# Effect of agro-ecological zones on the agronomic performance of cowpea in the Central African Republic

**Abstract**

Cowpea (*Vigna unguiculata* (L.) Walp.) is a legume cultivated and consumed in the Central African Republic. Few studies have been carried out on cowpea in the Central African Republic. For this reason, four local accessions (Kahkir, Gbarah, Aie-toung and Bambalassa) collected in different localities were evaluated at three different sites. Yield squares were laid out according to randomized block design with four replications. These accessions were selected on the basis of quantitative parameters such as height, growth, number of pods, weight of pods (g), pod yield, haulm yield and seed yield. The data was subjected to analysis of variance (ANOVA). The results show that the seed yield, pod yield and haulm yield are statistically different among the four accessions studied. The emergence rate of all accessions was over 75%. The analysis of variance showed that height of the plants are significantly different compared to the study areas ($p < 0.05$). The study showed that all accessions were susceptible to viral diseases with a prevalence of more than 50 to 98%. The analysis showed that the Kahkir and Gbarah accessions were the best in pod, seed and biomass production and that the most productive sites were that of M'Baïki.

**Keywords:** Agronomic performance, local accessions, cowpea, field cultivation

## I. Introduction

Cowpea (*Vigna unguiculata* (L.) Walp, Fabaceae) is one of the seed legumes cultivated today in all the tropical and intertropical zones of Africa, Asia, Europe, the United States, Central and South America. It is domesticated and cultivated in tropical Africa since Neolithic times and is a Diploid species with 2n= 22 chromosomes (Oumarou et al, 2017; Diouf, 2022). World production is 6.4 million tons of dry seeds, more than 80% of which are produced in Africa (Mamadou. 2021). 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 protein content (20 to 25%), vitamin, mineral and high calorie content and occupies an important place in the diet of many populations (Neya *et al*., 2002; Mamadou. 2021). Cowpea, due to its nutritional qualities, is an ingredient of choice for combating malnutrition and ensuring the development of livestock farming (Smale *et al*. 2020). It is consumed from the seedling stage to the harvest, it is used in the preparation of several African dishes. It is a plant that is not very demanding on the quality of the soil and mainly needs heat and light for its development (Zougmore *et al*., 2000; Cruz *et al.*, 2019). It is cultivated mainly in West Africa, which represents almost two thirds of world production, with Burkina Faso, Nigeria, Mali and Niger as the main producers. On the other hand, its production remains low in East Africa ( particularly in Ethiopia, Tanzania and Uganda) , Central Africa ( Cameroon, Chad, the Democratic Republic of Congo) and the Central African Republic (Cruz *et al.*, 2019). In the Central African Republic (CAR), the best production of cowpea is recorded in the Sudano-Oubanguian zone which covers the prefectures of Ouham, Ouham-Pendé and Nana-Mambéré (Ministry of State for Planning and Economy, 2011). On the other hand, in the Guinean forest zone, cowpea production remained low. Cowpea represents a potential source of additional income and sometimes covers the immediate food needs of the family unit. However, despite its many benefits, cowpea has remained an underexploited crop and one of the most neglected crops in scientific research (Yaya *et al.,* 2013; Baudoin *et al.*, 1995). The average yield of cowpea in the peasant environment is never mentioned in the statistics of the production of food crops which occupy 663,000 ha and are present in almost all Central African farms. In CAR, very little information is currently available on the distribution, genetic diversity, cultivation and consumption of cowpea. 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) funded by the African Union aims to study and build the conditions for greater insertion of cowpea in agricultural systems, in order to improve and popularize the cultivation of cowpea.

## 2. Materials and methods

### 2.1. Agro-ecological characteristics of the study sites

**Table 1:** The 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 |

The study was conducted simultaneously in M'baïki in the forest, in Pissa II in the wooded savannah and in Zawa in the wooded savannah of the Central African Republic, which constitute the three pilot study areas. The choice of these three sites was based on their geographical positions and their easy accessibility, the geographical coordinates of which are given in Table I.

