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Influence of seeding density on agronomic parameters of cowpea (*Vigna unguiculata* L.) accession grown in Daloa, west center of Côte d'Ivoire

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Abstract

Cowpea (*Vigna unguiculata* L.) is most important food legume in tropical regions of Africa. In Côte d'Ivoire, its cultivation is neglected and is carried out on small surfaces with a strong concentration in North of the country. The objective of this study was to determine, in addition to the sowing density, the ideal number of plants per sowing hole for a better cowpea production. Experimental design used was a completely randomized Fisher block with three replications and six treatments per block. The tested spacings with the number of plants per sowing hole are : 20 cm x 20 cm x 01 plant per sowing hole, 20 cm x 20 cm x 02 plants per sowing hole; 30 cm x 30 cm x 01 plant per sowing hole, 30 cm x 30 cm x 02 plants per sowing hole; 40 cm x 40 cm x 01 plant per sowing hole, 40 cm x 40 cm x 02 plants per sowing hole. Observations were made on nine agronomic parameters (plant height, number of leaves, number of branches, span, fresh biomass, number of pods, fresh weight of pods, dry weight of pods and grain weight. Results show that seeding densities and number of plants per sowing hole significantly influence the agronomic parameters. Thus, the lowest sowing densities (62500 plants/ha) corresponding to 40cm x 40cm spacing with one plant per sowing hole gave the best yields while the highest densities (250000 plants/ha) corresponding to 20cm x 20cm spacing with two plants per sowing hole gave the lowest yields for all agronomic parameters.

Keywords: Cowpea; *Vigna unguiculata*; Density; Number of plants per sowing hole; Agronomic parameters

1. Introduction

Legumes are one of the largest families of flowering plants. They play a triple role of soil protection against degradation, weed control, soil fertility improvement through atmospheric nitrogen fixation [1]. Among them, there is cowpea [*Vigna unguiculata* (L.) Walp.] which is grown and consumed in tropical and subtropical areas of Africa [2]. Annual global production varies between 3 and 5.5 million tons of dry seeds [3], of which more than 64% is produced in Africa [4]. Due to its high protein (19-25%), carbohydrate and mineral content, cowpea plays an important role in human nutrition and in the fight against malnutrition [5]. In Africa, it constitutes the staple food of millions of people because of its adaptation to biotic (diseases and enemies) and abiotic (drought, phosphorus and nitrogen deficiencies, soil acidity) constraints [6]. It is cultivated primarily for its seeds, which are cooked in a variety of ways. In many regions, its young leaves, fresh or dried, and its immature pods are also consumed. The leaves are also used in livestock feed [7]. They contain 24 amino acids that are essential for a good diet, according to the needs of the human organism (except sulphur amino acids) and have two to three times more protein than cereals [8]. Thanks to its capacity for symbiotic fixation of atmospheric nitrogen, the insertion of cowpea in crop rotations and crop associations makes it possible to meet the nitrogen fertilizer needs of subsequent crops. In Côte d'Ivoire, notwithstanding the important role of cowpea in agroforestry practices and in human and animal consumption, it remains a neglected crop with a production of about 36,310 tons/year, or less than 2% of African production. Yields rarely exceed 400 to 500 kg of seeds per hectare in

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traditional cultivation [9]. Several problems explain these low yields recorded, including the presence in the environment of numerous parasites that are very active during the various stages of the plant's development [10]. Also, the cultivable land put under permanent cultivation leading to a depletion of the soil in organic matter and mineral elements. The phenomenon of climate change attributed to greenhouse gas emissions due to deforestation, industrialization and urbanization and the poor monitoring of technical production itineraries, including the density of sowing contribute to the reduction of yield [11].

Indeed, the yields of 400 to 600 kg/ha obtained in rural areas [12] are far lower than the potential of the crop, which can reach 1,500 kg/ha and more [2] due to poor cultivation practices, mainly the wrong choice of spacing [13]. Thus, work on seeding rates conducted by Kouassi *et al.* [14] and Kouamé *et al.* [15] indicated that seeding rate positively influences legume production. In view of the above, cowpea cultivation technique should be improved in order to increase production. This study is aimed to determine an efficient seeding density for improve cowpea production.

