1.

Table 2: Disease incidence at four different dates at Kamboinsé

Cowpea variety	Total No. of plants	Days post inoculation (%)			
		6	10	15	21
V1	27	0.0 <sup>a</sup>	33.3	62.9	100
V2	33	63.6	81.8	93.9	100
V3	28	0.0	0.0	64.3	100
V4	36	72.2	100.0	100.0	100
V5	31	90.3	100.0	100.0	100
V6	31	25.8	77.4	100.0	100
V7	29	6.9	51.7	93.1	100
V8	28	0.0	0.0	64.3	100
V9	28	0.0	50.0	100.0	100
V10	23	0.0	56.5	78.3	100
V11	33	36.4	69.7	87.9	100
V12	34	11.8	41.2	70.6	100
V13	31	9.7	42.0	74.2	100
V14	28	17.9	53.6	89.3	100
V15	25	16.0	56.0	96.0	100
V16	33	9.1	42.4	78.8	100
V17	36	16.7	44.5	72.2	100
V18	30	16.7	50.0	83.3	100
V19	35	14.3	42.9	71.4	100
V20	34	41.2	70.6	85.3	100
V21	36	0.0	44.4	72.2	100

<sup>a</sup>Percentages of symptomatic plants were determined from the total number of plants in each row

Table 3: Disease incidence at four different dates at Farako-Bâ

Cowpea variety	Total No. of plants	Days post inoculation (%)			
		6	10	15	21
V1	22	0.0	18.2	54.5	100
V2	29	37.9	72.4	89.7	100
V3	35	0.0	0.0	80.0	100
V4	25	60.0	100.0	100.0	100
V5	35	80.0	100.0	100.0	100
V6	23	34.8	100.0	100.0	100
V7	32	3.1	46.9	84.4	100
V8	32	0.0	0.0	56.3	100
V9	36	0.0	38.9	77.8	100
V10	28	0.0	46.4	82.1	100
V11	34	35.3	70.6	88.2	100
V12	29	13.8	48.3	82.8	100
V13	33	15.2	45.5	75.8	100
V14	29	17.2	51.7	86.2	100
V15	28	14.3	50.0	85.7	100
V16	31	12.9	48.4	77.4	100
V17	30	20.0	53.3	86.7	100
V18	36	13.9	41.7	69.4	100
V19	28	17.9	53.6	89.3	100
V20	26	53.8	92.3	100.0	100
V21	30	0.0	33.3	66.6	100

<sup>a</sup>Percentages of symptomatic plants were determined from the total number of plants in each row

**Effect of plant infection on the number of flowers, pods and grain yield:** In general the healthy plants produced higher number of flowers, pods and higher grain yield than diseased plants (Table 4). The analysis of variance showed a significant difference between the average number of flowers, pods and grain yield per type of plant.