## 2.2. Plant material

The plant material consists of four local accessions (Table 2) which were collected in cowpea production areas, particularly in the West and North-West in the Sudano-Guinean agro-ecological zone of the Central African Republic.

## 2.3. Experimental apparatus

The four-replicate block-file design was applied at all three sites. The experimental plots each have an area of 1296 $m^2$. The elementary plots had an area of 5m x 5m = 25$m^2$ with a spacing of 0.5m between the lines and 0.5m between the pockets on the line in order to reach a maximum density of 121 feet per plot or 1936 plants on 16 elementary plots. A spacing of 2m between the plots and 2m between the blocks, then 5m between the block and the border. The sowing of cowpea was carried out on June 6th, 2020 at ISDR, on June 9th, 2020 at PISSA 2 and on June 13th, 2020 at ZAWA. The seeds were sown in pure culture and 2 to 3 seeds were deposited per pocket. Maintenance care consisted of weeding and ridging. A total of 3 weedings were carried out from the 45th day after sowing (DAS), at an interval of 15 days from each. On 15 DAS, a thinning of one plant per pocket was done. Yield squares of 2m x 2m=4$m^2$ were placed inside each elementary plot. The following agro-morphological parameters were measured: seedling emergence rate, plant size, number of mature pods, disease incidence, total fresh biomass, pod weight, number of branches and yield. The different agro-morphological parameters were measured according to the recommendations of the pea descriptors (Useni *et al*, 2014).



## 2.4. Evaluation of the severity of viral diseases

The various types of mosaic symptoms described by Ludwig (2016) and Palanga *et al.*, *(*2017) were actually observed in the experimental field in the three study localities, namely vein mosaic, mottled or intervened, speckled mosaic and spotted mosaic. The degree of severity of leaf symptoms was assessed on the plants in observation plots with the Fargette scale (Fargette, 1987 and Neya et al., 2019) in the experimental sites. This scale includes five levels from 0 to 4. Thus, the score

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0= no symptoms was defined;

1 = slight mosaics without deformation and covering less than 20% of the leaf surface;

2 = mosaics and chloroses covering about 50% of the leaf surface with sometimes 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: S= S: severity of symptoms dss: degree of severity of symptoms on leaf area of diseased leaves; Pt: number of diseased feet during the control period.

$$S = \frac{\sum_{i=1}^{25} dss}{Pi}$$

The prevalence of viruses was calculated using the following formula: P= Where, P: prevalence; Pt: number of diseased feet during the control period; N: total number of plants in the square.

$$P = \frac{\sum_{i=1}^{25} Pi}{N}$$

### 2.5. Statistical analysis of data

The agronomic performance data were compared between the cultivated varieties, at the end of the crop cycle, thanks to 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 diseased plants at the end of the crop cycle. Two-way ANOVA was used to compare plant growth, number and weight of pods/seeds taking as factors locality and varieties grown. All these tests were done with the R software and the probability level for a significant difference of 0.05. In the graphs presented, the histograms accompanied by the different letters are statistically different ($P<0.05$).

## 3. Results

### 3.1. Plant emergence rate according to agro-ecological zones.

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:** Rate of survey of local accessions in the study localities (month of July).