2. Material and methods

2.1. Presentation of the study site

The studies were conducted on an experimental plot at the University Jean Lorougnon Guédé of Daloa from April to August 2021 (Figure 1). The city is located in the Haut Sassandra Region in the central-western part of Côte d'Ivoire between 6°53'58'' N latitude and 6°26'32'' W longitude, with an area of 15200 km. Daloa is also characterized by four seasons. The big rainy season starts from April to mid-July, the small dry season from mid-July to mid-September, the small rainy season from mid-September to mid-November and the big dry season from December to March. It is a humid tropical zone with a dense forest vegetation with regressive evolution due to the practice of extensive and shifting agriculture coupled with the uncontrolled exploitation of forest species [16]. The soil substrate of Daloa belongs to the old Precambrian basement composed of granites, migmatites. These soils, leached and deep (20 m) are due to heavy rainfall and rapid alteration of the rocks. The soils of the region are mostly ferralitic (typical). They are generally very deep with a high organic matter content. The average rainfall, temperature and atmospheric humidity for the Daloa study site during the test period from May to August, corresponding to the main rainy seasons, are 142.81 mm, 26.42°C and 83.7% respectively [17].

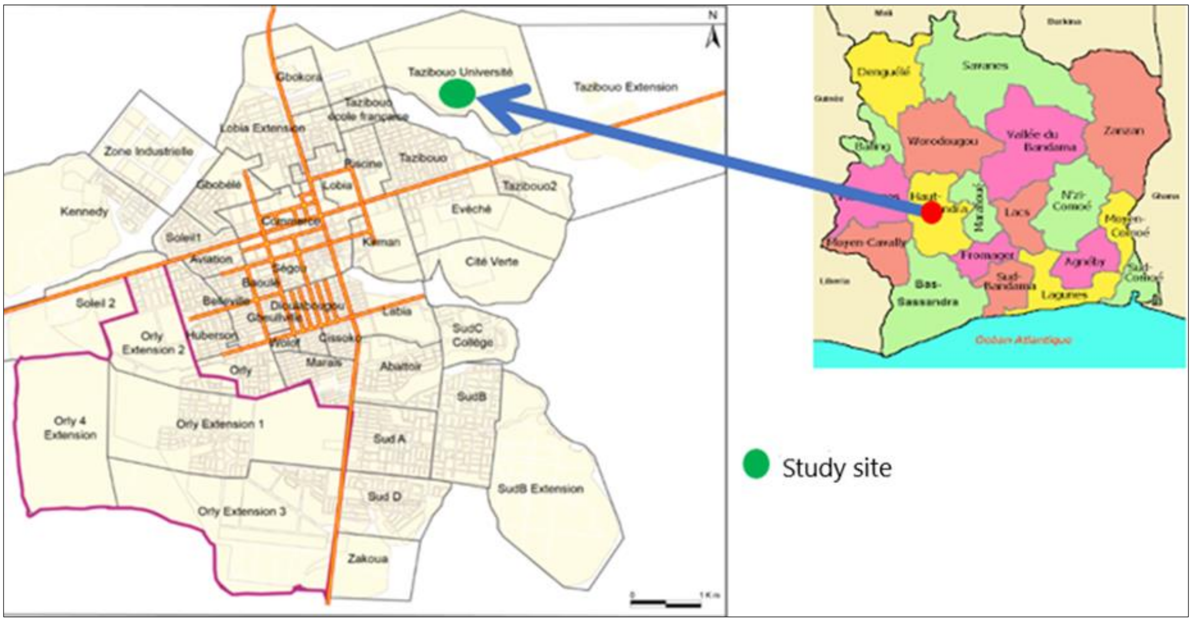


Figure 1 Map of study site

2.2. Materials

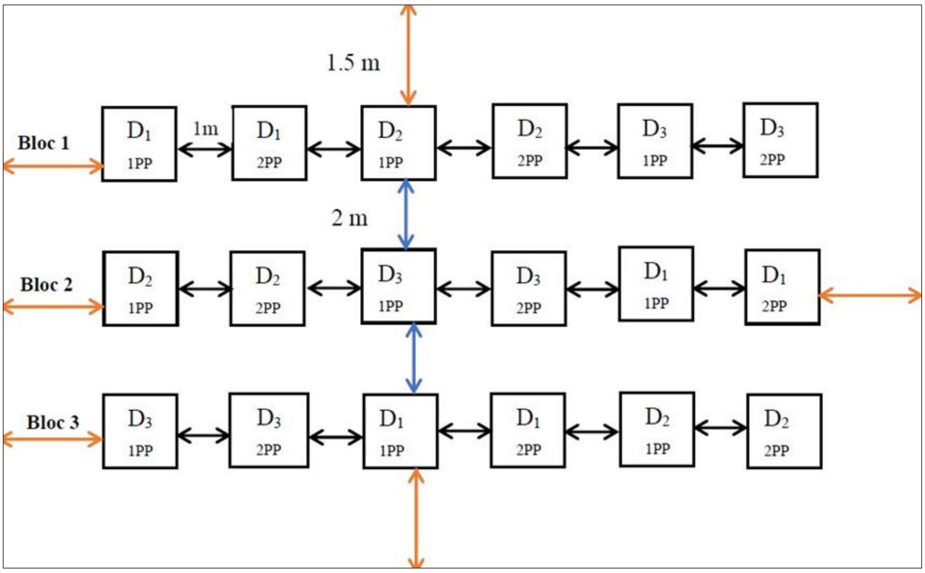
The material used in this study consists of seeds of a local variety of cowpea. This local variety has reddish seeds (Figure 2). The cycle varies from 80 to 90 days with a production of 2 to 2.5 tons/h. It is resistant to rust and virus infection, and is adapted to mechanized cultivation

Figure 2 Seeds of a local variety of cowpea (*red cowpea*)

2.3. Methods

2.3.1. Experimental design

