RESEARCH ARTICLE

Screening of vegetable cowpea [*Vigna unguiculata* (L.) Walp.] varieties introduced in Burkina Faso for Cowpea aphid-borne mosaic virus resistance

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ABSTRACT

Vegetable cowpea is a variant of cowpea where the pods are consumed at the immature stage. Like other legumes, vegetable cowpea is subject to several constraints including Cowpea Aphid-Borne Mosaic Virus (CABMV) which seriously hampers its production. The objective of this study was to assess the impact of CABMV on the growth of vegetable cowpea varieties. The experiment was conducted in the greenhouse at the Kamboinsé experimental station and consisted of an artificial infestation of twenty (20) varieties in pots with CABMV in a randomized complete block design with three replications. At the end of the infestation of seedlings, carried out one week after sowing, fourteen (14) quantitative characteristics were measured. The study revealed the existence of several discriminating resistance and agronomic parameters, thus translating the existence of diversity within the varieties. Correlations were also observed between severity at 21th DAI and 30th DAI; between severity at 30th DAI and AUDPC; between flowering and vegetable cowpea stage. Results of the multivariate analysis show that the diversity of resistance and agro-morphological parameters is structured with a division of varieties into three distinct groups based on the discriminating characters namely the degree of disease severity and AUDPC. From this study, four (4) varieties IT84S-2246, UG-CP-8, IT85F-2805-5, and Telma were resistant to CABMV. Varieties IT85F-2805-5 and Telma expressed the best agro-morphological performance and resistance to CABMV. The high variability for all traits shows potential for breeding for vegetable cowpea improvement.

Key words: vegetable cowpea, resistance, Cowpea Aphid-Borne Mosaic Virus, Burkina Faso.

Introduction

Legumes are the main source of dietary protein in most developing countries (ICRISAT, 1991). Cowpea [*Vigna unguiculata* (L.) Walp.] is one of the major seed legumes in the world (Pasquet and Baudoin, 1997). It is mainly grown for seed, but a small proportion (about 10%) is grown as green leafy vegetables and fodder in Africa or as fresh pods in East Asia (Boukar et al., 2015). Due to its high nutritional value, soil fertilizing capacity, and year-round availability when other crops are scarce, cowpea is used in hunger and malnutrition programs. The multiple uses of immature pods and mature seeds would indicate the existence of two botanical types within the species, namely vegetable and seed cowpeas. Generally, the seed cowpea varieties have short pods with many seeds. Vegetable cowpea is a good alternative vegetable because of its long, tender, immature pods, sweetness over a long period of time with fewer seeds that ripen late, and its tolerance to drought (Pandey et al., 2006). Despite its potential, very little agronomic information exists on vegetable cowpea (Ano, 2006); research activities generally focus on seed cowpea, thus classifying vegetable cowpea as a *'neglected legume'* (Ndukwe et al., 2012). Therefore, further research on vegetable cowpea in Burkina Faso will provide a better understanding of the genetic diversity of this crop for future breeding work. Like other legumes, vegetable cowpea faces many abiotic and biotic constraints including viruses. Of all viral diseases, the cowpea mosaic virus transmitted by aphids is the most damaging and widespread (Reeves, 1983). In Burkina Faso, yield losses associated with CABMV have ranged from 7% to 60% in a dozen varieties (Neya et al., 2015). Since its discovery, this virus has been the subject of several works. This work has mainly focused on dry-seeded cowpea, but few have focused on the conditions of resistance and adaptation of vegetable cowpea varieties to CABMV. It is in this context that this study was conducted with the general objective of evaluating the resistance of twenty (20) vegetable cowpea varieties [*Vigna unguiculata* (L.) Walp] to CABMV. Specifically, the aim is to (i) determine the behaviour of vegetable cowpea varieties to mechanical inoculation with CABMV and (ii) identify vegetable cowpea varieties resistant to CABMV.

Materials and Methods

Materials

Plant material

A total of twenty (20) varieties of vegetable cowpea from the germplasm of the World *Vegetable* Center in Mali were used. These varieties are distinguished from each other by the size and shape of their pods.

Study site

The study was conducted from the greenhouse of the cowpea breeding unit at the Formation and Agricultural, Environment Research Center (CREAF) of Kamboinsé of the National Institute for the Environment and agricultural research (INERA), Burkina Faso. This center is located in the northern Sudanian sector of the Sudanian domain (Thiombiano and Kampmann, 2010). It is located at 296 m above sea level, 12 ° 28 North latitude, and 1 ° 32 West longitude. The cumulative rainfall for the 2019-2020 agricultural season, was 782.5 mm spread over 8 months (Meteo CREAF/Kamboinsé, 2019).

