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Effect of Cowpea Seeding Density on Growth Parameters and Grain Yield of Maize in a real Crop Situation in Northern Côte d'Ivoire.

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Abstract— *Soil depletion and degradation as well as climate variability are responsible for the decrease in agricultural yields and the poverty of the rural population in northern Côte d'Ivoire.The present study was conducted in a participatory manner with two (2) food producer groups from the villages of Kolokaha and Sohouo (Korhogo Department) to determine the density of semi cowpea seeding that maximizes the growth and yield of maize.In this perspective, three densities of cowpea tested in this system of association with pure maize culture during two growing seasons with two improved maize varieties and a local variety.This is the T0 treatment: pure corn culture; T1_SNL: corn + semi-cowpea in interbedded line; T2_SNLDI: corn + semi-cowpea in double line; T3_SNQ: corn + semi-cowpea staggered.The results show that improved varieties of maize produce more and grow faster than the local variety. At each of two study sites, there was no marked effect of cowpea seeding density on plant height and grain yield per unit area.Although the three association modalities are efficient, SNL and SNLDI association models, which are confirmed as the most competitive, can preferably be recommended in a rural environment. However, the study of the use of cowpea with corn could be considered to allow a better use of the soil resources and consequently an improvement of the productivity of the associated crops.*

Keywords*— *Association, cowpea, maize, semi density, soil.

I. INTRODUCTION

Soil depletion and degradation as well as climate variability are responsible for decrease in agricultural yields and worsening poverty in northern Côte d'Ivoire. With the strong land and demographic pressure observed in this zone, farmers are forced to practice continuous cultivation and to make the most of available land (N'guessan et al., 2019, N'goran et al., 2018), as is the case in the cotton zone of Burkina Faso reported by Coulibaly et al., (2012), Barro et al., (2016) and Ouattara et al., (2016). Today, farmers are worried about the fatigue of their soils, say that the land does not produce as before. In the cotton and maize cropping systems that predominate in the dense area of Korhogo Department, the use of mineral fertilizers alone does not maintain soil fertility.In this zone, legumes occupy only a marginal part in cropping systems, whereas they can play a very important role, whether grown in rotation or in association. Several studies conducted on legumes indicate that they can help improve soil fertility through the symbiotic fixation of nitrogen in the air (Gbakatchetche et al., 2010, Barro et al., 2016 and Ouattara et al. 2016, Kouassi et al., 2017), to produce quality feed for animals (Zoundi et al., 2006, Bambara et al., 2008 and Ouattara et al., 2016) and to provide income for agricultural exploitations.With the strong land and demographic pressure observed in recent years in the northern part of Côte d'Ivoire, the use of soil restoration techniques with tree legumes is becoming problematic. The use of herbaceous legumes thus becomes an alternative for improving soil fertility. Of these, cowpea is the best choice because it is one of the main sources of protein and food for the rural and urban populations of the area as well as for livestock.To do this, the research question that arises is the corn-legume combination mode that can reduce competition between crops and promote yield improvement. Therefore, this study was undertaken to help determine the seedling density of cowpea that optimizes growth parameters and grain yield of corn in the corn-cowpea association system.

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II. MATERIAL AND METHOD

Study site

The study was conducted in the villages of Kolokaha and Sohouo located in the sub-prefectures of Sinematiali and Sohouo in the Korhogo department respectively (***Figure 1***). These two villages are mainly populated by Senoufo natives whose main activity is agriculture and livestock. The general pattern of the region is a tabular set of ferruginous cuirasses with gentle breaks caused by garlands of hills and hillocks with rounded reliefs set on plateaus of medium height (Avenard et al., 1971).According to Beaudou and Sayol, (1980), the geological substratum consists of calc-alkaline granites of the Precambrian. The soil cover of this region is characterized by the very large predominance of ferrallitic soils (Avenard et al., 1971). At the climatic level, the savanna district is bathed in a two-season tropical Sudanian climate, a dry season from November to April and a rainy season from May to October.

