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Effect of Agro Ecological Zones on Cowpea Performance in the Central African Republic

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Abstract
Cowpea (*Vigna unguiculata* L, Walp) is a vegetable grown and consumed in tropical Africa. Few studies have been done on cowpea in the Central African Republic (CAR). The best popularization of accessions in circulation requires a study of varietal selection. For this reason, four local accessions of cowpea (Kahkir, Gbarahn Aie-toung and Bambalassa) collected from different localities were evaluated in three different sites representing main climatic zones in the CAR. An experimental device consisting of randomized square blocks was installed to perform the study. Quantitative parameters such as the growth in height and pod, haulm and seed yields were measured. Results showed that seed, pod and haulm yields are statistically different between the four cowpea accessions. The emergence rate of all the accessions was greater than 75%. Heights of the plants were significantly different depending on the study sites. The study also showed that all accessions are susceptible to the cowpea mosaic disease (CMD) with prevalence between 50 and 98%. The Kahkir and Gbarah accessions gave better pods, seeds and biomass and the most productive sites were M'Baïki in the climatic zone of Guinean forest.
Keywords: Agronomic performance, local accessions, cowpea, field cultivation

1. Introduction

Domesticated and cultivated in tropical Africa since the Neolithic period, cowpea, also known as black-eyed cowpea is one of the seed-legumes cultivated in all tropical and intertropical zones of Africa, Asia, Europe, the United States, Central and South America. Annual global production is 6.4 million tonnes of dry seeds, of which more than 80% of tonnes are produced in Africa (FAOSTAT, 2019). The annual cultivated area in the world amounts to more than 12.7 million hectares, of which 10.8 million hectares are in Africa (Neya et al, 2019). Cowpea is suitable for cropping systems in many parts of Africa. It has a high content of proteins (20 to 25%), vitamins, minerals and high caloric elements which occupy an important place in the diet of many populations. Cowpea, because of its nutritional qualities, is an ingredient of choice in the fight against malnutrition and the development of livestock farming. It is consumed from the seedling stage to the harvest. Cowpea is also used in the preparation of several African meals. It is a plant that is not very demanding on the quality of the soil and which, above all, needs heat and light for optimal growing. According to Gumedzoe et al. (2021) cowpea is grown mainly in West Africa (with as the main producers Niger, Nigeria, Mali, Burkina Faso), which represents nearly two thirds of world production and with a lesser quantity in East Africa (Ethiopia, Tanzania and Uganda) and in Central Africa (Cameroon, Chad, the Democratic Republic of Congo and the CAR). In the CAR, cowpea is mainly produced in the Sudano-Oubanguian zone (Northern and North-Western parts of the country). In the Guinean forest zone cowpea production is low. Cowpea represents a potential source of additional income and sometimes covers the immediate food needs of the family unit. However, despite its many advantages, cowpea has remained an underexploited crop and one of the most neglected and therefore less studied crops (Yaya Toure et al, 2013).

In the CAR, very little information is currently available on the distribution, genetic diversity, cultivation and uses of cowpea in the major production areas. The development of a program of prospecting, collection and selection of elite varieties of cowpea is therefore essential. In this context, the MACOWECA project (Maize and Cowpea for Sustainable food and Nutrition Security in Western and Central Africa), in which this study is part, aims to study and build the conditions for a greater insertion of cowpea in agricultural systems throughout the CAR territory. In the framework of improving and popularizing the culture of better cowpea varieties, this study presents the agronomic performance of four local cowpea ascensions identified in the main production areas in the CAR.

2. Materials and methods

2.1. Agro ecological characteristics of the study sites

The study was conducted in 3 sites corresponding to the forest, savannah and wooded savannah areas of the CAR. Localities of Yaloké (savannah area), Pissa (wooded savannah area) and M'Baïki (forest area) were selected to serve as pilot localities. The choice of these three localities is based on their geographical positions and their accessibility whose geographical coordinates are recorded in the table 1.