Methods

Experimental design

The test was established according to a randomized complete block design with three replications. In each replication, a vegetable cowpea variety was sown in a pot. Each replication was composed of twenty (20) varieties. The trial consisted of a total of 60 pots, 20 per replication, each representing an elementary plot. The pots were placed next to each other in the same replication and the replications were 0.8 cm apart.

Technique for obtaining the inoculation buffer

The inoculum used for variety screening was prepared from infected leaves of a cowpea variety susceptible (Gorom local) to CABMV serotype D. Virus-infected leaves of the susceptible cowpea variety (local Gorom) were collected and ground in a porcelain mortar at a grinding ratio (weight of plant material to the volume of buffer) of 1g/10ml. Then, the grind was homogenized in the presence of a solution containing 0.01 M sodium phosphate buffer at pH 7.4. The purpose of this buffer is to avoid inhibition of the virus by tannins and oxidizing systems contained in some plants.

Transmission technique by mechanical inoculation

Inoculation was carried out according to the method described by Neya (2011). Thus, one week after sowing (two-leaf stage), a drop of the grind was placed on healthy leaves previously cleaned with cotton and sprinkled with 600 mesh carborundum. Carborundum is an abrasive product that causes many slight wounds on the leaves when rubbed. Using the pestle dipped in the previously obtained extract, the upper surface of the leaves of the young plants of each variety was gently rubbed. Excess carborundum and filtrate were removed by rinsing the leaf with distilled water to avoid necrosis

Conduct of the trial

Sowing was done in August 2019 in pots arranged in a greenhouse. In each pot, three seeds were initially sown. After emergence (5 DAS) a de-sowing to one seedling per pot was done. CABMV infestation was performed one week after sowing.

Maintenance operations consisted of spading as needed to facilitate water infiltration and promote plant growth; application of NPK 14-23-14-6S-1B fertilizer at the rate of 2 g/pot and insecticide treatments with Pacha 25 EC at the rate of 2ml/l of water (15 g of Lamda-cyhalothrin and 10 g of acetamiprid Concentrate) at the flowering and pod formation stages. Stakes were used to maintain some climbing varieties. The plants were watered by direct application of water to the foot in case of rain absence.

Data collection

CABMV resistance parameters, vegetable cowpea phenological traits, morphological traits, and yield components were determined. These are:

- symptom emergence date (SED) (Barro et al., 2016);
- area under the disease progress curve (AUDPC) proposed by Shaner and Finnay (1977); the degree of expression or severity of the disease noted on 21 and 30 days after mechanical inoculation on a six-class scale (0 - 5) Barro *et al.* (2016);
- date of appearance of the first flower;
- of the vegetable cowpea stage;
- of the number of days at 95% maturity;
- chlorophyll content (SPAD).
- the length of the pods;
- the height of the plants;
- the number of pods per plant;
- of the weight of the pods;
- the number of seeds per pod;
- of the weight of one hundred (100) seeds;

- and the weight of the seeds.

Statistical analysis

XLSTAT 2016 software was used to analyse the data. Analysis of variance (ANOVA), was performed to determine the characters that discriminate the varieties. The relationships between these traits were studied using Pearson's correlation matrix. Principal component analysis (PCA) was performed to determine the association between the studied traits. The well-represented and poorly correlated variables were used for grouping the varieties by ascending hierarchical clustering (CAH) according to Ward's aggregation method using Euclidean distance. The groups resulting from this classification were characterized by a discriminating factorial analysis (AFD).

Results

Resistance of vegetable cowpea to CABMV

Analysis of variance results (Table 1) showed that the symptom emergence date, severity at 21th, 30th DAI, and AUDPC discriminated significantly at the 5% and 1% threshold between the varieties studied. Thus, with a mean symptom emergence date of 7 days and a low coefficient of variation of 13%, the varieties RW-CP-5, Tumaini, IT85F-867-5 showed the disease early (6th DAI), while the variety LBR7 showed symptoms late.

Symptom severity varied by variety at 21th and 30th DAI on a scale of 0 to 5. Their coefficients of variation of 42% and 39% respectively were high. The reaction of the observed varieties was composed of asymptomatic, stunted, chlorotic plants, plants with deformations, and mosaic of leaves (Figure 1). Thus, varieties IT84S-2246, UG-CP-8 showed green mosaic while varieties Niébé baguette grimpant, IT85F-867-5 showed symptoms of yellow mosaic and severe mosaic.