Plant material

The plant material used consisted of three varieties of maize seed with or without local cowpea seed purchased from the Korhogo market (***Figure 2***). Corn seeds included two improved varieties, namely the Komsaya and EV 87 varieties and the local variety supplied by the farmers. The seeds of the Komsaya variety are characterized by yellow-orange grains of the dentate horn type. They have a crop cycle that ranges from 85 to 90 days with a potential yield of 8 to 9.5 t / ha for an optimal density of 60 000 plants / ha.This seed is suitable for areas receiving an annual rainfall ranging from 800 to 900 mm / year. The seeds of the selected variety EV 87 are composed of yellow-toothed grains characterized by a crop cycle that ranges from 80 to 95 days with a potential yield of 3 to 5 t / ha and an optimum density of 42. 500 plants / ha. It is suitable for areas receiving an annual rainfall of about 1000 mm.

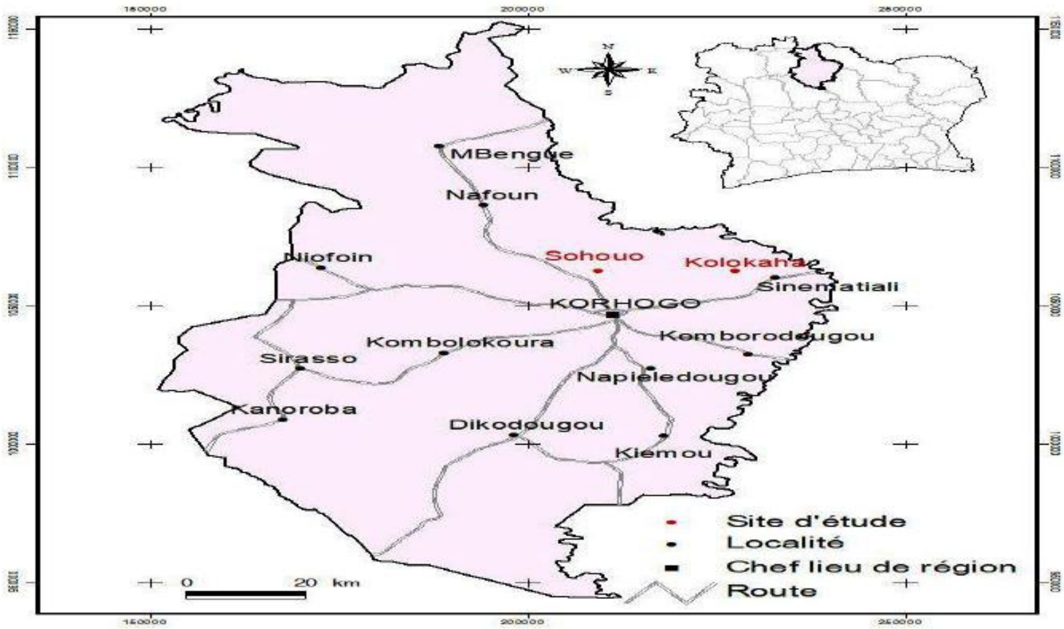

Fig.1: Map showing the location of the study areas.