Table 1: *Geographical coordinates of the study sites*

Site	Locality	Latitude	Longitude	Altitude (m)	Pluviometry (mm)
PISSA	Pissa II	N *04°02'46,4''*	E*18°09'51,6''*	372	1600
Mbaïki	ISDR	N *3°52'47''*	E*17°57'58,5''*	343	1600
YALOKE	Zawa	N *05°22'37,4''*	E*16°57'10,7''*	723	1400

2.2. Plant material

The plant material consists of four local accessions which were collected in cowpea production areas, especially in the West and North-West in the Sudano-Guinean agro-ecological zone of the CAR. These are the Kahkir, Gbarah, Bambalassa and Aie-toung accessions.

2.3. Experimental device

The four-replicate split plot design was applied at all the three experimental sites. The elementary plots had an area of 25m^2 (5m x 5m) with a spacing of 0.5m between plants on the line in order to reach a maximum density of 121 pockets per elementary plot or 1936 plants on the whole of the 20 elementary plots. A block is defined as a group of 4 elementary plots (with the 4 accessions) which were separated with a spacing of 2m. To avoid anthropic disturbances, the whole of the 20 plots was isolated at 5m from borders.

Cowpea sowing was carried out on June 6, 2020 in M'Baïki, June 9, 2020 in PISSA and June 13, 2020 in YALOKÉ. 2 to 3 seeds were deposited per pocket. The maintenance of the plots consisted of weeding and ridging. A total of 3 weeding were carried out from the 45th day after sowing (DAS), at intervals of 15 days. At the 15th DAS, a thinning of one plant per pocket was done. The 2m x 2m yield squares were defined in the middle of each elementary plot for the collection of data on 25 pockets of the yield square.

Following agro morphological parameters were measured: seedling emergence rate, plant height, number of mature pods, disease prevalence, total fresh biomass, pod weight, number of branches and seed yield pods. The agro morphological parameters were measured according to the recommendations of the descriptors of the bambara pea (Ipgri et al, 2000).

2.4. Evaluation of the severity of viral diseases

Various types of mosaic symptoms described by LUDWIG MERCKE (2016) namely vein mosaic, marbled or intervenal mosaic, speckled mosaic and spotted mosaic were actually observed in the three study localities. Thus, it was important to assess the severity of viral diseases using the scale described by Fargette

(1987). This scale includes five levels from 0 to 4. Thus, the score 0 = no symptoms was defined; 1 = slight mosaics without deformation and covering less than 20% of the leaf surface; 2 = mosaics and chlorosis covering approximately 50% of the leaf surface with occasional deformation of the leaf; 3 = mosaics covering most of the leaf accompanied by necrosis, deformation of the leaf blade; 4 = terminal stage characterized by the death of the plant. The severity was calculated using the following formula:

$$\boldsymbol{S} = \frac{\sum_{i=1}^{25} \mathrm{dss}}{\mathrm{Nd}}$$

Where ***S*** is the severity of the symptoms evaluated on the diseased pockets of the yield square; ***dss*** is the degree of severity of symptoms on the leaf area of diseased leaves; ***Nd*** is the number of diseased plants or pockets.

The prevalence of viruses was calculated using the following formula:

$$\boldsymbol{P} = \frac{\sum_{i=1}^{25} n}{\mathrm{N}} \times 100$$

where ***P*** is the prevalence (%); ***n*** is the number of diseased pockets; ***N*** is the total number of pockets in the square.

2.5. Statistical analysis of data

The agronomic performance data (height of pockets) were compared between the accessions, at the end of the crop cycle, using a generalized linear model following the Poisson distribution. The Chi-square test was used, followed by a post hoc multi-comparison test (Bonferroni method) to compare the proportions of emerging seeds in the first month (July) and those of diseased plants at the end of the crop cycle (September). Two-way ANOVA was used to compare plant growth, branching numbers, pod/seed numbers and weights taking as factors locality and varieties given that these data follow a normal distribution (Shapiro test, $P>0.05$). All these tests were performed with the R software and the probability level for a significant difference of 0.05.

3. Results

3.1. Plant emergence rate

A high rate of seedling emergence was reported in the locality of M'Baïki with values greater than 95% in all accessions (Table 2). In Pissa, the emergence rates were higher than 93% with the exception of the Kahkir accession where a drop in the rate to 77% was observed, significantly lower than those of the other accessions in the different localities ($P<0.05$). In Yaloké, the rates were over 90%. Gbarah was the accession that had a high emergence rate in all localities (>96%).