Regarding the Area Under Disease Progress Curve (AUDPC) values, the average was 28.8 with a high coefficient of variation of 39%. The lowest AUDPC was noted in varieties IT84S-2246 (10.5), UG-CP-8 (10.5); while it was high in UG-CP-3 (39), IT85F-867-5 (40.5) and Niébé baguette grimpant (42)

Phenological characteristics

Results of the analysis of variance (Table 2), reveal that all phenological variables discriminate varieties at the 1% threshold. The average first flower appearance date for all varieties was 41 days after sowing (DAS). Thus, the varieties Telma (36 DAS), RW-CP-2 (37 DAS), IT83S-872 (38 DAS)

Table 1. *Results of resistance parameters of vegetable cowpea to CABMV*

Variables	Minimum	Maximum	Average	CV (%)	Pr > F
SED	6	8,33	6,75	13	0,001**
SEV21	1	4,33	2,983	42	0,025*
SEV30	1,33	5	3,417	39	0,003*
AUDPC	10,5	42	28,8	39	0,008*

Legend*: ns = not significant (P>0.05), *: significant difference at 5%, **: significant difference at 1%, CV: Coefficient of Variation, SED: Symptom emergence date, SEV21: severity at 21th DAI, SEV30: severity at 30th DAI, AUDPC: Area Under Disease Progress Curve.*

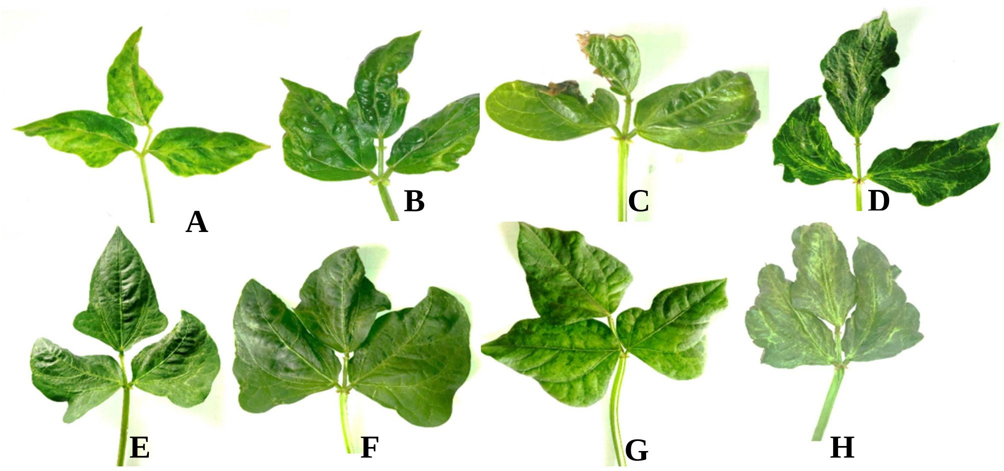

Figure 1. *Different symptoms of CABMV observed on leaves*

Legend: *Yellow mosaic, no leaf deformation (A, G); Yellow mosaic with deformation (C, H); Green mosaic, as large spots, with leaf curling and deformation (B, D); Mosaic visible only in backlight, leaves curled downwards (E, F)* flowered early.

On the other hand, the varieties UG-CP-3 (45 DAS) and TZA-2344 (46 DAS) flowered late. The varieties studied have an average cycle of 50 and 60 days of vegetable cowpea stage and 95% pod maturity respectively. Thus, Telma, Ex-Iseke were the first varieties to reach the vegetable cowpea date (50 days before the pod maturity date) and UG-CP-3, TZA-2344 were the last to reach this date (54 days before the pod maturity date).

95 % maturity date was 58 days for the varieties UG-CP-8, Baguette, Niébé baguette grimpant and 66 days for the vegetable cowpea variety TZA-2344, the latest. For leaf chlorophyll content (SPAD), the varieties showed an average content of 48.60%.

Telma variety recorded the highest chlorophyll content (48.06%) and the Niébé baguette variety the lowest (36.83%). For all the variables studied, the coefficient of variation was very low and ranged from 3% for the 95% maturity date to 13% for the chlorophyll content.

Table 2. *Results of the analysis of variance of phenological diversity of varieties*

Variables	Minimum	Maximum	Average	CV (%)	Pr > F
SPAD	36,83 %	48,06%	48,6%	16	0,001**
FFAD	36	46	41	8	0,005*
VCS	50	54	51	5	0,006*
Mat95%.	58	66	60	3	0,001**

Legend: **: significant difference at 5%; **: significant difference at 1%; CV: coefficient of variation, FFAD: first flower appearance date, VCS: vegetable cowpea stage, Mat 95 %: maturity at 95 %. SPAD: chlorophyll content*

Table 3. *Results of analysis of variance of morphological characteristics and yield components*

Variables	Minimum	Maximum	Average	CV (%)	Pr > F
PHei	31,67	265	113,91	58	0,001**
LengP	10	30	15,79	30	0,001**
NPP	5	14	10	45	0.108ns
NSP	6	18	11	38	0,040*
HSW	6,63	18,2	10,92	30	0,001**
SWei	5,67	20,17	10,1	50	0,002*