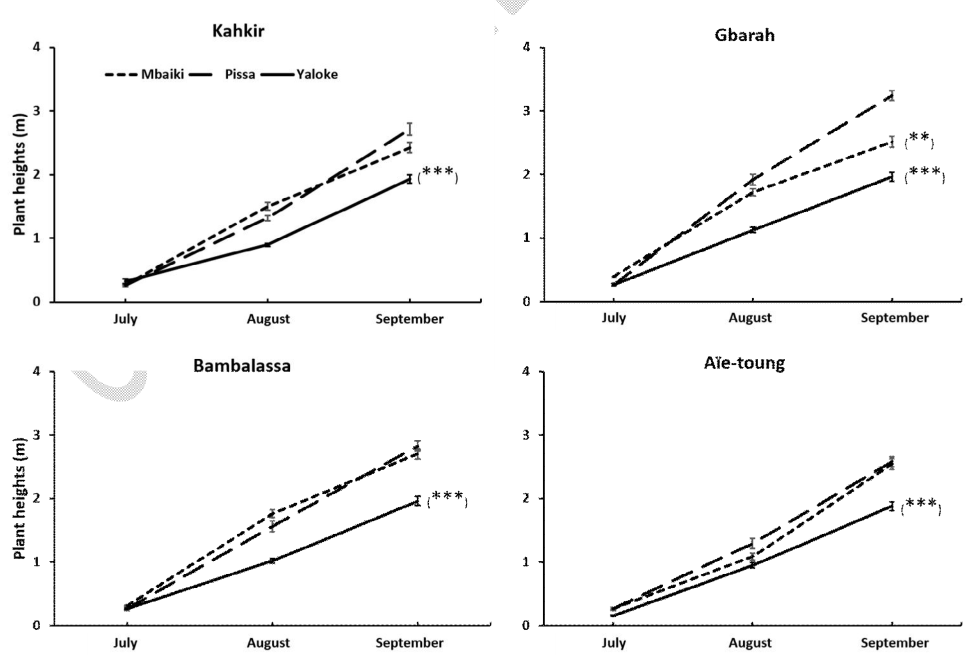
| Kahkir | Gbarah | Bambalassa | Aïe-toung |
|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| ***Mbaïki*** | 97[a] | 98[a] | 96[a] | 97[a] |
| ***Pissa*** | **77[b]** | 97[a] | 94[a] | 97[a] |
| ***Yaloke*** | 92[a] | 97[a] | 97[a] | 93[a] |

*The best emergence rate was obtained with the Gbarah (97%) and Bambalassa (97%) accessions against the Kahkir (92%) and Aïe-Toung (93%) accessions with an error distribution of the Binomial family (P <0.05).*

### 3.2. Height growth of accessions according to study sites.

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). The analysis of variance showed that the heights of the plants are significantly different compared to the study sites (p < 0.05). The Yaloke site shows poor plant height growth in the study sites (p < 0.005).



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

### 3.3. Number of 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 offshoots 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$^{a}$ |

*The number of ramifications is better in M'Baïki than in Pissa and Yaloké according to the generalized model with an error distribution of the Binomial family (P<0.05).*

## 4. Prevalence of viral diseases

The prevalence of symptom-based viral diseases in Kahkir and Gbarah accessions remained stable at around 20% between July and August in M'baïki. The same trend can be observed with the accession of Aït-toung to Yaloké between July and August. Three months after sowing, the prevalence of diseases reached a significant proportion for all varieties and on all study sites with a variation of 50% to 98%. These results show that all varieties were susceptible to viral diseases. The statistical analysis of comparison does not show significant differences in the prevalence of viral diseases between the local accessions studied and the study sites (p<0.05).