Table 2. *Emergence rate (%) after planting of local accessions in the study localities (month of July)*

	Kahkir	**Gbarah**	**Bambalassa**	**Aïe-toung**
Mbaïki	97^a	98^a	96^a	97^a
Pissa	$\mathbf{77^b}$	97^a	94^a	97^a
Yaloke	92^a	97^a	97^a	93^a

The rates were compared vertically in the table (i.e. according to the localities). The proportions accompanied by different letters are statistically different with a Chi-square test followed by a post hoc multicomparison test using the Bonferroni method ($P<0.05$).

3.2. Height growth of accessions

One month after sowing, plant height was less than 0.5 m in all accessions (Figure 1). Two months after sowing, a difference in growth appeared by a weak evolution of the plants in the locality of Yaloké. At the third month, this trend became clearer with significant differences ($P<0.0005$). Indeed, the plants had a height of at least 2.5 m at the end of the crop cycle in Mbaïki and Pissa, while in Yaloké the height of the plants hardly exceeded 2 m (Figure 1). The Gbarah accession reached a height of 3 m in the locality of Mbaïki even significantly exceeding its height in Pissa ($P<0.005$).

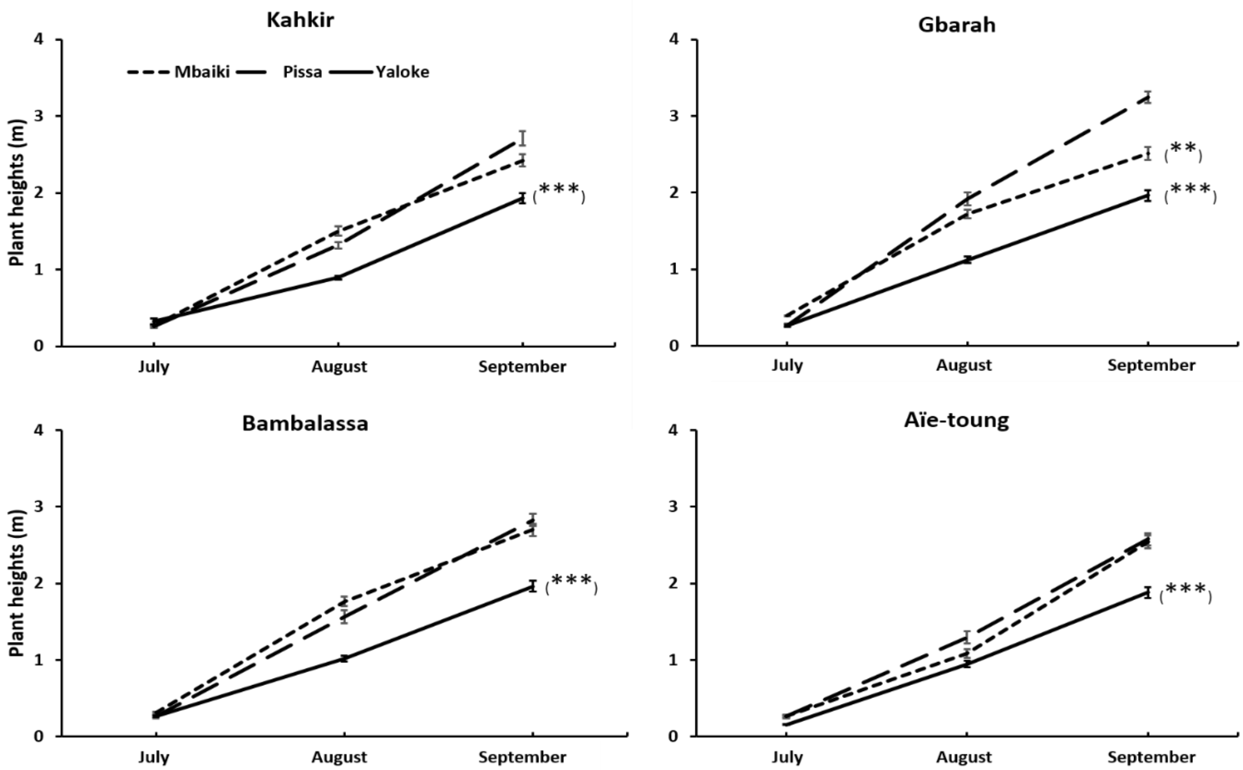

Figure 1 : Heights of pockets in the study localities. The heights were compared at the end of the crop cycle (September) taking the locality of M'baïki as a reference for these comparisons (two-factor ANOVA, *P<0.05, **P<0.005, ***P<0.0005).