Legend: *ns = not significant (P>0.05); *: significant difference at 5%, **: significant difference at 1%, CV: coefficient of variation, PHei: plant height, LengP: pod length, NPP: number of pods per plant, NSP: number of seeds per pod, HSW: hundred seed weight, SWei: seed weight.*

Morphological characteristics and yield components

Results of the analysis of variance (Table 3) show that, with the exception of the number of pods per plant, the five (5) other variables discriminate the varieties studied at the 5% and 1% threshold. The height of the plant, with an average height of 113.91 cm, varied from 31.67 cm for the variety IT86F-2089-5 to 265 cm for the variety Niébé baguette grimpant.

Regarding pods, with an average number of 10 pods per plant, the average pod length was 15.79 cm. The longest pod (30 cm) was recorded in the variety Niébé baguette grimpant. While the shortest pod (10 cm) was observed in the variety IT83S-818. For seeds, the average number of seeds per pod per plot was 11 seeds.

Variety IT85F-2805-5 had the highest number of seeds per pod (18 seeds) and variety IT83S-818 had the lowest number of seeds per pod (4 seeds). The average hundred seed weight was 10.92 g; while the average value of total seed weight per elementary plot was 10.10 g. The best hundred-seed weight and total seed weight were obtained with Telma. The lowest hundred seed weight and total seed weight were recorded in variety IT86F-2089-5 (6.63 g) and variety IT85F-867-5 (5.67 g) respectively. For all the variables studied, the coefficient of variation was high (CV ≥ 30%); it varied by 30% for pod length, hundred seed weight, and 58% for plant height.

Correlations between the quantitative characteristics studied

Pearson correlation matrix analysis results revealed the existence of several variables that are either positively or

Table 4. *Results of the correlation matrix between the different varieties*

Variables	SED	SEV21	SEV30	AUDPC	SPAD	FFAD	VCS	Mat95%.	PHei	LengP	NPP	NSP	HSW	SWei
SED	1													
SEV21	-0,238	1												
SEV30	-0,231	0,894**	1											
AUDPC	-0,241	0,969**	0,976**	1										
SPAD	0,123	-0,472*	-0,465*	-0,481*	1									
FFAD	-0,05	0,299	0,161	0,232	-0,271	1								
VCS	-0,094	0,291	0,151	0,222	-0,315	0,730*	1							
Mat95%.	0,094	-0,019	-0,05	-0,036	-0,077	0,532*	0,418	1						
PHei	-0,382	0,308	0,29	0,307	-0,22	-0,141	-0,039	-0,203	1					
LengP	-0,221	0,374	0,32	0,355	-0,099	-0,04	0,05	-0,121	0,716*	1				
NPP	0,069	-0,264	-0,26	-0,269	0,247	0,052	0,016	-0,001	-0,312	-0,102	1			
NSP	-0,385	0,097	-0,086	0,001	0,016	0,558*	0,491*	0,284	0,169	0,198	-0,194	1		
HSW	-0,017	0,024	-0,039	-0,01	0,285	-0,329	-0,470*	0,087	0,409	0,373	-0,174	-0,098	1	
SWei	-0,134	-0,211	-0,302	-0,267	0,382	-0,011	-0,131	0,143	0,263	0,376	0,444*	0,324	0,541*	1

Legend*: *: significant difference at 5%, **: significant difference at 1%, ns = not significant (P>0.05), CV: Coefficient of Variation, SED: Symptom emergence date, SEV21: severity at 21 DAI, SEV30: severity at 30 DAI, AUDPC: Area Under Disease Progress Curve, FFAD: first flower appearance date, VCS: vegetable cowpea stage, Mat 95 %: maturity at 95 %. SPAD: chlorophyll content, PHei: plant height, LengP: pod length, NPP: number of pods per plant, NSP: number of seeds per pod, HSW: hundred seed weight, SWei: seed weight.*

Table 5. *Eigen values and percentage of variation expressed by the first three axes of the principal component analysis.*

Main component	F1	F2	F3
Eigen value	4,057	2,785	2,334
Total variance (%)	28,978	19,890	16,675
Total cumulative variance (%)	28,978	48,868	65,543
SED	0,138	0,037	0,104
SEV21	**0,837**	0,007	0,013
SEV30	**0,759**	0,018	0,081
AUDPC	**0,840**	0,013	0,045
SPAD	**0,405**	0,042	0,055
FFAD	0,168	**0,477**	0,187
VCS	0,199	**0,452**	0,125
Mat95%.	0,005	0,229	0,197
PHei	0,207	**0,420**	0,093
LengP	0,202	**0,330**	0,161
NPP	0,156	0,022	0,030
NSP	0,065	0,070	**0,561**
HSW	0,008	**0,525**	0,090
SWei	0,069	0,141	**0,591**

negatively correlated (Table 4). Indeed, the severity at 21th DAI is positively and strongly correlated with the severity at 30th DAI (r = 0.894) and with the AUDPC (r = 0.969). On the other hand, the severity at 21th DAI is negatively and weakly correlated with SPAD (r = -0.472). There is also a positive and strong correlation between severity at 30th DAI and AUDPC (r = 0.976). However, a negative and weak correlation is observed between the severity at 30th DAI and the SPAD (r = -0.481).