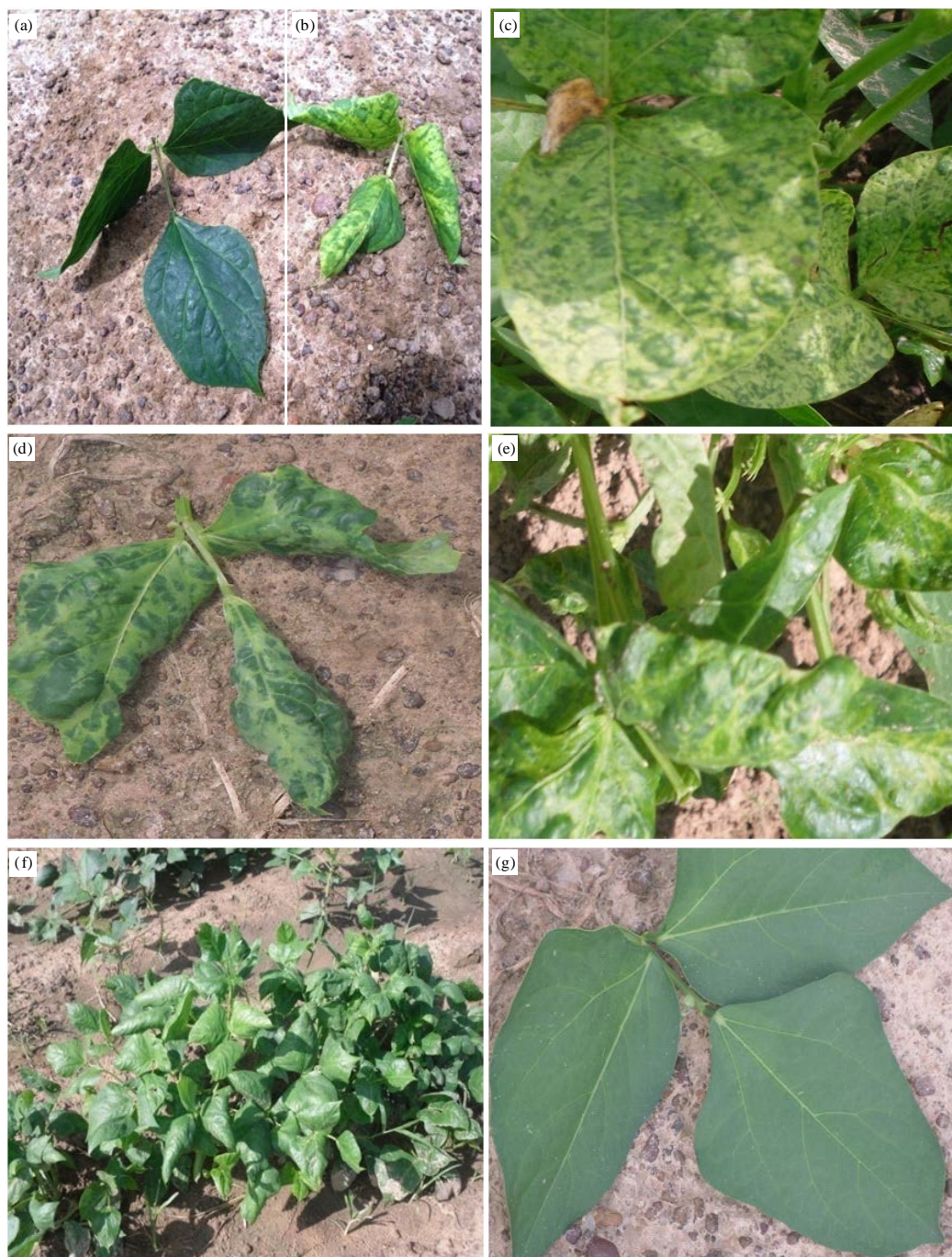


Fig. 1(a-g): Different types of symptoms observed in field, (a) Green mosaic, (b) Yellow mosaic without foliar distortion, (c) Severe yellow mosaic, (d) Yellow mosaic with foliar distortion, (e) Yellow mosaic with defoliation, (f) Green mosaic with foliar distortion and (g) Healthy leaf (Photo NEYA, 2012)

Type plants	No. of flowers	No. of pods	Grain yield (kg ha <sup>-1</sup> )
HP*	17.4 <sup>a</sup>	28.4 <sup>a</sup>	2894.0 <sup>a</sup>
DP**	11.9 <sup>b</sup>	21.0 <sup>b</sup>	1709.0 <sup>b</sup>
p-value	0.0002	<0.0001	<0.0001

\*HP: Healthy and \*\*DP: Diseased plants. <sup>a,b</sup>Data on healthy and diseased plants in a column with the same letters are not significantly different at p = 0.05

**Effect on the number of flowers:** At 50% flowering, the numbers of flowers of 10 healthy plants and 10 diseased plants were counted at Farako-Bâ and Kamboinsé in 2012 and 2013. The results obtained from Healthy Plants (HP) and Diseased Plants (DP) are presented in Table 5.

Table 5: Number of flowers produced by healthy and diseased cowpea plants at Farako-Bâ and Kamboinsé in 2012 and 2013

Cowpea varieties	Farako-Bâ 2012		Kamboinsé 2012		Farako-Bâ 2013		Kamboinsé 2013	
	HP*	DP**	HP	DP	HP	DP	HP	DP
V1	17.00 <sup>a</sup>	5.60 <sup>b</sup>	26.0 <sup>a</sup>	25.7 <sup>a</sup>	29.95 <sup>a</sup>	25.10 <sup>b</sup>	26.90 <sup>a</sup>	24.50 <sup>a</sup>
V2	18.20 <sup>a</sup>	17.30 <sup>a</sup>	28.4 <sup>a</sup>	26.4 <sup>a</sup>	32.25 <sup>a</sup>	31.55 <sup>a</sup>	25.50 <sup>a</sup>	24.40 <sup>a</sup>
V3	16.90 <sup>a</sup>	11.90 <sup>b</sup>	28.3 <sup>a</sup>	25.1 <sup>b</sup>	23.65 <sup>a</sup>	19.55 <sup>b</sup>	27.90 <sup>a</sup>	24.30 <sup>b</sup>
V4	13.50 <sup>a</sup>	10.70 <sup>a</sup>	29.8 <sup>a</sup>	19.8 <sup>b</sup>	43.30 <sup>a</sup>	23.75 <sup>b</sup>	28.20 <sup>a</sup>	25.00 <sup>b</sup>
V5	16.10 <sup>a</sup>	12.20 <sup>b</sup>	36.2 <sup>a</sup>	26.5 <sup>b</sup>	19.40 <sup>a</sup>	14.00 <sup>b</sup>	12.40 <sup>a</sup>	7.60 <sup>b</sup>
V6	14.40 <sup>a</sup>	11.90 <sup>a</sup>	21.3 <sup>a</sup>	17.9 <sup>b</sup>	37.55 <sup>a</sup>	23.70 <sup>b</sup>	31.10 <sup>a</sup>	18.80 <sup>b</sup>