3.3. Number of plant branches

The average number of ramifications was higher in M'Baïki (5.16 – 5.84 ramifications) than in Pissa (4.34 – 4.98 ramifications) and Yaloké (4.13 – 4.34 ramifications). No significant difference was established between the mean numbers of ramifications in the accessions and in the different localities (GLM with an error distribution of the Poisson family, P<0.05; Table 3).

***Table 3.** Number of ramifications of the accessions studied*

	Kahkir	Gbarah	Bambalassa	Aïe-toung
Mbaïki	5.84±1.6[a]	5.22±0.3[a]	5.16±0.3[a]	5.46±0.2[a]
Pissa	4.98±0.7[a]	4.96±0.2[a]	4.34±0.5[a]	4.86±0.1[a]
Yaloke	4.3±0.9 [a]	4.2±0.3[a]	4.13±0.2[a]	4.34±0.1[a]

Numbers were compared using a two-way ANOVA; no significant difference between the values.

3.4. Prevalence of cowpea mosaic diseases

The prevalence of cowpea mosaic disease on Kahkir and Gbarah accessions remained stable around (12 and 22% respectively) between July and August in M'baïki (Figure 2). The same trend was observed with the accession Aït-toung to Yaloké between July and August with a prevalence of about 12.5% (Figure 2). Three months after sowing, the disease prevalence reached a significant proportion in all varieties and on all study sites with variation from 43 to 98%. These results show that the all accessions are susceptible to cowpea mosaic disease. The comparison of the disease prevalence showed that they are significantly low (two-factor ANOVA, P<0.005) in the Kahkir and Gbarah accessions in the locality of Mbaïki (Figure 2).

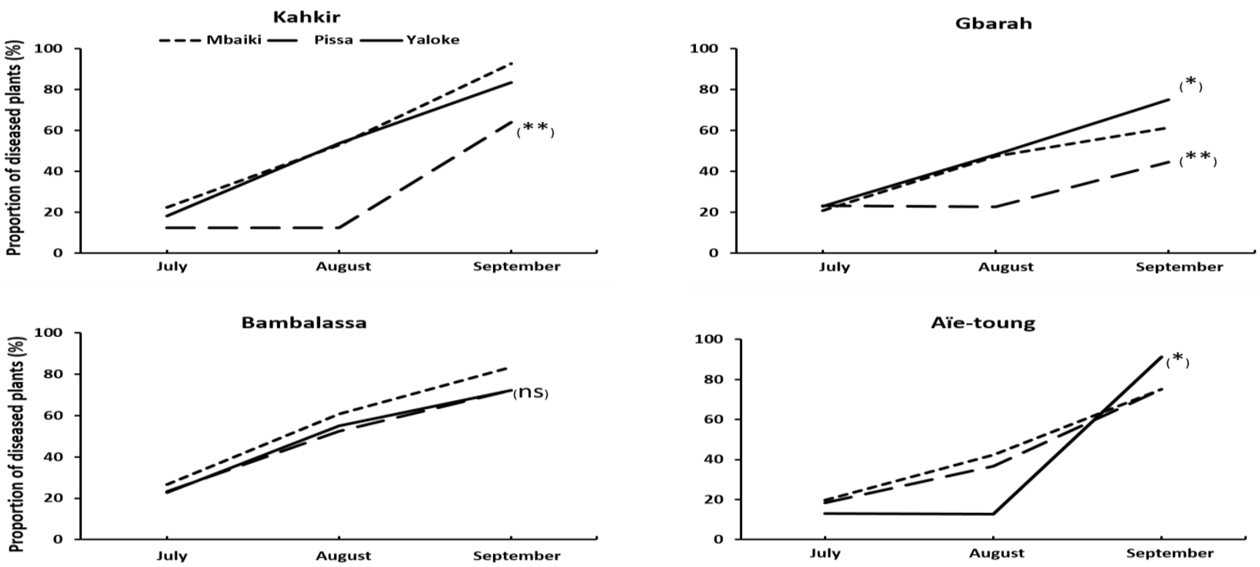

Figure 2. Proportion of infected plants the study localities. The proportions were compared at the end of the crop cycle (two-way ANOVA, *P<0.05, **P<0.005, ns= no significant difference).