Then, strong positive correlations were observed between the flowering cycle and vegetable cowpea stage (r = 0.730), on the one hand, and between the flowering cycle and maturity (r = 0.532) on the other hand. In addition, the vegetable cowpea stage was positively and weakly correlated with the number of pods per seed (r = 0.491) but negatively with hundred seed weight (r = -0.470). Finally, a positive and weak correlation is observed between the weight of hundred seeds and the total weight of seeds (r = 0.541).

Principal Component Analysis (PCA)

The results of the principal component analysis (Table 5) show that the first three factorial axes express 65.54% of the overall variability. The first component (axis 1) with 28.97% of the variability associates the variables severity at 21th DAI, severity at 30th DAI, and AUDPC. This axis 1 thus defines the parameters of resistance to CABMV. The second axis with 19.89% of the total variability associates the vegetative development and phenological variables. Parameter's date of appearance of the first flower, vegetable cowpea stage cowpea, plant height, and pod length are associated with this axis. The third axis with 16.675% of the total variability associates the variables number of seeds per pod and seed weight. This axis thus defines the yield component variables.

Characterization of the groups resulting from the CAH

Dendrogram resulting from the ascending hierarchical clustering (CAH) carried out from the quantitative variables (Figure 2), gave a structuring of the accessions in three (3) groups with a truncation at the level of inertia 28. These three groups are composed of 4, 8, and 8 varieties, respectively. The structuring of the groups was carried out independently of the phenology and yield components. Nevertheless, it was done according to the virus severity classes.

Thus, group 1 includes varieties whose disease severity on 21th and 30th days after mechanical inoculation is on a scale of 0 to 2. This group is characterized by a low AUDPC and therefore resistant varieties. Group 2 is characterized by varieties of severity class 3, i.e., with intermediate resistance. Group 3 is a heterogeneous group made up of 2 varieties of severity class 3 and 6 varieties of severity class 4.

Discriminant Factor Analysis (DFA)

Discriminating factorial analysis (AFD) of the CAH groups allowed the reclassification of the varieties RW-CP-2 and TZA-2344 which belonged to group 3 into group 2 (Figure 3). These results show that the first two axes explain 100% of the total variability. The relationship of the groups with the axes showed that group 1 positively correlated with axis 1 and negatively correlated with axis 2 consisting of resistant individuals characterized by a severity class 0-2. Group 2, positively correlated to both axes, is made up exclusively of tolerant individuals with a severity class of 3. Group 3, which is negatively correlated to both axes, is composed of susceptible varieties with severity classes 4 and 5.

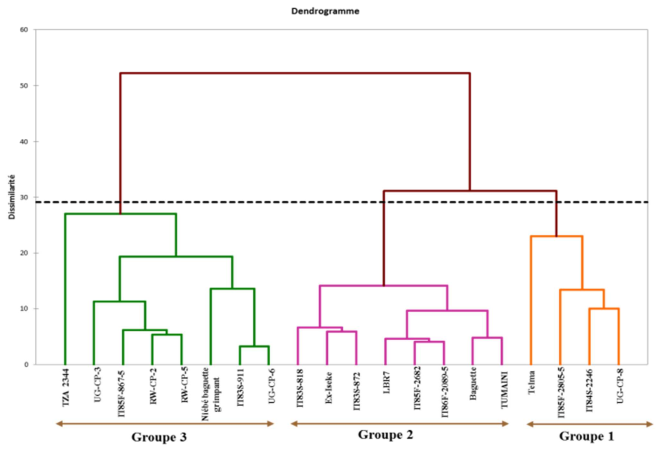

Figure 2. *Dendrogram from the hierarchical ascending classification of twenty (20) green cowpea varieties.*