The experimental setup used is a completely randomized Fisher block with three replications and 6 treatments. Each block is 23 m long and 3 m wide, or 69 m2. Each elementary plot is 3 m long and 3 m wide (9 m2). The distance between the blocks is 2 m and 1 m between the elementary plots. The total length of the plot is 26 m long and 16 m wide, i.e. an area of 416 m2 (Figure 3). In each block, three density levels corresponding to the spacing 20 cm x 20 cm (250000 plants/ha) ; 30 cm x 30 cm (111111.11 plants/ha) and 40 cm x 40 cm (62500 plants/ha) were tested. For each spacing, the seeds were sown at one per plot for some and two per plot for others, corresponding to 20 cm x 20 cm x 01 per plot (D11PP), 20 cm x 20 cm x 02 per plot (D1 2PP) ; 30 cm x 30 cm x 01 per plot (D21PP), 30 cm x 30 cm x 02 per plot (D22PP) ; 40 cm x 40 cm x 01 per plot (D31PP), 40 cm x 40 cm x 02 per plot (D32PP).



D : Density, D1 : 20 cmX20 cm, D2 : 30 cmX30 cm, D3 : 40 cmX40 cm, PP : plant per sowing hole

Figure 3 Diagram of the experimental set-up

2.3.2. Conduct of the trial

Soil preparation

The preparation of the soil consisted in clearing the land with a machete and ploughing it flat with a daba. The land was cleared of old vegetation. This operation is followed by a grubbing and removal of stones, pebbles and all objects that could constitute an obstacle to vegetables

Sowing

The delimitation of the elementary plots was done with ropes by specifying the sowing points according to the distances (Figure 4). With the help of a knife, the seedlings were sown on the seedling points marked on the lines. The seeding was done manually according to the spacing described above, at a rate of 3 grains per sowing hole, at a depth of 3 cm.

One month after the disbudding was done to leave the most vigorous plants while creating the devices of one or two plants per sowing hole (Figure 5).

Figure 4 Seeding methods

A B

Figure 5 Plants after thinning. (A) one plant per sowing hole, (B) two plants per sowing hole

Maintenance

The maintenance of the plots consisted of manual weeding of the plots. Three weedings were carried out. The first maintenance took place two weeks after sowing in order to eliminate weeds and allow a harmonious development of the young plants. The second weeding was done one month after sowing and the third was done two months after sowing. No phytosanitary treatment was carried out.