V7	12.3 <sup>a</sup>	5.70 <sup>b</sup>	35.4 <sup>a</sup>	24.4 <sup>b</sup>	43.90 <sup>a</sup>	32.95 <sup>b</sup>	47.83 <sup>a</sup>	34.60 <sup>b</sup>
V8	13.0 <sup>a</sup>	7.70 <sup>b</sup>	29.4 <sup>a</sup>	17.4 <sup>b</sup>	34.70 <sup>a</sup>	19.50 <sup>b</sup>	26.60 <sup>a</sup>	15.40 <sup>b</sup>
V9	13.70 <sup>a</sup>	7.00 <sup>b</sup>	31.9 <sup>a</sup>	15.8 <sup>b</sup>	51.20 <sup>a</sup>	32.90 <sup>b</sup>	50.40 <sup>a</sup>	36.70 <sup>b</sup>
V10	15.50 <sup>a</sup>	14.90 <sup>a</sup>	31.5 <sup>a</sup>	16.5 <sup>b</sup>	39.00 <sup>a</sup>	15.00 <sup>b</sup>	33.20 <sup>a</sup>	18.00 <sup>b</sup>
V11	18.50 <sup>a</sup>	15.60 <sup>a</sup>	45.7 <sup>a</sup>	43.3 <sup>a</sup>	44.30 <sup>a</sup>	27.15 <sup>b</sup>	39.90 <sup>a</sup>	21.50 <sup>b</sup>
V12	15.70 <sup>a</sup>	12.00 <sup>b</sup>	32.6 <sup>a</sup>	23.1 <sup>b</sup>	44.40 <sup>a</sup>	33.05 <sup>b</sup>	47.10 <sup>a</sup>	32.20 <sup>b</sup>
V13	15.60 <sup>a</sup>	15.30 <sup>a</sup>	27.9 <sup>a</sup>	26.5 <sup>b</sup>	39.30 <sup>a</sup>	30.70 <sup>b</sup>	38.40 <sup>a</sup>	24.90 <sup>b</sup>
V14	11.80 <sup>a</sup>	10.60 <sup>a</sup>	25.2 <sup>a</sup>	23.7 <sup>a</sup>	46.05 <sup>a</sup>	33.70 <sup>b</sup>	59.00 <sup>a</sup>	46.70 <sup>b</sup>
V15	18.00 <sup>a</sup>	10.10 <sup>b</sup>	36.6 <sup>a</sup>	21.7 <sup>b</sup>	31.95 <sup>a</sup>	27.90 <sup>b</sup>	29.90 <sup>a</sup>	24.90 <sup>b</sup>
V16	15.90 <sup>a</sup>	5.30 <sup>b</sup>	27.5 <sup>a</sup>	22.0 <sup>b</sup>	35.90 <sup>a</sup>	26.95 <sup>b</sup>	38.60 <sup>a</sup>	27.40 <sup>b</sup>
V17	12.40 <sup>a</sup>	9.60 <sup>a</sup>	18.3 <sup>a</sup>	15.2 <sup>b</sup>	35.05 <sup>a</sup>	21.55 <sup>b</sup>	35.60 <sup>a</sup>	23.50 <sup>b</sup>
V18	22.10 <sup>a</sup>	9.30 <sup>b</sup>	38.3 <sup>a</sup>	34.4 <sup>b</sup>	32.55 <sup>a</sup>	27.40 <sup>b</sup>	37.80 <sup>a</sup>	31.60 <sup>b</sup>
V19	12.20 <sup>a</sup>	10.50 <sup>a</sup>	35.6 <sup>a</sup>	26.0 <sup>b</sup>	50.20 <sup>a</sup>	19.95 <sup>b</sup>	38.68 <sup>a</sup>	26.90 <sup>b</sup>
V20	19.70 <sup>a</sup>	12.70 <sup>b</sup>	24.5 <sup>a</sup>	15.6 <sup>b</sup>	38.65 <sup>a</sup>	26.70 <sup>b</sup>	29.10 <sup>a</sup>	23.80 <sup>b</sup>
V21	20.70 <sup>a</sup>	12.00 <sup>b</sup>	41.1 <sup>a</sup>	23.5 <sup>b</sup>	27.65 <sup>a</sup>	15.45 <sup>b</sup>	26.60 <sup>a</sup>	12.27 <sup>b</sup>