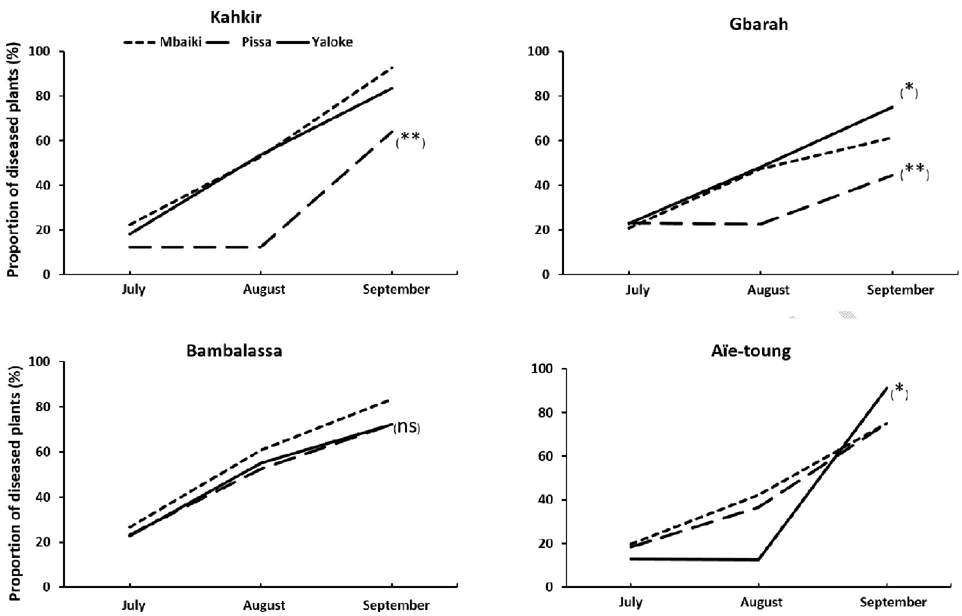



**Figure °2:** *Evaluation of the proportion of infected plants according to ecotypes and study sites. The proportions were compared at the end of the crop cycle, taking the locality of Pissa as a reference for these comparisons (two-factor ANOVA, *P<0.05, **P<0.005, ns= non-significant difference)*

### 3.5. Severity of symptoms in fields

The severity of viral diseases based on symptoms in the Kahkir and Gbarah accessions remained stable below 1 between July and August in M'baïki. The same trend is observed with the Aït-toung accession in Yaloké in July and August. Three months after sowing, disease severity reached a significant proportion for all varieties and on all study sites and varied from 2 to 3.2. The statistical analysis of comparison does not show significant differences in the severity of viral diseases between the accessions studied and the study sites (p<0.05).

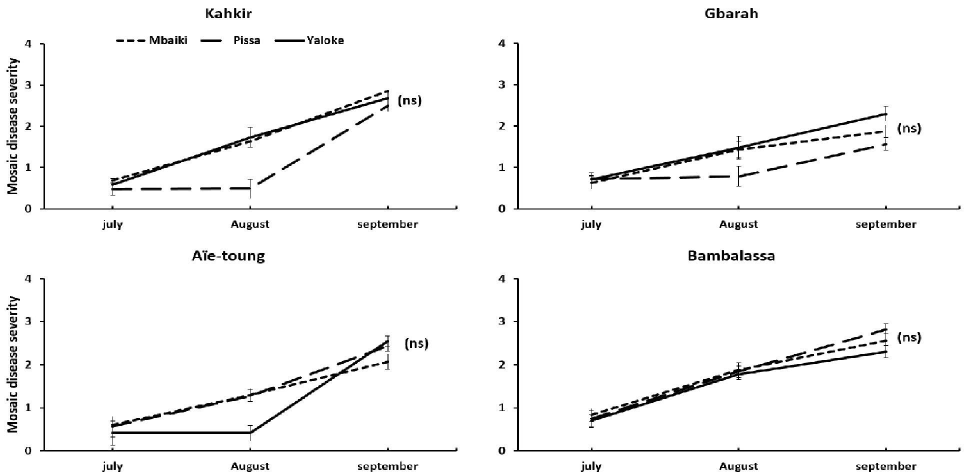



**Figure 3:** *The severity of viral diseases in the 4 cowpea accessions studied as a function of site and time.*

### 3.6. Pod yield

The weight of pods was higher in Pissa than in Mbaïki for the Gbarah and Aie-toung accessions with a significant difference. The Kahkir accession gives the same production (100g/plant) in Mbaïki and Pissa. The Bambalassa accession gives the same production (80g/plant) in Mbaïki and Pissa. The Kahkir accession produces better in M'baïki than the 3 other accessions. 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. It should be noted that in Yaloké production was nil for all the accessions tested during this period. This could be explained by the drop in rainfall in this area during this period.