2.3.3. Determination of agronomic parameters

Data collection started with the measurement of vegetative parameters on eleven randomly selected plants. After pod maturation, the yield parameters were evaluated. The set of parameters evaluated and the measurement methods are described in Table 1.

2.3.4. Statistical analysis of the data

The data collected were processed using STATISTICA software version 7.1 through two-factor analysis of variance (ANOVA 2). Test significance was determined by comparing the probability (P) associated with the statistic at the P = 0.05 threshold. When a significant difference was observed between the traits, the ANOVA was completed with the Smallest Significant Difference (SSD) test.

Table 1 Lists of agronomic parameters and measurement methods

Agronomic parameters	Measurement methods
Plant Height (PH in cm)	Measure the distance of the main stem from the collar to the most extreme leaf.
Number of Leaves (NL)	Count the leaves from the first two leaves at the base of the main stem at the collar to the last leaves at the tip
Number of Branches (NB)	Count the branches observed on the stem
Wingspan (W in cm)	Measure of the distance of each branch from the two most extreme leaves.
Fresh Biomass (FrB in g)	Measure of the weight of each plant in a fresh state
Number of pods (NP)	Count the number of mature pods after harvesting on the 15 plants initially selected.
Fresh weight of pods (FWP in g)	Determine the fresh weight of the pods after weighing on the electronic scale
Dry Weight of Pods (DWP in g)	Weigh after sun drying with an electronic scale the dry weight of the pods
Weight of the seeds (WS in g)	Weigh the seeds after dehulling

3. Results

3.1. Descriptive analysis of quantitative characteristics

The quantitative variables studied reveal strong dispersion, between minimum and maximum values (Table 2). Indeed, the height of plants with the average of 101.33 cm and the fresh biomass of average 135.60 g have raised very important differences. On the other hand, the mean number of ramification is very weak (4.52) with weak variations.

Table 2 Descriptive and quantitative analysis of agronomic caracters

Variable	workforce	Mean	Minimum	Maximum	Variance	Standard deviation
PH (cm)	180	101.3389	11.00000	200.0000	1388.326	37.26024
NL	180	28.4000	3.00000	65.0000	148.498	12.18599
NB	180	4.5222	1.00000	12.0000	3.000	1.73191
W (cm)	180	47.4889	25.00000	97.0000	87.748	9.36742
FrB (g)	180	135.6019	14.84000	575.7300	6819.814	82.58217
NP	180	9.2000	0.00000	50.0000	68.842	8.29714
FWP(g)	180	23.9610	0.00000	106.9000	384.651	19.61252
DWP(g)	180	8.0442	0.00000	54.8400	71.574	8.46014
WS(g)	180	4.5394	0.00000	31.7400	25.779	5.07733

PH : Plant Height, **NL** : Number of Leaves, **NB** : Number of Branches, **W** : Wingspan, **FrB** : Fresh Biomass, **NP** : Number of pods, **FWP** : Fresh weight of pods**, DWP** : Dry Weight of Pods, **WS** : Weight of the seeds

3.2. Correlation between quantitative traits

Among these 81 observed correlations, only six of these coefficients showed significant correlations, and its correlations are related to yield parameters (Table 3). The strongest correlation (r = 0.94) links pod dry weight to seed weight. Increasing the number of pods leads to increases in pod fresh weight (r=0.93), pod dry weight (r=0.92), and seed weight (0.89). Increasing fresh pod mass led to increases in pod dry mass (r= 0.86) and seed mass (r= 0.82). The analysis also showed that pod dry mass favored the increase in seed mass (r=0.94). These results indicate that the plant that produces a large number of pods has a large number of fresh and dry masses and therefore a high seed mass. No correlation was observed in the vegetative parameters.