\*HP: Healthy plants and \*\*DP: Diseased plants. <sup>a,b</sup>Data on healthy and diseased plants in a variety with the same letters are not significantly different at  $p = 0.05$

Table 6: Number of pods produced by healthy and diseased cowpea plants at Farako-Bâ and Kamboinsé in 2012 and 2013

Cowpea varieties	Farako-Bâ 2012		Kamboinsé 2012		Farako-Bâ 2013		Kamboinsé 201	
	HP*	DP**	HP	DP	HP	DP	HP	DP
V1	34.25 <sup>a</sup>	22.10 <sup>b</sup>	45.10 <sup>a</sup>	28.30 <sup>b</sup>	28.85 <sup>a</sup>	23.40 <sup>b</sup>	48.8 <sup>a</sup>	36.1 <sup>b</sup>
V2	23.00 <sup>a</sup>	19.35 <sup>b</sup>	23.90 <sup>a</sup>	22.60 <sup>a</sup>	36.05 <sup>a</sup>	33.35 <sup>a</sup>	28.1 <sup>a</sup>	25.2 <sup>a</sup>
V3	27.60 <sup>a</sup>	17.60 <sup>b</sup>	42.30 <sup>a</sup>	36.90 <sup>b</sup>	28.65 <sup>a</sup>	23.25 <sup>b</sup>	30.8 <sup>a</sup>	25.2 <sup>b</sup>
V4	22.65 <sup>a</sup>	21.20 <sup>a</sup>	30.50 <sup>a</sup>	23.90 <sup>b</sup>	33.95 <sup>a</sup>	20.75 <sup>b</sup>	42.1 <sup>a</sup>	13.3 <sup>b</sup>
V5	32.25 <sup>a</sup>	21.00 <sup>b</sup>	50.80 <sup>a</sup>	28.30 <sup>b</sup>	30.55 <sup>a</sup>	21.85 <sup>b</sup>	34.4 <sup>a</sup>	18.9 <sup>b</sup>
V6	21.85 <sup>a</sup>	12.10 <sup>b</sup>	50.40 <sup>a</sup>	31.50 <sup>b</sup>	33.65 <sup>a</sup>	24.05 <sup>b</sup>	58.7 <sup>a</sup>	30.4 <sup>b</sup>
V7	14.50 <sup>a</sup>	14.00 <sup>a</sup>	37.00 <sup>a</sup>	20.50 <sup>b</sup>	29.10 <sup>a</sup>	23.95 <sup>b</sup>	36.4 <sup>a</sup>	21.8 <sup>b</sup>
V8	15.50 <sup>a</sup>	10.25 <sup>b</sup>	27.20 <sup>a</sup>	22.00 <sup>b</sup>	36.65 <sup>a</sup>	19.85 <sup>b</sup>	26.6 <sup>a</sup>	19.4 <sup>b</sup>
V9	33.50 <sup>a</sup>	23.15 <sup>b</sup>	42.60 <sup>a</sup>	31.90 <sup>b</sup>	42.60 <sup>a</sup>	36.70 <sup>b</sup>	40.2 <sup>a</sup>	32.1 <sup>b</sup>
V10	15.75 <sup>a</sup>	10.25 <sup>b</sup>	47.30 <sup>a</sup>	19.80 <sup>b</sup>	26.75 <sup>a</sup>	17.20 <sup>b</sup>	53.0 <sup>a</sup>	31.8 <sup>b</sup>
V11	33.15 <sup>a</sup>	22.75 <sup>b</sup>	52.20 <sup>a</sup>	39.40 <sup>b</sup>	37.95 <sup>a</sup>	29.70 <sup>b</sup>	65.6 <sup>a</sup>	40.6 <sup>b</sup>
V12	14.50 <sup>a</sup>	13.00 <sup>a</sup>	28.40 <sup>a</sup>	22.50 <sup>b</sup>	41.05 <sup>a</sup>	36.65 <sup>b</sup>	28.4 <sup>a</sup>	17.0 <sup>b</sup>
V13	14.50 <sup>a</sup>	12.50 <sup>b</sup>	31.30 <sup>a</sup>	22.00 <sup>b</sup>	40.80 <sup>a</sup>	23.45 <sup>b</sup>	42.6 <sup>a</sup>	30.0 <sup>b</sup>
V14	43.75 <sup>a</sup>	29.00 <sup>b</sup>	47.20 <sup>a</sup>	27.50 <sup>b</sup>	48.35 <sup>a</sup>	29.70 <sup>b</sup>	35.6 <sup>a</sup>	27.4 <sup>b</sup>
V15	21.30 <sup>a</sup>	19.00 <sup>a</sup>	34.10 <sup>a</sup>	20.20 <sup>b</sup>	31.80 <sup>a</sup>	21.80 <sup>b</sup>	41.2 <sup>a</sup>	29.7 <sup>b</sup>
V16	15.70 <sup>a</sup>	10.70 <sup>b</sup>	34.90 <sup>a</sup>	28.40 <sup>b</sup>	31.90 <sup>a</sup>	25.05 <sup>b</sup>	36.4 <sup>a</sup>	27.3 <sup>b</sup>
V17	17.00 <sup>a</sup>	15.50 <sup>a</sup>	22.10 <sup>a</sup>	20.30 <sup>a</sup>	37.00 <sup>a</sup>	23.50 <sup>b</sup>	26.1 <sup>a</sup>	23.8 <sup>a</sup>
V18	37.50 <sup>a</sup>	21.65 <sup>b</sup>	54.10 <sup>a</sup>	21.90 <sup>b</sup>	34.25 <sup>a</sup>	21.05 <sup>b</sup>	25.2 <sup>a</sup>	24.5 <sup>a</sup>
V19	38.75 <sup>a</sup>	25.50 <sup>b</sup>	44.00 <sup>a</sup>	28.60 <sup>b</sup>	39.90 <sup>a</sup>	21.10 <sup>b</sup>	30.0 <sup>a</sup>	25.1 <sup>b</sup>
V20	10.00 <sup>a</sup>	9.50 <sup>a</sup>	31.40 <sup>a</sup>	15.50 <sup>b</sup>	36.60 <sup>a</sup>	24.30 <sup>b</sup>	24.0 <sup>a</sup>	12.7 <sup>b</sup>
V21	16.20 <sup>a</sup>	13.10 <sup>b</sup>	27.40 <sup>a</sup>	20.30 <sup>b</sup>	28.05 <sup>a</sup>	23.15 <sup>b</sup>	27.8 <sup>a</sup>	20.0 <sup>b</sup>

\*HP: Healthy plants and \*\*DP: Diseased plants. <sup>a,b</sup>Data on healthy and diseased plants in a variety with the same letters are not significantly different at  $p = 0.05$

It notices that in 2012 at Farako-Bâ site, for healthy plants and for each variety, the average of opening flowers each day varied from 11.8-20.7 and from 5.3-17.3 for diseased plants. Similarly, during the same year, at Kamboinsé site, the number of opening flowers each day, per variety, varied from 18.3-45.7 for healthy plants compared to 15.6-43.3 for diseased plants. The analysis of variance showed a significant difference between the average number of flowers for healthy plants and diseased plants for 12 of the varieties at Farako-Bâ compared to 17 varieties at Kamboinsé (Table 5). In general,

in each location and per year, healthy plants produced in average more flowers than diseased plants (Table 8).

**Effect on the number of pods:** At 50% of pod formation, the number of pods of 10 healthy plants and 10 diseased plants was counted at Farako-Bâ and at Kamboinsé in 2012 and 2013. The results obtained from Healthy Plants (HP) and from Diseased Plants (DP) are recorded in Table 6. A highly significant difference was observed between the type of plant ( $p < 0.0001$ ) and between varieties ( $p = 0.0020$ ).