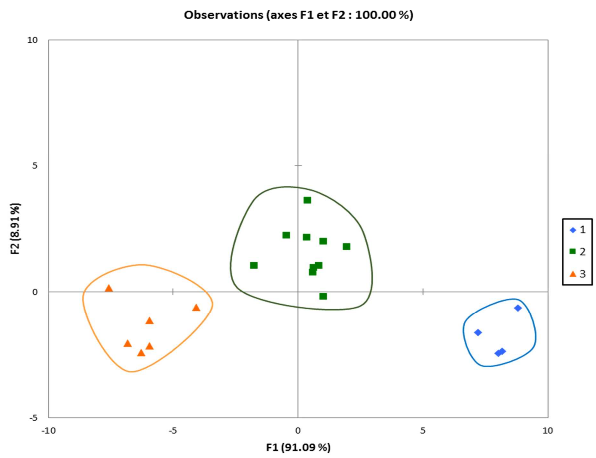

Figure 3. *Projection of the three (03) groups in the plane formed by the first two axes of the SFM.*

Discussion

The study revealed significant genetic variability within the varieties studied across phenological traits, morphological traits, yield components, and CABMV resistance parameters. This observed variability offers probabilities of choice of genitors for the creation of new varieties meeting the needs of the producers. In fact, the coefficients of variation were greater than 30% for all the quantitative characteristics studied except for phenological parameters and the date of appearance of symptoms. Thus, the varieties would be very heterogeneous for the characters with high CV (CV > 30%) (Aljane and Ferchichi, 2007).

Vegetable cowpea varieties used reacted in different ways to CABMV inoculation. A wide range of symptoms was observed with mosaic as a common feature. Thus, the symptom emergence date between 6 to 8 DAI, corresponds to the normal symptom emergence date as observed by Neya (2011). Indeed, according to the latter symptoms are visible in susceptible varieties between 6 to 7 days after inoculation.

Correlations between severity at 21th DAI, severity at 30th DAI, and AUDPC show that resistant and tolerant varieties are those with low severity and low AUDPC and susceptible varieties have high severity and high AUDPC.

This result is similar to that of Nanama et al. (2020) on vegetable cowpea varieties inoculated with CABMV. AUDPC is a component of epidemiology that takes into account the progression of the disease over time. It implies a notion of disease installation, increase, and final incidence (Barro et al., 2016). The information obtained from the AUDPC assessment helps breeders to identify the best varieties for their ability to slow down disease progression (Orawu, 2007). The data obtained show that resistance, tolerance, and susceptibility are discriminating factors among varieties. This justifies the structuring of varieties into three groups based on the degree of disease severity. These results are similar to the work of Barro et al. (2016) who classify cowpea varieties into three categories based on the degree of severity. Thus, the first group consisting of resistant varieties such as IT84S-2246, UG-CP-8, IT85F-2805-5 and Telma belong to severity classes 0; 1 and 2. As for the second group, it includes the tolerant varieties IT83S-818, Tumaini, IT85F-2682, IT86F-2089-5, LBR7, RW-CP-2, Baguette, IT83S-872, Ex-Iseke, TZA-2344 which have a severity class 3. Finally, the third group consists of susceptible varieties such as RW-CP-5, UG-CP-6, IT83S-911, UG-CP-3, IT85F-867-5, Niébé baguette grimpant belonging to classes 4 and 5.

The average values of 40 days before flowering and 50 days before vegetable cowpea stage would indicate that the varieties studied are of a short cycle. These results corroborate those of Vural et al. (2000). Indeed, for this author, the harvest period of vegetable pods is 5 to 9 weeks after sowing, depending on ecological conditions. However, these results differ from those of Peksen et al. (2013), on vegetable cowpea varieties in Turkey whose vegetable cowpea stage was 54 JAS. This observed difference could be due to genotype or soil-climate effects. This earliness of cowpea varieties is an important agronomic characteristic that could contribute to coping with climate change phenomena and particularly with drought (Coulibaly et al., 2020). For Pandey et al. (2006), the optimal harvesting stages for vegetable cowpea are essential for the vegetable market as well as for the production of quality seeds.

In addition, the average value (60 days) of the number of days to 95% pod maturity would indicate the extra earliness of the varieties. Indeed, according to Dugje et al. (2009), cowpea varieties with a maturity cycle of 60 days are extra early, 60 to 80 days early and over 80 days late.

For Gbaguidi et al. *(*2013), earliness is an avoidance mechanism of a crop to biotic and abiotic constraints. Thus, these extra-early varieties can be used as germplasm in breeding programs for varieties resistant to drought, to the parasitic weed *Striga gesnerioides*, and to cowpea diseases and pests.

The average pod length of 15.9 cm shows that the majority of the varieties have a medium pod length. Indeed, according to Uguru (1996), based on length, cowpea varieties can be classified into three groups namely short pod (<13.5 cm), medium pod (13.5-19.9 cm), and long pod (> 20 cm) varieties. However, the cowpea varieties climbing baguette and Telma with pod lengths of 31 cm and 24 cm respectively are long-podded varieties. These varieties better meet the expected agronomic characteristics of vegetable cowpea. According to Kar et al. (1995), pod length is one of the major factors affecting the pod yield of vegetable cowpea. Longer pods are the preferred and attractive market traits of vegetable cowpea.