Table 3 Correlation between quantitative traits

	PH	NL	NB	W	FrB	NP	FWP	DWP	WS
PH	1.00								
NL	0.36	1.00							
NB	0.17	0.28	1.00						
W	0.35	0.36	0.13	1.00					
FrB	0.14	0.57	0.11	0.30	1.00				
NP	0.21	0.50	0.08	0.21	0.38	1.00			
FWP	0.25	0.52	0.07	0.25	0.41	0.93	1.00		
DWP	0.16	0.47	0.09	0.16	0.31	0.92	0.86	1.00	
WS	0.13	0.46	0.02	0.17	0.31	0.89	0.82	0.94	1.00

Values in bold represent significant (> 0.7) and positive correlations; **PH** : Plant Height, **NL** : Number of Leaves, **NB** : Number of Branches, **W** : Wingspan, **FrB** : Fresh Biomass, **NP** : Number of pods, **FWP** : Fresh weight of pods**, DWP** : Dry Weight of Pods, **WS** : Weight of the seeds

3.3. Effect of densities on the agronomic parameters of cowpea

Table 4 shows that both morphological parameters and yield parameters were all influenced by the different seeding densities ($p<0.05$). The three densities showed significant difference for height, span, number of leaves, number of pods, fresh weight of pods, fresh biomass. The low seeding densities (62500 plants/ha) resulted in an increase in leaf number, number of branches, fresh biomass and span. Height was high for the densities of 62500 plants/ha and 250000 plants/ha, which were statistically equal. The highest values, in terms of yield parameters, were obtained with the low seeding densities of 62500 plants/ha in contrast to the high seeding densities (250000 plants/ha and 111111.11 plants/ha) which gave low results. The densities of 62500 plants/ha allowed an increase in average number of pods, fresh weight of pods, dry weight of pods and seed weight.

Table 4 Inffluence of densities on the agronomic parameters of cowpea

Variables/ Density	Means (± standard deviation)			Probability (P)
	20 cm x 20 cm	30 cm x 30 cm	40 cm x 40 cm	
PH	107.68±32.32^{a}	88.15±36.32^{b}	108.18±39.77^{a}	0.0031
NL	23.91±9.58^{c}	27.58±13.24^{b}	33.70±11.54^{a}	<0.0001
NB	2.26±1.67^{b}	2.53±1.72^{b}	4.96±1.73^{a}	0.0496
W	45.01±9.84^{c}	47.00±8.55^{b}	50.45±8.98^{a}	0.0051
FrB	99.14±67.65^{c}	143.29±92.80^{b}	164.39±72.43^{a}	<0.0001
NP	4.43±4.11^{c}	8.35±5.28^{b}	14.81±10.39^{a}	<0.0001
FWP	11.94±10.39^{c}	22.87±15.02^{b}	37.06±22.59^{a}	<0.0001
DWP	3.84±3.60^{c}	7.11±4.70^{b}	13.17±11.68^{a}	<0.0001
WS	1.97±1.79^{c}	4.20±2.79^{b}	7.43±7.20^{a}	<0.0001

For each character means in the line followed by a common letter are not significantly different at the 5% level

PH : Plant Height, **NL** : Number of Leaves, **NB** : Number of Branches, **W** : Wingspan, **FrB** : Fresh Biomass, **NP** : Number of pods, **FWP** : Fresh weight of pods**, DWP** : Dry Weight of Pods, **WS** : Weight of the seeds

3.4. Effect of the number of plants per sowing hole on the agronomic parameters of cowpea

The analysis of variance at the level of the number of plants per sowing hole shows significant differences on the agronomic parameters of cowpea (Table 5). Vegetative parameters, apart from plant height and number of branching which do not show significant difference, there is a strong significant difference in number of leaf, span and fresh biomass when plants are at one grain per sowing hole. As for the parameter related to yield, they all show a highly significant difference. The highest values were obtained with the plants at one grain per sowing hole There was an average increase in the number of pods, fresh weight of pods, dry weight of pods, seed weight with the plants with one grain per sowing hole. The plants with two grains per sowing hole gave low averages.