Table 7: Effect of plant infection on grain yield on healthy and diseased cowpea plants in Farako-Bâ and Kamboinsé in 2012 and 2013

Cowpea varieties	Farako-Bâ 2012		Kamboinsé 2012		Farako-Bâ 2013		Kamboinsé 2013	
	HP*	DP**	HP	DP	HP	DP	HP	DP
V1	2266 <sup>a</sup>	937 <sup>b</sup>	883 <sup>a</sup>	508 <sup>a</sup>	6094 <sup>a</sup>	3125 <sup>b</sup>	5313 <sup>a</sup>	3125 <sup>b</sup>
V2	781 <sup>a</sup>	312 <sup>a</sup>	703 <sup>a</sup>	633 <sup>a</sup>	5312 <sup>a</sup>	2969 <sup>b</sup>	5313 <sup>a</sup>	3438 <sup>b</sup>
V3	1406 <sup>a</sup>	312 <sup>b</sup>	1102 <sup>a</sup>	836 <sup>a</sup>	4844 <sup>a</sup>	2813 <sup>b</sup>	4688 <sup>a</sup>	2344 <sup>b</sup>
V4	1016 <sup>a</sup>	187 <sup>b</sup>	406 <sup>a</sup>	297 <sup>a</sup>	4063 <sup>a</sup>	3281 <sup>b</sup>	5469 <sup>a</sup>	3750 <sup>b</sup>
V5	891 <sup>a</sup>	469 <sup>a</sup>	328 <sup>a</sup>	172 <sup>b</sup>	4375 <sup>a</sup>	2500 <sup>b</sup>	3437 <sup>a</sup>	1250 <sup>b</sup>
V6	391 <sup>a</sup>	234 <sup>a</sup>	398 <sup>a</sup>	250 <sup>b</sup>	5000 <sup>a</sup>	4063 <sup>b</sup>	5156 <sup>a</sup>	3437 <sup>b</sup>
V7	1578 <sup>a</sup>	703 <sup>b</sup>	1367 <sup>a</sup>	828 <sup>b</sup>	5625 <sup>a</sup>	2969 <sup>b</sup>	5625 <sup>a</sup>	3594 <sup>b</sup>
V8	547 <sup>a</sup>	312 <sup>a</sup>	1023 <sup>a</sup>	305 <sup>b</sup>	5469 <sup>a</sup>	4063 <sup>b</sup>	4688 <sup>a</sup>	4375 <sup>a</sup>
V9	1250 <sup>a</sup>	781 <sup>a</sup>	719 <sup>a</sup>	531 <sup>b</sup>	4062 <sup>a</sup>	2969 <sup>b</sup>	3750 <sup>a</sup>	3437 <sup>a</sup>
V10	1328 <sup>a</sup>	781 <sup>b</sup>	1906 <sup>a</sup>	1039 <sup>b</sup>	5938 <sup>a</sup>	3750 <sup>b</sup>	4687 <sup>a</sup>	2812 <sup>b</sup>
V11	703 <sup>a</sup>	547 <sup>a</sup>	1602 <sup>a</sup>	1070 <sup>b</sup>	4531 <sup>a</sup>	3906 <sup>b</sup>	5312 <sup>a</sup>	5156 <sup>a</sup>
V12	1953 <sup>a</sup>	234 <sup>b</sup>	1180 <sup>a</sup>	812 <sup>a</sup>	4219 <sup>a</sup>	4063 <sup>a</sup>	2969 <sup>a</sup>	2187 <sup>b</sup>
V13	969 <sup>a</sup>	859 <sup>a</sup>	1820 <sup>a</sup>	484 <sup>b</sup>	5781 <sup>a</sup>	4063 <sup>b</sup>	5469 <sup>a</sup>	3750 <sup>b</sup>
V14	1563 <sup>a</sup>	813 <sup>b</sup>	547 <sup>a</sup>	391 <sup>a</sup>	5937 <sup>a</sup>	3437 <sup>b</sup>	6094 <sup>a</sup>	4750 <sup>b</sup>
V15	1016 <sup>a</sup>	703 <sup>a</sup>	1562 <sup>a</sup>	859 <sup>b</sup>	4062 <sup>a</sup>	3750 <sup>b</sup>	4844 <sup>a</sup>	4219 <sup>b</sup>
V16	1875 <sup>a</sup>	781 <sup>b</sup>	930 <sup>a</sup>	812 <sup>a</sup>	4844 <sup>a</sup>	3906 <sup>b</sup>	4844 <sup>a</sup>	2969 <sup>b</sup>
V17	703 <sup>a</sup>	547 <sup>a</sup>	1939 <sup>a</sup>	1055 <sup>b</sup>	5469 <sup>a</sup>	2812 <sup>b</sup>	5781 <sup>a</sup>	3750 <sup>b</sup>
V18	969 <sup>a</sup>	625 <sup>a</sup>	1125 <sup>a</sup>	828 <sup>a</sup>	4844 <sup>a</sup>	3594 <sup>b</sup>	5625 <sup>a</sup>	4219 <sup>b</sup>
V19	703 <sup>a</sup>	547 <sup>a</sup>	367 <sup>a</sup>	289 <sup>a</sup>	5625 <sup>a</sup>	3594 <sup>b</sup>	5312 <sup>a</sup>	2656 <sup>b</sup>
V20	2111 <sup>a</sup>	1409 <sup>b</sup>	1687 <sup>a</sup>	937 <sup>b</sup>	4688 <sup>a</sup>	2188 <sup>b</sup>	6250 <sup>a</sup>	3437 <sup>b</sup>
V21	1484 <sup>a</sup>	1094 <sup>a</sup>	648 <sup>a</sup>	492 <sup>a</sup>	4219 <sup>a</sup>	2969 <sup>b</sup>	4687 <sup>a</sup>	2812 <sup>b</sup>

\*HP: Healthy and \*\*DP: Diseased plants. <sup>a,b</sup>Data on healthy and diseased plants in a variety with the same letters are not significantly different at  $p = 0.05$

Table 8: Average number of flowers, pods and grain yield per type of plant, per year and per site