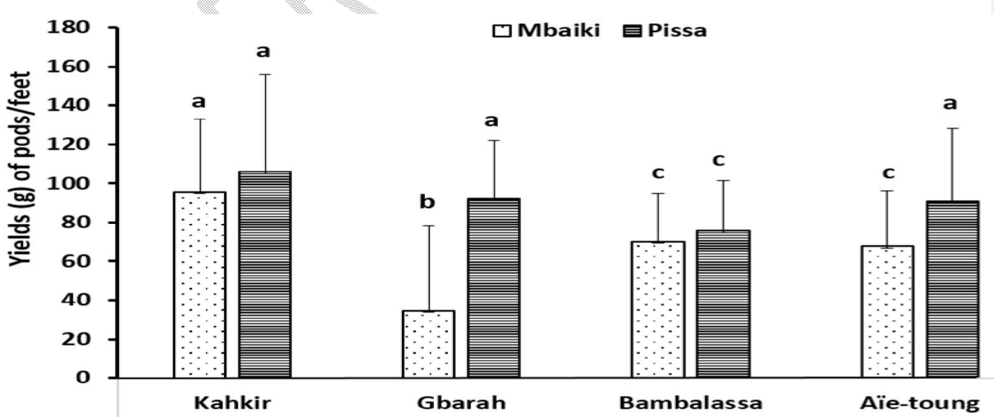



**Figure 4:** *Pod weight per plant in field yield plot. The values with the different letters are statistically different according to the generalized model with an error distribution of the Binomial family (P<0.05). 3.7.*

### 3.7. Seed yield

In M'baïki the best yield was obtained with the Kahkir accession (1.2 t/ha) followed by the other accessions which have a production of (0.9 t/ha). On the other hand, in Pissa, the Kahkir, Gbarah and Aie-toung accessions each have a yield of 1.3 t/ha followed by the Bambalassa accession which produces (0.9 t/ha) with a significant difference. 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.

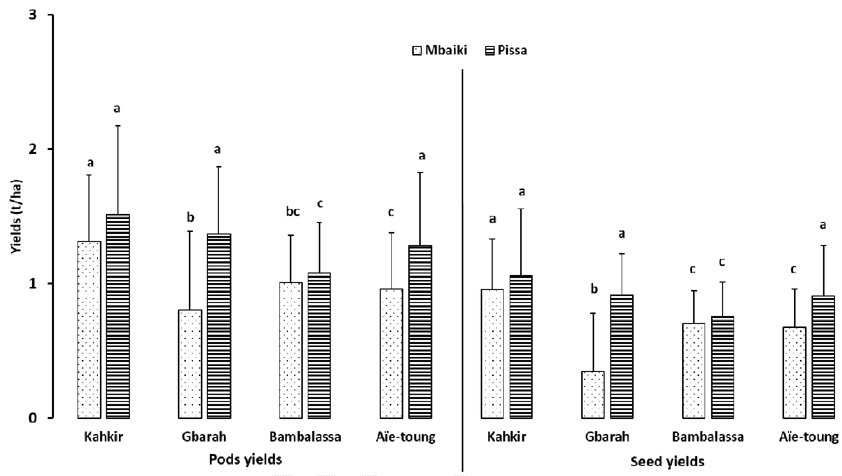



**Figure 5:** *Estimated pod yield (left) and seed yield (right) in tonne per hectare (t/ha). The values with the different letters are statistically different according to the generalized model with an error distribution of the Binomial family (P<0.05).*

### 3.8. Haulm yield

The best biomass yield is obtained on the M'baïki site (5.9 g/plant) with the Kahkir, Bambalassa and Aie-toung accessions and followed by the Gbarah accession with a yield of 5.7 g/plant. In 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. In Yaloké, all the accessions generated the same haulm yield, which is 4.2g/plant.