Table 5 Agronomic characteristics as a function of the number of plants per sowing hole

Variables / plants per sowing hole	Means (± standard deviation)		Probability (P)
	1 PS	2 PS	
PH	98.44±33.04[a]	104.23±41.02[a]	0.2986
NL	33.62±11.49[a]	23.17±10.55[b]	<0.0001
NB	4.42±1.29[a]	4.62±2.08[a]	0.4400
W	49.08±8.81[a]	45.88±9.67[b]	0.0215
FrB	167.67±87.94[a]	103.52±62.45[b]	<0.0001
NP	10.92±10.04[a]	7.47±5.62[b]	0.0050
FWP	27.62±22.01[a]	20.30±16.18[b]	0.0118
DWP	10.41±10.49[a]	5.67±4.75[b]	0.0001
WS	5.93±6.45[a]	3.08±2.43[b]	<0.0001

For each character means in the line followed by a common letter are not significantly different at the 5% level

PH : Plant Height, NL : Number of Leaves, NB : Number of Branches, W : Wingspan, FrB : Fresh Biomass, NP : Number of pods, FWP : Fresh weight of pods, DWP : Dry Weight of Pods, WS : Weight of the seeds

3.5. Effect of density-number of plants per sowing hole interaction on agronomic parameters of cowpea

Table 6 Agronomic characteristics as function of the interaction between density and number of plants per sowing hole (PS)

Means (± standard deviation)							Probability (P)
Variables	1 PS			2 PS			
	20X20	30X30	40X40	20X20	30X30	40X40	
PH	106.30±28.38[b]	99.43±35.51[c]	89.60±33.74[d]	109.06±36.27[b]	76.86±34.05[e]	126.76±36.95[a]	<0.0001
NL	29.20±8.09[b]	36.40±12.19[a]	35.26±12.65[a]	18.63±7.97[c]	18.76±6.85[c]	32.13±10.33[a]	0.0004
NB	2.73±1.15[c]	2.03±1.32[c]	4.20±1.21[a]	3.50±1.77[b]	3.63±2.02[b]	5.73±1.85[a]	<0.0001
W	47.70±11.85[b]	51.13±7.49[a]	48.43±5.92[b]	42.33±6.44c	42.86±7.58[c]	52.46±10.99[a]	0.0003
FrB	114.28±78.88[d]	202.92±88.83[a]	185.83±71.04[b]	84.00±51.14[e]	83.67±47.69[e]	142.89±68.37[c]	0.0009
NP	3.36±3.36[d]	10.00±5.80[b]	19.40±40[a]	5.50±4.55[c]	6.70±4.17[c]	10.23±6.80[b]	<0.0001
FWP	10.31±10.04[e]	29.76±15.95[c]	42.78±24.06[a]	13.58±10.66[e]	15.98±10.30[d]	31.33±19.79[b]	0.0078
DWP	4.03±4.36[c]	8.31±4.59[b]	18.88±13.29[a]	3.65±2.69[d]	5.92±4.58[c]	7.46±5.77[b]	<0.0001
WS	1.68±1.61[d]	4.83±2.48[b]	11.45±8.10[a]	2.26±1.93[c]	3.57±2.65[b]	3.41±2.52[b]	<0.0001

For each character means in the line followed by a common letter are not significantly different at the 5% level (Tukey's multiple range test)

PH : Plant Height, **NL** : Number of Leaves, **NB** : Number of Branches, **W** : Wingspan, **FrB** : Fresh Biomass, **NP** : Number of pods, **FWP** : Fresh weight of pods**, DWP** : Dry Weight of Pods, **WS** : Weight of the seeds

Table 6 shows that the density-number of plants per sowing hole interaction significantly influenced all agronomic parameters. The highest plant height and fresh biomass were obtained with the 40 cm x 40 cm density with two seeds per sowing hole and the 30 cm x 30 cm density with one grain per sowing hole, respectively. The largest spread was obtained with the 40 cm x 40 cm density at two seeds per sowing hole and 30 cm x 30 cm at one seed per sowing hole. The number of branches was greatest at both the 40 cm x 40 cm density at one seed per sowing hole and at two seeds per sowing hole. The highest number of leaves was observed with the 30 cm x 30 cm, 40 cm x 40 cm spacing at one grain per sowing hole and 40 cm x 40 cm at two grains per sowing hole. In terms of yield parameters, the highest number of pods, fresh pod mass, dry pod mass and grain mass were observed only at 40 cm x 40 cm when plants were at one grain per sowing hole.