Type of plants	No. of flowers				No. of pods				Grain yield (kg ha <sup>-1</sup> )			
	2012		2013		2012		2013		2012		2013	
	Kamboinsé	Farako Bâ	Kamboinsé	Farako Bâ	Kamboinsé	Farako Bâ	Kamboinsé	Farako Bâ	Kamboinsé	Farako Bâ	Kamboinsé	Farako Bâ
HP*	8.9 <sup>a</sup>	8.6 <sup>a</sup>	12.9 <sup>a</sup>	37.6 <sup>a</sup>	38.3 <sup>a</sup>	12.4 <sup>a</sup>	27.9 <sup>a</sup>	35.0 <sup>a</sup>	2762 <sup>a</sup>	1235 <sup>a</sup>	2556 <sup>a</sup>	5022 <sup>a</sup>
DP**	6.5 <sup>b</sup>	6.7 <sup>b</sup>	8.9 <sup>b</sup>	25.2 <sup>b</sup>	25.4 <sup>b</sup>	14.2 <sup>a</sup>	19.4 <sup>b</sup>	24.9 <sup>b</sup>	1925 <sup>b</sup>	611 <sup>b</sup>	925 <sup>b</sup>	3348 <sup>b</sup>
P	0.0183	0.0210	0.0023	<0.0001	<0.0001	0.0686	0.0083	<0.0001	0.0008	<0.0001	<0.0001	<0.0001

\*HP: Healthy and \*\*DP: Diseased plants. <sup>a,b</sup>Data on healthy and diseased plants in a variety with the same letters are not significantly different at  $p = 0.05$

It notices that in 2012, at Farako-Bâ site, the average number of pods for healthy plants per variety varied from 10-43.75 and from 9-29 for diseased plants. Similarly, at Kamboinsé site, the number of pods produced for healthy plants per variety varied from 22.10-52.2 compared to 15.5-39.40 for diseased plants depending to the variety. The analysis of variance showed a significant difference between the average number of pods for the healthy plants and diseased plants for 16 of the varieties of cowpea at Farako-Bâ compared to 19 varieties at Kamboinsé (Table 6).

In 2013, it notices that the average number of pods per variety varied from 26.75-48.35 for healthy plants and from 17.20-36.70 for diseased plants at Farako-Bâ site. At Kamboinsé, this number varied from 24-65.6 for healthy plants and from 12.7-40.6 for diseased plants per variety. The analysis of variance showed a significant difference between the average number of pods of healthy plants and diseased plants for 20 varieties at Farako-Bâ compared to 19 varieties at Kamboinsé (Table 6). In general, in each location and per year, healthy plants produce in average more pods than diseased plants (Table 8).

**Effect on grain yield:** After drying, pods from each plot were threshed and grain yields were estimated per hectare at Farako-Bâ and Kamboinsé in 2012 and 2013. The results obtained for healthy plants and diseased plants and presented in Table 7 showed that yields varied depending to the variety and the plant type.

In 2012 at Farako-Bâ site, per variety, grain yield varied from 391-2266 kg ha<sup>-1</sup> for healthy plants and from 187-1094 kg ha<sup>-1</sup> for diseased plants. Similarly, at Kamboinsé site, grain yield from healthy plants per variety varied from 328-1906 kg ha<sup>-1</sup> and from 172-1070 kg ha<sup>-1</sup> for diseased plants depending to the variety. The analysis of variance showed a significant difference in grain yield between healthy and diseased plants for nine of the tested varieties at Farako-Bâ and ten at Kamboinsé (Table 7).

In 2013 at Farako-Bâ site, grain yield per variety varied from 4062-6094 kg ha<sup>-1</sup> for healthy plants and from 2188-4063 kg ha<sup>-1</sup> for diseased plants. Similarly, at Kamboinsé site, grain yield for healthy plants per variety varied from 2969-6250 kg ha<sup>-1</sup> compared to 1250-5156 kg ha<sup>-1</sup> for diseased plants depending to the

Table 9: Average grain yield and yield losses in two localities

Cowpea varieties	Farako-Bâ			Kamboinsé		
	Yield (kg ha <sup>-1</sup> )			Yield (kg ha <sup>-1</sup> )		
	HP*	DP	Yield losses (kg ha <sup>-1</sup> )	HP	DP	Yield losses (kg ha <sup>-1</sup> )
V1	3359 <sup>a</sup>	1953 <sup>b</sup>	1406	3312 <sup>a</sup>	1906 <sup>b</sup>	1406
V2	3359 <sup>a</sup>	2656 <sup>b</sup>	703	1516 <sup>a</sup>	1383 <sup>a</sup>	133
V3	3181 <sup>a</sup>	1563 <sup>b</sup>	1618	2930 <sup>a</sup>	2227 <sup>b</sup>	703
V4	3633 <sup>a</sup>	2656 <sup>b</sup>	977	2477 <sup>a</sup>	1758 <sup>b</sup>	719
V5	2617 <sup>a</sup>	1094 <sup>b</sup>	1523	3172 <sup>a</sup>	1364 <sup>b</sup>	1808
V6	3789 <sup>a</sup>	1875 <sup>b</sup>	1914	3320 <sup>a</sup>	2398 <sup>b</sup>	922
V7	4180 <sup>a</sup>	2477 <sup>b</sup>	1703	1328 <sup>a</sup>	1195 <sup>a</sup>	133
V8	2188 <sup>a</sup>	1953 <sup>a</sup>	235	1094 <sup>a</sup>	961 <sup>b</sup>	133
V9	2664 <sup>a</sup>	2070 <sup>b</sup>	594	3398 <sup>a</sup>	3102 <sup>a</sup>	296
V10	2461 <sup>a</sup>	1719 <sup>b</sup>	742	2836 <sup>a</sup>	2172 <sup>b</sup>	664
V11	2539 <sup>a</sup>	2461 <sup>a</sup>	78	4000 <sup>a</sup>	2844 <sup>b</sup>	1156
V12	2500 <sup>a</sup>	1836 <sup>b</sup>	664	2051 <sup>a</sup>	1773 <sup>a</sup>	278
V13	3516 <sup>a</sup>	1992 <sup>b</sup>	1524	3383 <sup>a</sup>	1203 <sup>b</sup>	2180
V14	3164 <sup>a</sup>	2203 <sup>b</sup>	961	2781 <sup>a</sup>	1875 <sup>b</sup>	906
V15	3164 <sup>a</sup>	2734 <sup>a</sup>	430	3203 <sup>a</sup>	2875 <sup>a</sup>	328
V16	3102 <sup>a</sup>	1563 <sup>b</sup>	1539	3422 <sup>a</sup>	2500 <sup>b</sup>	922
V17	3375 <sup>a</sup>	2153 <sup>b</sup>	1222	2703 <sup>a</sup>	1148 <sup>b</sup>	1555
V18	2359 <sup>a</sup>	1914 <sup>a</sup>	445	3719 <sup>a</sup>	2426 <sup>b</sup>	1293
V19	3790 <sup>a</sup>	2111 <sup>b</sup>	1679	2977 <sup>a</sup>	2055 <sup>b</sup>	922
V20	3086 <sup>a</sup>	1758 <sup>b</sup>	1328	1703 <sup>a</sup>	805 <sup>b</sup>	898
V21	3203 <sup>a</sup>	1289 <sup>b</sup>	1914	1977 <sup>a</sup>	1555 <sup>a</sup>	422