The variety IT85F-2805-5 with a high average number of 18 seeds per pod could be selected as a breeding parent for dual-purpose cowpea production (fresh pods and dry cowpea); a common practice among farmers in Nigeria (Uguru, 1996). This yield component could possibly be used as a main criterion for the selection of dual-purpose cowpea in countries where vegetable cowpea is traded. Thus, vegetable cowpea varieties with the highest number of seeds per pod can also be used as dry cowpeas. The observed variability would reflect a difference between accessions in the efficiency of assimilate mobilization to reserve structures (Boyé et al., 2016).

According to Khan et al. (2010), the significant difference in hundred seed weight for vegetable cowpea varieties shows that the accumulation of reserves in seeds depends on genotype type but also on climatic factors. Thus, Telma and IT86F-2089-5 varieties which presented the highest values for hundred seed dry weight of 18.06 g and 17 g respectively had good reserve accumulation. These results thus confirm the existence of a difference in the efficiency of assimilate mobilization and hence the ability of varieties to ensure seed filling. The capacity to fill seeds would be more important in the varieties Telma and IT86F-2089-5 which expressed the weights of hundred seeds the highest.

The correlations between flowering, vegetable cowpea stage, and maturity show that early flowering plants are early in the vegetable cowpea stage and maturity. This result is in agreement with that of Benee (1988) who stated that the earlier a variety produces flowers, the earlier it will mature. This relationship is particularly interesting in plant breeding in that only one of these traits; namely flowering, can be used to predict vegetable cowpea stage and maturity. For Adeyanju et al. (2007), the date of flowering determines the time of harvest of mature pods. Thus, any extension of this time is attributable to damage by CABMV which causes some flowers to abort, and hence, delays the date of pod appearance and poor pod formation (Barro et al., 2016).

CONCLUSION

Study of resistance through parameters of resistance to CABMV, phenological and morphological characters, and yield components revealed the existence of a great variability within vegetable cowpea varieties. In total, 12 of the 13 traits discriminate the varieties studied. Mechanical inoculation allowed the observation of various generalized symptoms of CABMV. Many correlations between characters were observed. These correlations are, among others, the positive correlation between severity at 21th DAI and severity at 30th DAI; between severity at 30th DAI and AUDPC; between flowering and vegetable cowpea stage. The study also showed that the reaction of the twenty (20) vegetable cowpea varieties to CABMV allowed them to be grouped into three (3) groups according to the degree of severity of the disease, group 1 consisting of four (4) phenotypically resistant varieties, group 2 of ten (10) tolerant varieties and group 3 of six (6) susceptible varieties. Thus, the resistant varieties IT85F-2805-5, Telma with low severity ratings, high pod length, and relatively short vegetable cowpea sate can be recommended to farmers for vegetable cowpea production.

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References

Adeyanju AO, Ishiyaku MF, Omoigui LO. 2007. Inheritance of time to first flower in photo insensitive cowpea [*Vigna unguiculata* (L) Walp]. *Asian J. Plant Sci* 6: 435-437.

Ano AO. 2006. Effect of vegetable cowpea population on component crop yields and productivity of yam, minisett based system. *Nigerian Journal of Agriculture*, 37: 81-84.

Barro A, Sawadogo M, Kiébré Z, Néya BJ. 2016. Evaluation de la résistance de quelques lignées et écotypes de niébé [*Vigna unguiculata* (L.) Walp.] au Cowpea Aphid-Borne Mosaic Virus au Burkina Faso. *Int. J. Inn. Appl. Stud.*, 15: 387-394.

Benee CKA. 1988. *An assessment of plant characters that facilitate harvesting and shelling on sixteen varieties of cowpea (Vigna unguiculata (L.) Walp).* Unpublished BSc dissertation. School of Agric., Univ. of Cape Coast, Ghana.

Boukar O, Fatokun CA, Roberts PA, Abberton M, Huynh BL, Close TJ, Boahen SK, Higgins TJV, Ehlers JD. 2015. "Cowpea", in Grain Legumes, Series *Handbook of Plant Breeding*, A. M. De Ron (ed.), Springer-Verlag, New York, pp. 219-250.

Boyé MAD, Yapo SES, Koffi N'dodo BC, Kouassi N'dri J, Tonessia DC, Soko DF, Ballo EK, Seu J G, Ayolié K, Kouadio YJ. 2016. Étude de la qualité agronomique et biochimique de quelques variétés de niébé [*Vigna unguiculata* (L) Walp (*Fabaceae*)] provenant de la Côte d'Ivoire. *European Scientific Journal* 12(24): 362-375.