3.5. Severity of symptoms of cowpea mosaic disease

The average severity index of symptoms of the cowpea mosaic disease in Kahkir and Gbarah accessions was less than 1 and remained stable between July and August in M'baïki. The same trend was observed with the Aït-toung accession to Yaloké in July and August (Figure 3). Three months after sowing, the disease severity index has increased significantly in all accessions and on all study sites and was between 2 to 3.2. No statistical difference was recorded in the disease severities between the accessions studied (two-way ANOVA, p<0.05).

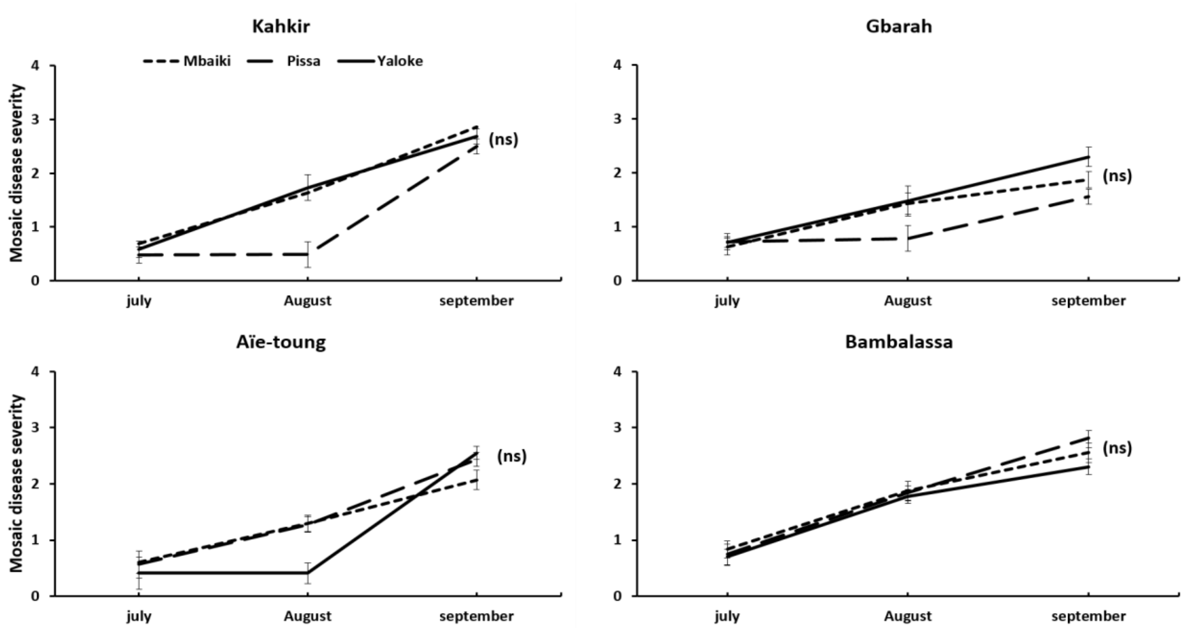

Figure 3. Severity of cowpea mosaic disease on plants over the 3 months of survey. The disease severities were compared at the end of the crop cycle (two-way ANOVA, ns= no significant difference)

3.6. Pod yields

The weight in pods was significantly higher in Pissa than in Mbaïki for the Gbarah and Aie-toung accessions (two-way ANOVA, P<0.05; Figure 4). The pod yields in the Kahkir accession were statistically the same in Mbaïki (97±27 g/plant) and Pissa (125±29 g/plant). The Bambalassa accession gave also the same production (71±16 g/plant) in Mbaïki and Pissa (79±16 g/plant). Globally the Kahkir accession had produce better in M'baïki than the 3 other accessions (Figure 4). On the other hand, the same level of production in pods was recorded in the Kahkir, Gbarah and Aie-toung accessions at Pissa, higher than that of the Bambalassa accession (P<0.05). It should be noted that in Yaloké the experiment was interrupted in all the accessions. Indeed, cowpea has never been cultivated in this region of the CAR and we recorded flower death in all the plants at the third month after planting resulting in no pod and seed yields.