\*HP: Healthy and \*\*DP: Diseased plants. <sup>a,b</sup>Data on healthy and diseased plants in a variety with the same letters are not significantly different at  $p = 0.05$

Table 10: Results on CABMV detection in seeds from 21 infected varieties

Codes	Varieties	Seeds tested positive (%)
V1	KV×745-11P	1.07
V2	KV×442-3-25	1.07
V3	KV×771-10	1.07
V4	Moussa local	31.18
V5	Gorom local	37.63
V6	KV×61-1	1.07
V7	KV×396-4-5-2D	1.07
V8	TZ1 Gourgou	1.07
V9	KV×775-33-2	2.15
V10	[2D×693] BC4F5	3.21
V11	[8-1×693] BC4F5	1.07
V12	[775×693] BC4F5-1	2.15
V13	[775×693] BC4F5-2	2.15
V14	[775×693] BC4F5-3	1.07
V15	[775×693] BC4F5-4	1.07
V16	[775×693] BC4F5-6	1.07
V17	[775×693] BC4F5-7	1.07
V18	[775×693] BC4F5-8	1.07
V19	[771×693] BC4F5-1	2.15
V20	[Moussa×693] Bulk-F6	10.75
V21	TZ1 Donsin	3.21

variety. The analysis of variance showed a significant difference in grain yield between healthy plants and diseased plants for all varieties at Farako-Bâ except one variety (V12) and for three of the varieties (V8, V9 and V11) at Kamboinsé (Table 7). In both sites, grain yield was relatively low in 2012 compared to 2013.

In general, in each locality and per year, the average yield for healthy plant was significantly higher than yield for diseased plants (Table 8).

#### Effect of plant infection on grain yield losses due to CABMV in the two sites:

The difference between grain yield recorded on healthy plants and grain yield recorded on diseased plants per variety at Farako-Bâ was comprised between 78 and 1914 kg ha<sup>-1</sup>. Variety V11 seemed to be the best one because this variety presented the lowest yield losses (78 kg ha<sup>-1</sup>) that is to say 3.07% in presence of CABMV. At Kamboinsé, the difference of grain yield between healthy plants and diseased plants was comprised between 133 kg and 2180 kg ha<sup>-1</sup>. At this site, variety V7 was the best with grain loss of only 133 kg ha<sup>-1</sup> (Table 9). At Farako-Bâ 13 varieties showed yield losses comprised between 30 and 60%, 5 varieties showed 16-29% of losses and varieties V8, V11 and V15 showed losses comprised between 0 and 15% (Fig. 2a). At Kamboinsé, 8 varieties showed losses ranked from 30-64%. For seven varieties, yield losses were comprised between 16-29% while for six varieties losses were ranked from 0-15% (Fig. 2b).

In both sites 7 varieties (V13, V17, V5, V20, V1, V19 and V14) presenting yield losses up to 30% were susceptible and 2 varieties (V8 and V15) were resistant with yield losses less than 15%.

**CABMV detection in seed of infected plants:** Results on CABMV detection by ELISA variant ACP in seeds of infected plants of 21 varieties are put in Table 8. Among 93 tested seeds per variety, Gorom local and Moussa local varieties presented high seed transmission rates (38 and 31%) followed by (Moussa X 693) Bulk-F6 variety (10.75%). The other varieties presented low seed transmission rates comprised between 1 and 3% (Table 10).