4. Discussion

The results of the work done to compare the three cowpea seeding rates showed a significant difference for morphological and yield parameters. Among the different seeding rates tested, the agronomic parameters of cowpea increased with the lower rates. Thus, the densities of 62500 plants/ha gave the highest averages for all the parameters determined. The lowest averages were recorded at the high seeding rate (250000 plants/ha) except for height, which was also important at this rate with an average of 107.63. These results are in agreement with those of kouassi *et al*. [14]. Indeed, the strong intraspecific competition and the availability of resources for the plant are the main causes of these observed differences. The large number of plants per unit area promotes intraspecific competition among them for sharing light, mineral elements and water. Thus, the height observed at a density of 250000 plants/ha is explained by the search for light, which is the origin of the rapid growth of the plants. These results corroborate those of Taffouo *et al*. [2]. The number of leaves produced increases significantly as the planting density decreases. Cowpea produced more leaves per plant at low stand density than at high stand density. These results are consistent with those of kouassi *et al*. [14]. According to these authors, the 40 cm X 40 cm spacing facilitates the circulation of light to better perform the photochemical act. When the density is high, the plants create more and more shade. Thus, the light crosses with difficulty the plants to reach the leaves which are towards the bottom of the plant. They can no longer participate in the photochemical activity. The quantity of substance elaborated by the plant decreases, making it unable to initiate the formation of new leaves. Under reduced light conditions, the number of photoreceptor sites involved in photosynthesis would be reduced, hence the reduction of the amount of organic matter synthesis. This will lead to a reduction in the formation of new leaves.

The low density leads to an increase in the number of branches and the number of pods. For example, a study conducted on soybeans showed that high seeding rates delayed flowering and decreased the number of branches [18]. These results corroborate those of N'gbesso *et al.* [9] on cowpea. For these researchers, the important development of fruiting branches and the abundant production of pods could be due to the presence of numerous nodules on the roots and stem collars that would have favored good atmospheric nitrogen fixation. Good branching leads to an increase in the number of leaves and thus in fresh biomass. Seed yields increased with increasing spacing. The increase in yield at low density is explained by the high exposure of plants to light [19]. Thus, when the planting density is high and competition appears, the yield per plant decreases. Similar observations had also been reported by Unesi *et al*. [20] on cowpea.

The number of grain per sowing hole influenced the agronomic parameters of cowpea. When there was one grain in the sowing hole, the values were high. Thus, leaf number, fresh biomass, span showed more significant values at one plant per sowing hole. These results are identical to those of Yalombe *et al*. [21] who working on cowpea attest that at one grain per sowing hole the plant develops better and therefore induces a good yield. Indeed, the living space creates a particular microclimate, thus ensuring good living conditions [21]. The number of pods, the fresh mass of pods, the dry mass of pods as well as the mass of grains increased with the sowing of one grain per sowing hole. This result could be explained by the fact that when the number of grains per packet is lower, the plant assimilates easily the nutrients for its growth. These results differ from that of Unesi *et al*. [20]. For these authors, cowpea yield is more advantageous at three grains per sowing hole than at one grain per sowing hole. This difference is due to the spacing between plants.

5. Conclusion

The study of the influence of seeding density on the agronomic parameters of cowpea in Daloa made it possible to distinguish the ideal spacing and number of plants per sowing hole to boost cowpea production. The measured agronomic parameters were influenced by the tested seeding densities. All agronomic parameters increased for low seeding rates (62500 plants/ha) with one grain per sowing hole gave the best yield. The fresh biomass gave an important value to the density 30 cm x 30 cm x 01 grain per sowing hole contrary to the higher densities. With the exception of plant height, the lowest parameters were recorded at 20 cm x 20 cm x 2 plants per sowing hole. It is recommended to the farmers of the Haut Sassandra region the density of 62500plants/ha corresponding to the spacing of 40 cm x 40 cm with one grain per sowing hole, with economy in reserve of mineral elements.

Compliance with ethical standards

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Disclosure of conflict of interest

No competing interests exist.

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