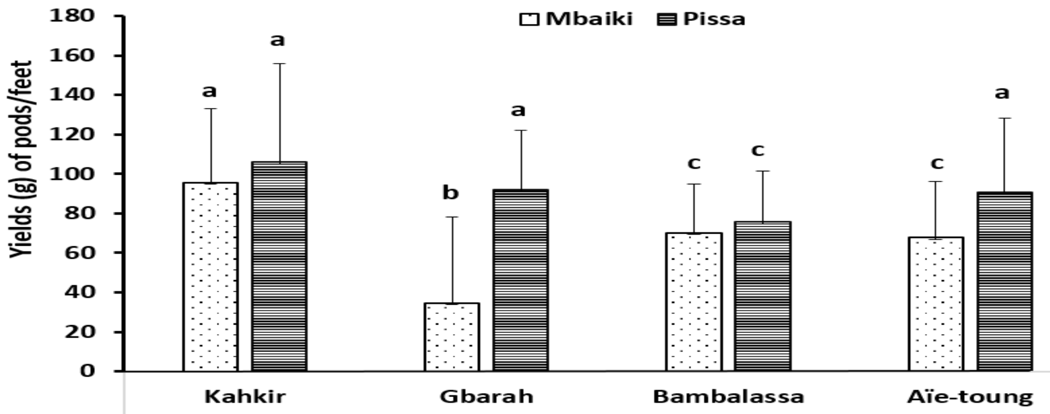

Figure 4 . Pod weight per plant. The values with the different letters are statistically different according to the generalized model with an error distribution of the Poisson family (P<0.05).

3.7. Seed yield

In M'baïki the best yield was obtained with the Kahkir accession (1.2 t/ha)(Figure 5). On the other hand, in Pissa, the Kahkir, Gbarah and Aie-toung accessions each had a yield of 1.3, 1.1 and 1.2 t/ha, respectively, with no statistical difference (GLM with error distribution of the Poisson family, P>0.05). Only the seed yield in the Bambalassa accession (0.9 t/ha) which was statistically different (P<0.05). Pod yields for all accessions showed the same trend as seed yields at both sites. This reveals a correlation between pod yield and seed yield. That is, the higher the pod yield, the higher the seed yield.

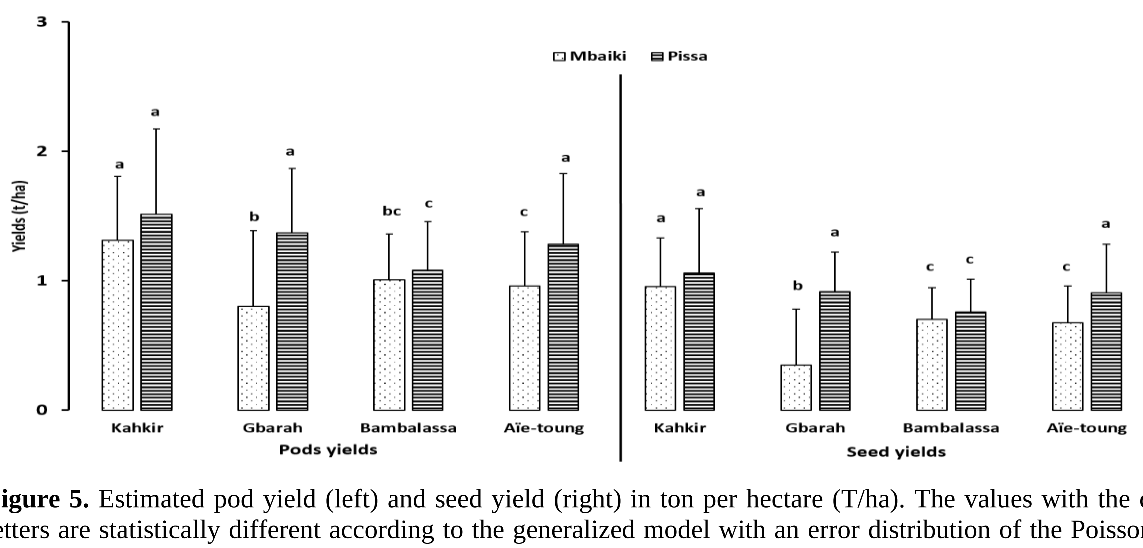

Figure 5. Estimated pod yield (left) and seed yield (right) in ton per hectare (T/ha). The values with the different letters are statistically different according to the generalized model with an error distribution of the Poisson family (P<0.05).