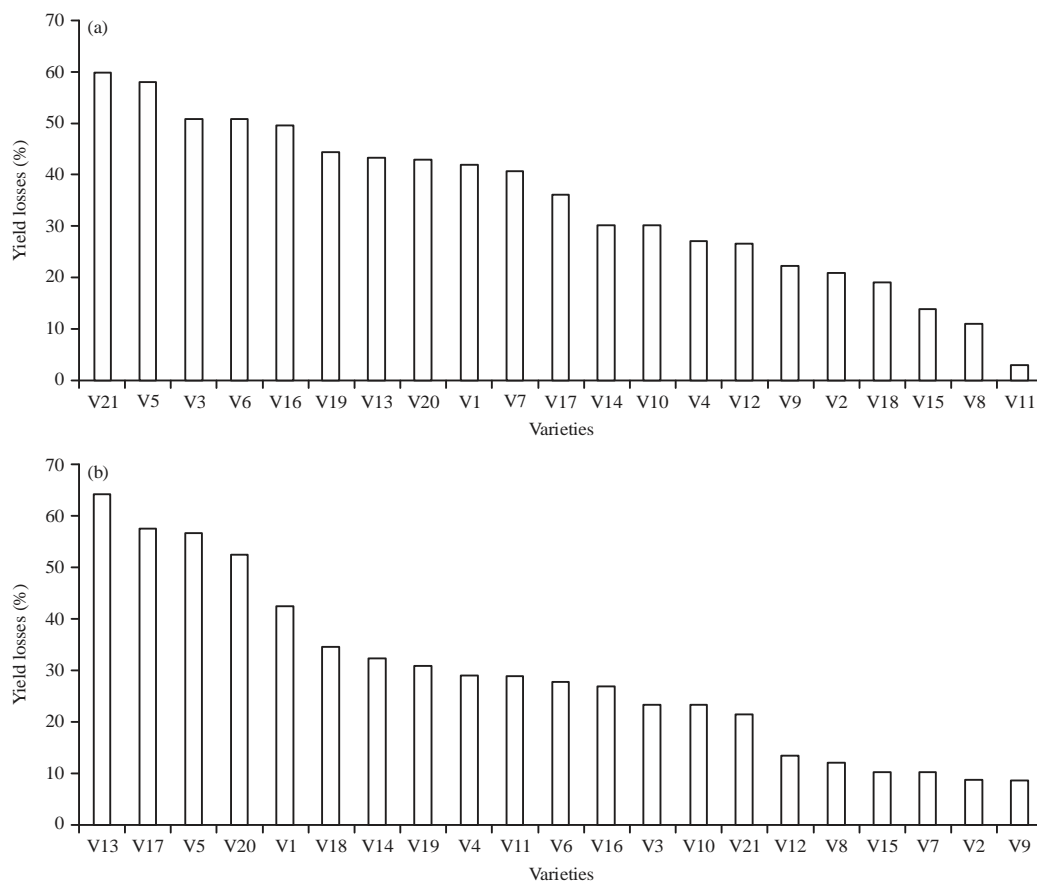


Fig. 2(a-b): Yield losses caused by CABMV on different varieties of cowpea at (a) Farako-Bâ and (b) Kamboinsé

## DISCUSSION

Among the 21 tested varieties, some are very susceptible to viral infection. The mechanical inoculation allowed noting that 15 varieties reacted to the viral infection 6 days post inoculation (dpi) in the 2 sites. The other varieties presented symptoms 21 dpi. The normal time allowed for symptoms appearance is 6-7 days post inoculation for susceptible varieties. A great diversity of symptoms was observed depending to cowpea variety. Several authors showed that the cowpea virus induces mosaic symptoms, foliar distortion on susceptible varieties of cowpea (Yawovi and Gumedzoe, 1993). Although the mosaic is the common element of symptom expression, we observed a great variability of symptoms. These results are in correlation with those of Singh and Rachie (1985) who said that most of the cultivated varieties of cowpea are susceptible to CABMV. But according to Singh *et al.* (1987) and Hampton *et al.* (1997), there is some resistance sources to the viral infection because the virus cannot easily multiply inside. Resistance of cowpea to CABMV is governed by a single gene often reported as dominant (Taiwo *et al.*, 1981; Fisher and Kyle, 1994, 1996) and sometimes associated to minors genes (Patel *et al.*, 1982). Despite the existence of resistant varieties to CABMV, a

problem of stability of the identified resistances is posed in relationship with insufficient knowledge on CABMV variability. Some authors underlined the necessity to use transgenic resistant varieties, due to the limited number of natural resistance sources and problems of stability of this resistance (Hampton and Thottappilly, 2003). This approach could take advantage of possibilities given by the determination of the complete sequence of the CABMV genome (Mlotshwa *et al.*, 2002).

The ELISA test underlined a great variation of reaction levels (absorbance value) between the 21 varieties due to the qualitative character of this test. The absorbance variation indicates differences of viral concentration in tested samples. These results are in agreement with those found by Neya (2011) using other varieties of cowpea.

The number of flowers and pods strongly varied depending to the type of plants and to the variety for most of the used varieties. This situation could be due to the important flower loss observed on the diseased plants, inducing various crop losses. In opposite, there was no variation on some varieties. This could mean that the virus does not affect flower formation, nor pod formation. Yields recorded on the different varieties varied from 703-6628 kg ha<sup>-1</sup> depending to the variety, the type of plant, the site and the year. Most of these

yields are markedly higher than those usually obtained on station with the same varieties. This yield increase is due to the insecticide treatments applied every 15 days after inoculation against aphids. However, these results are close to those obtained by Cisse *et al.* (2003); Adegbite *et al.* Amusa (2008) who said that yields considerably vary depending to varieties used, the amount of inputs used (fertilizers, pesticides) and the agro climatic conditions. Crop losses varied from 3.07-60% at Farako-bâ and from 8.71-64.44% at Kamboinsé depending to the variety. Varieties V8 and V15 were the most resistant to CABMV with crop losses comprised between 10 and 14% in both sites. These results are similar to those obtained by Aboul Ata *et al.* (1982) and Thottappilly and Rossel (1992).

Regarding CABMV transmission by seed, the results showed a difference in seed contamination rates depending to the varieties (1.07-37.63%). These differences were similar to those obtained by Bashir *et al.* (2002) with CABMV or several other viruses transmitted by seeds (Johansen *et al.*, 1994). These results show that seeds represent an effective way to maintain the virus and these seeds constitute a source of primary inoculum of CABMV.

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