Coulibaly Z, Barro A, Tignegre JB., Kiebre Z, Batieno BJ, Dieni Z, Nanama J. 2020. Évaluation des performances agronomiques de douze (12) variétés de niébé vert [*Vigna unguiculata* (L.) walp.] au Burkina Faso. *J. Appl. Biosci.* 153: 15745 – 15755

Dugje IY, Omoigui LO, Ekeleme F, Kamara AY, Ajeigbe H. 2009. *Production du niébé en Afrique de l'Ouest ;* Guide du paysan IITA.

Gbaguidi AA, Dansi A, Loko LY, Dansi M, Sanni A. 2013. Diversity and agronomic performances of the cowpea (*Vigna unguiculata* Walp.) landraces in Southern Benin. *International Research Journal of Agricultural Science and Soil Science* 3(4):121-133.

ICRISAT (International Crops Research for the Semi-Arid Tropics). 1991. *West African programs annual report*, 1990. ICRISAT Sahelian Centre, Niamey, Niger. 132 pp.

Kar N, Dasgupta T, Hazra P, Som MG. 1995. Association of pod yield and its components in vegetable cowpea. *Indian Agriculturist* 39: 231-238.

Khan A, Bari A, Khan S, Shan NH, Zada I. 2010. Performance of cowpea genotypes at higher altitude of NWFP. *Pak. J. Bot.* 42(4): 2291-2296.

Nanama J, Barro A, Batieno BJ, Dieni Z, Kiebre Z, Coulibaly Z, Sawadogo M. 2020. Genetic Study of the Resistance of Twelve (12) Varieties of Vegetable Cowpea [*Vigna unguiculata* (L.) Walp.] to Cowpea Aphid Borne Mosaic Virus, Burkina Faso. *Int. J. Curr. Microbiol. App. Sci*. 9(11): 2032-2043.

Ndukwe OO, Muoneke CO, Umana PE, Okpara DA, Asawalam DO. 2012. Productivity of vegetable cowpea [*Vigna unguiculata* (L.) Walp.] and maize (*Zea mays* L.) intercropping system as influenced by component density in a humid tropical zone of south-eastern Nigeria. *Int'l journal of agric. And rural dev*. 15 (1):835-847.

Neya BJ. 2011. *Sérologie, pathogénie, épidémiologie et contrôle de la mosaïque Cowpea aphid-borne mosaic virus (CABMV) du niébé [Vigna unguiculata (L.) Walp.] transmis par pucerons par des pucerons (Aphis craccivora, A. gossypii) au Burkina Faso.* Thèse de doctorat unique, Université de Ouagadougou, 153p.

Neya BJ, Zida PE, Sérémé D, Lund OS, Traoré O. 2015. Evaluation of Yield Losses Caused by *Cowpea aphid-borne mosaic virus* (CABMV) in 21 Cowpea [*Vigna unguiculata* (L.) Walp] Varieties in Burkina Faso. *Pakistan Journal of Biological Sciences* 18(7): 304-313.

Orawu M. 2007. *Occurrence of cowpea aphid borne mosaic virus and prospects of* *improving resistance in local cowpea landraces in uganda*. PhD Thesis, University of Kwazulu-Natal, 137p.

Pandey YR, Pun AB, Mishra RC. 2006. Evaluation of vegetable type cowpea varieties for commercial production in the river basin and low hill areas. *Nepal Agriculture Research Journal*, 7: 16-20.

Pasquet RS, Baudoin JP. 1997. *Cowpea tropical plant breeding*, CIRAD, P 211-219.

Peksen E, Peksen A. 2013. Agronomic and Morphological Characters of Newly Registered Peksen and Reyhan Vegetable Cowpea Cultivars in Turkey. *Int. J. Curr .Microbiol. App. Sci (*2013) 2(9): 133-140.

Reeves WH. 1983. *Le niébé*. International Institute of Tropical Agriculture. Ibadan Nigeria, 170p.

Shaner G, Finney RE. 1977. The effect of nitrogen fertilization on the expression of slow-milde wing resistance in Knox wheat. *Phytopathology*, 67 : pp 1051 -1056.

Thiombiano A, Kampmann D. 2010. *Atlas de la biodiversité de l'Afrique de l'ouest*, Tome II, Burkina Faso, Ouagadougou et Frankfurt/Main.

Uguru MI. 1996. A note on the Nigerian vegetable cowpea. *Genetic Res. and Crop* vol. 43 (2): 125-128.

Vural H, Esiyok D, Duman I. 2000. *Cultivated Vegetables (Vegetable Cultivation)*. Ege University, Bornova, Izmir, Turkey. P.440.