3.8. Haulm yield

The best biomass yield is obtained on the M'Baïki site (>5 g/plant) with all the accessions. In the locality of Pissa, the Kahkir, Gbarah and Aie-toung accessions each produced 5g/plant more than the Bambalassa accession which had a haulm yield of 4.2 g/plant. Statistical comparison of these biomass yields in the localities of M'baïki and Pissa showed no differences except in the Bambalassa accession where biomass production in Pissa was statistically less (GLM with error distribution of the Poisson family, $P<0.05$; Figure 6). As expected, the lowest biomass production was recorded in the locality of Yaloké (4.2-4.5 g/plant).

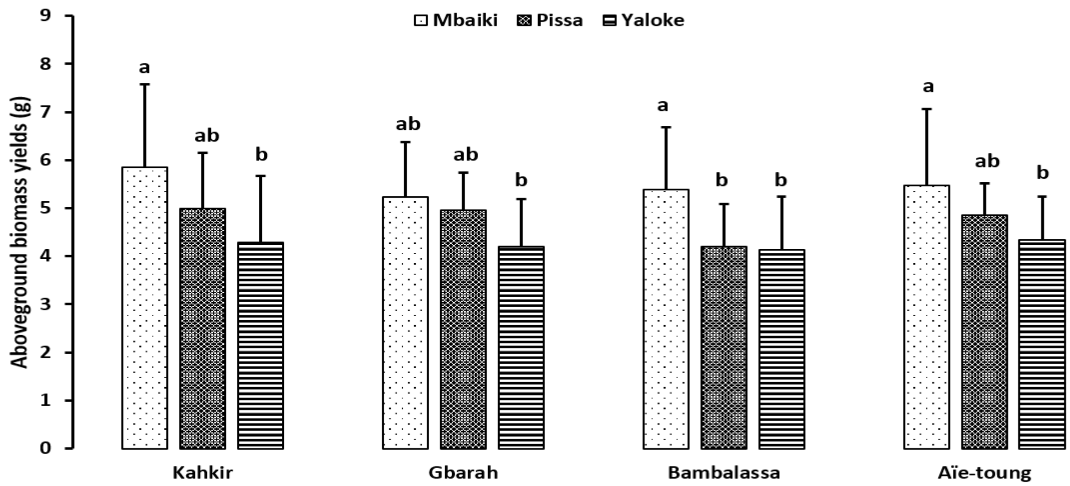

Figure 6. Above-ground biomass yield (t/ha). The values with the different letters are statistically different according to the generalized model with an error distribution of the Poisson family ($P<0.05$).

4. Discussion

In the CAR, few studies have been carried out on cowpea. The objective of this work was to make a varietal selection on the cowpea accessions. Four (4) accessions were used to carry out this work. These are Kahkr, Gbarah, Aie-toung and Bambalassa, all local accessions. According to the results the best emergence rate after planting was obtained with the Gbarah (97%) and Bambalassa (97%) accessions against the Kahkir (92%) and Aïe-Toung (93%). All the studied accessions gave a good level of emergence rate which is higher than 75% which meets the standards. They are therefore comparable to those obtained by Joseph et al. (2014) in the Congo in a rural environment. Three months after sowing, the height growth of all the accessions varies from 2.5 m to 3 m on the Pissa and M'Baïki sites. On the other hand, in Yaloké growth is homogeneous for all accessions at a value of 2 m, three months after sowing. These results can be explained by the fact that rainfall is better in Pissa and M'Baïki than in Yaloké. Pissa and M'Baïki are located in the Guinea Forest agroclimatic zone with a rainfall of 1600 m, while Yaloké is located in the Sudano-Oubanguien agroclimatic zone with a rainfall of 1200 m. The results could also partly reflect the sensitivity of cowpea to variations in photoperiod (Andargie et al, 2013). Indeed, many studies have shown that day length has variable effects on the vegetative and physiological development of cowpea (Mukhtar and Singh, 2006).