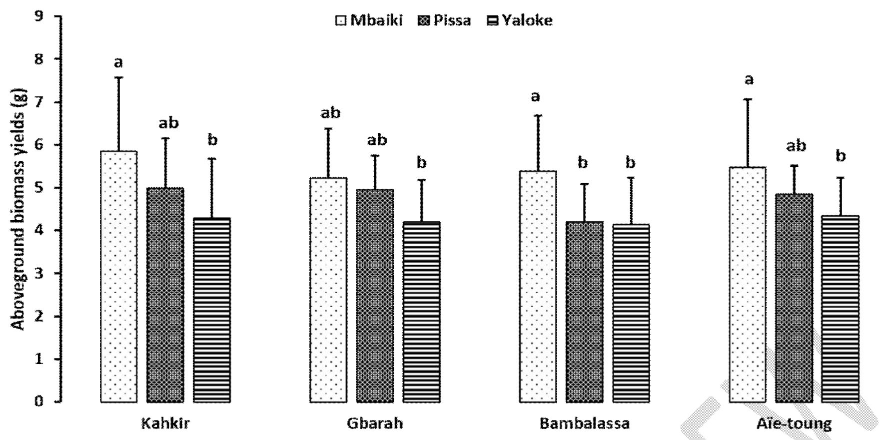



**Figure 6:** *Aboveground biomass yield (t/ha). The values with the different letters are statistically different according to the generalized model with an error distribution of the Binomial family (P<0.05).*

## 4. Discussion

In the Central African Republic, few studies have been carried out on cowpea. The objective of this work is to make a varietal selection on 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 analysis of the results, the best survey rate was obtained with the Gbarah (97%) and Bambalassa (97%) accessions against the Kahkir (92%) and Aïe-Toung (93%) accessions with a Binomial family error distribution (P< 0.05). These 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 setting. Three months after sowing, the growth of all the accessions combined 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 2m, 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 rainfall around 1600 m, while Yaloké is located in the Sudano-Oubanguien agroclimatic zone with rainfall around 1200 m. The same observation is made by Daillo *et al* (2019) on Voandzou in Ivory Coast. Indeed, many studies have shown that day length has variable effects on the vegetative and physiological development of cowpea (Sossa, 2012; Andargie *et al.*, 2013), but our study could not provide clarification on this point aspect. The number of ramifications is better in M'Baïki than in Pissa and Yaloké according to the generalized model with an error distribution of the Binomial family (P<0.05). The presence of many nodules on the roots would have favoured a good fixation of atmospheric nitrogen which would have induced a significant development of the fruiting branches and an abundant production of seeds and tops in the varieties (Francois *et al.*, 2013; Falalou H., 2006; Gbaguidi *et al.*, 2015). Three months after sowing, the prevalence of diseases reached a significant proportion for all accessions and on all study sites. The lowest prevalence (50%) was obtained with the Gbarah

**Comment [A3]:** Missing in the reference part

**Comment [A4]:** Not found in reference part variety in M'baïki and the highest (98%) with the Khakir variety in Pissa. The results of this study show that all accessions are susceptible to viral diseases (Neya *et al.*, 2015). The statistical analysis of comparison does not show significant differences in the prevalence of viral diseases between the local accessions studied and the study sites ($p<0.05$). 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, 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 (Charles *et al.*, 2007; Abera G. *et al.*, 2011; Neya *et al., 2019*). The results of this study show that the severity of the diseases reached a significant proportion for all the accessions three months after sowing. The statistical analysis of 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 positive correlation between the evaluation of the prevalence and that of the severity on all the accessions studied. The pod weight 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 (100g/plant) in Mbaïki as in Pissa. The Bambalassa accession has an identical production (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 (Omoigui *et al.*, 2020; Palm *et al*, 2001). This could also suggest that the period chosen does not correspond to favorable conditions for cowpea production in this area (Hoa *et al.*, 2002). The best seed yield was obtained with the Kahkir accession which produced 1.2 t/ha in Mbaïki and 1.3 t/ha in Pissa, followed by the Gbarah and Aie-tung accessions.

## 5. Conclusion

The study made it possible to evaluate the seed yield, haulm yield and pod yield 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 yield, pod yield and haulm yield were statistically different among 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 choices for breeding programs. Molecular characterization is needed to clarify synonymies and for rational use of available resources.

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