The same observation is made by Bonny and Djè (2011) on Voandzou site in Ivory Coast. The number of ramifications was better in M'Baïki than in Pissa and Yaloké. The presence of many nodules on the roots would have favoured a good fixation of atmospheric nitrogen resulting a significant development of the fruiting ramifications and an abundant production of seeds and tops in the varieties (François et al., 2013). Three month after sowing, the prevalence of diseases reached a significant proportion for all accessions and on all study sites and varied from 50% to 98%. These results show that all accessions are susceptible to the cowpea mosaic disease. The statistical cross comparison did not show significant differences in the prevalence of viral diseases between the local accessions studied and the study sites (two-way ANOVA followed by Tukey HSD test, $p>0.05$). Viral diseases are the basis of production loss (Adam, 1986; Habiba, 2004). Parameters such as environment and parasites generally have a direct influence on the vegetative growth, the reproductive phase and the yield of cowpea. The low yields observed in most of the accessions studied could be partly explained by the effects of agro-ecological zones which favour the emergence of diseases and the fluctuation of rainfall (Adam, 1986; Habiba, 2004). Three months after sowing, the severity of diseases reached a high proportion for all varieties and on all study sites and varied from 2 to 3.2. The statistical comparison does not show significant differences in the severity of viral diseases between the accessions studied and the study sites ($p>0.05$). These results revealed a correlation between the evolution of the prevalence and that of the severity on all the accessions studied. The weight in pods is better in Pissa than in Mbaïki for the Gbarah and Aie-toung accessions with a significant difference ($p<0.05$). The Kahkir accession has an identical production (ca. 100g/plant) in Mbaïki as in Pissa. The Bambalassa accession has an identical production (ca. 80g/plant) in Mbaïki as in Pissa. The Kahkir accession produces better in M'baïki than the 3 other accessions with a significant difference ($p<0.05$). On the other hand, the Kahkir, Gbarah and Aie-tung accessions have the same level of pod production at Pissa, higher than that of the Bambalassa accession. The results revealed that in Yaloké the pod production was nil for all the combined accessions tested during this period. This could be explained by the fall in rainfall in this area during this period or the prolongation of the drought. The best seed yield was obtained with the Kahkir accession which produced 1.2 t/ha at Mbaïki and 1.3 t/ha at Pissa, followed by the Gbarah and Aitoung accessions which each produced 0.9 t/ha at M'Baïki and 1.3t/ha in Pissa. The Bambalassa accession generated an identical seed yield on both up to 0.9 t/ha. Seed yield for all varieties was zero at the Yaloké site. This could be explained for a drastic drop in rainfall in this area. This suggests that the study period chosen is not favourable to the cultivation of cowpea in this area. Indeed, according to Addam (1999), nodulation causes rapid plant growth in cowpea and also acts favourably on seed production. The best haulm yield was obtained at M'Baïki (5.9g/plant) with the Kahkir, Bambalassa and Aie-toung accessions. The lowest yield was obtained at Yaloké with a quantity of 4.2g/plant identical to all the accessions. These results confirm the effect of agroclimatic zones on the agronomic parameters of cowpea.

The results of this study show that the local accessions (Kahkir and Gbarah) gave the best seed yield. On the other hand, Kahkir, Bambalassa and Aie-toung gave the best yield in haulm. Pissa and M'baïki are the most productive sites in seed and biomass. On the other hand, the Yaloké site showed its limits in production during the study period. This information needs to be taken into account in the cowpea extension program in the CAR. An additional and in-depth study could be conducted in the Yaloké area to better understand environmental factors relative to the abortion of cowpea cultivation in this area.

5. Conclusion

The study made it possible to evaluate the yields of seeds, haulms and pods of 4 local accessions in the experimental field. All of these results testify to the existence of significant diversity within the local cowpea accessions studied. The level of seed, pod and haulm yield are statistically different between the four accessions and the localities. This variability in agronomic performance could result from the expression of a strong agroecological effect but also from the influence of environmental factors. High yielding local accessions such as Kahkir and Gbarah are good candidates for breeding programs. Molecular characterization is needed to clarify synonymies and for rational use of available resources.

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