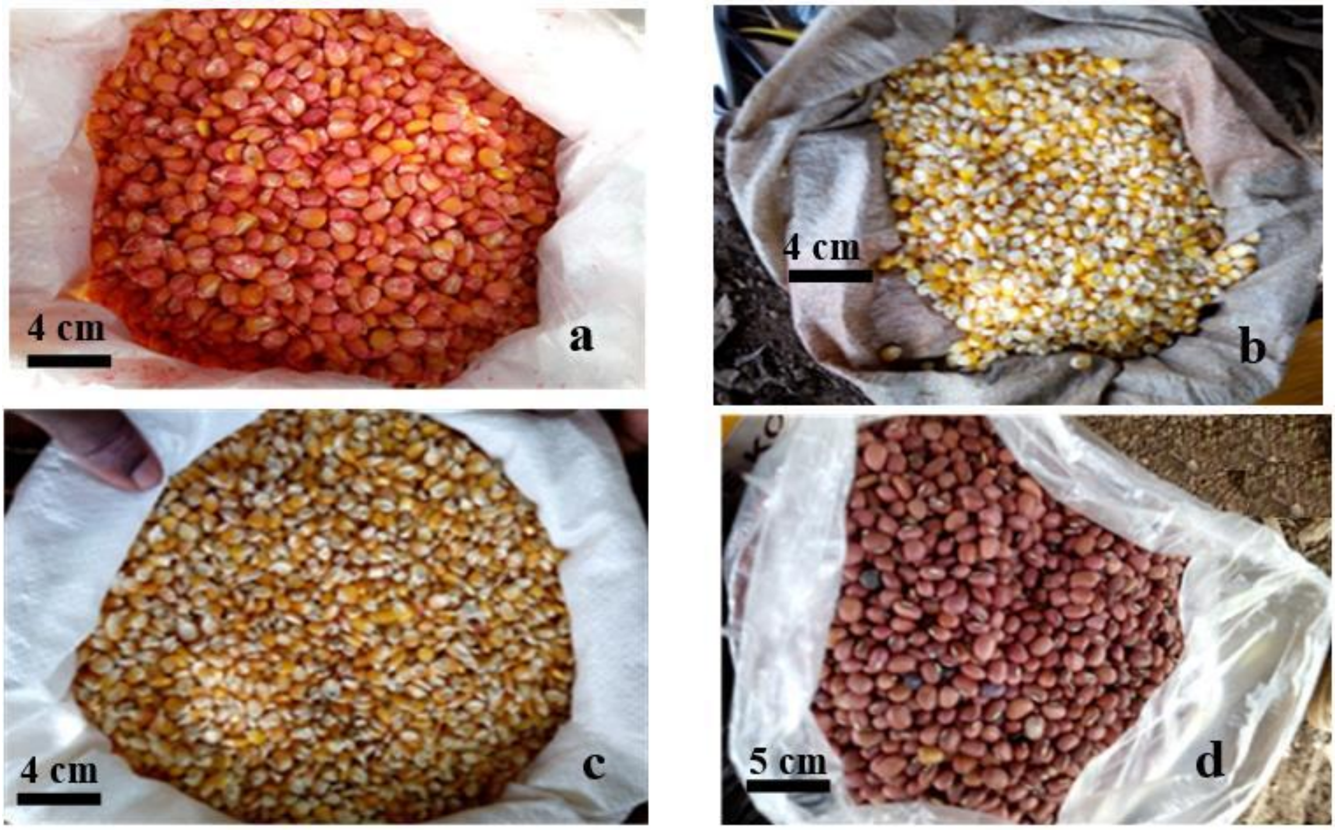

Fig.2: Morphological aspect of maize and cowpea grain seeds (a: Komsaya maize variety, b: Maize local variety, c: EV87 maize seed, d: cowpea seed)

According to the farmers, the seeds of the local variety can produce between 02 to 03 t / ha. Regarding cowpea, the seed is characterized by a cycle of 75 days. Its potential grain yield is 1.5 t / ha and is suitable for areas with annual rainfall ranging from 400 to 800 mm of water.

Establishment and operation of demonstration plots

Out of the nine villages benefiting from the project, the two groups of Kolokaha and Sohouo have a total of 50 direct beneficiaries, distributed among 35 members in Kolokaha (70%), including 03 men (8.42%) and 32 women (91%). , 43%) and 15 people in Sohouo (30%) with 02 men (13.33%) and 13 women (86.67%). In each of these villages, the members of the target groups were volunteers and the choice of the plot dedicated to the project and its location were done by the farmers themselves.They were trained in the proposed new technologies and participated fully in all the phases (semi, weeding, fertilizer spreading, harvesting, etc.) of the field work. In addition to agricultural inputs (improved maize seed, NPK fertilizer, urea, herbicides, insecticide), land preparation costs (clearing, plowing, spraying, herbicide pre-treatment of the plowed plot, etc.) were borne by the farmer project. On each of the demonstration plots, plowing followed by ridging was carried out using a bovine traction plow.The demonstration plot was then grided into 3 blocks and each block consists of 3 sub-blocks subdivided into 4 elementary parcels of 30 m2 measuring 6 m long and 5 m wide. Each of the sub-blocks within a block is dedicated to one of the three varieties of corn. The spacing between the elementary parcels within the block is 2 m and one block to another is 3 m. The operation of semi was done manually by the women of the two groups following spacings of 0.80 m in line and 0.30 m between the pockets.On each elementary plot, we had 13 lines and on each line, 15 poquets. two to three seeds were sown per poquet. Thus, each elemental plot of 30 m2 included 195 plants per unit of surface on all three blocks. In the association system, maize and cowpea were placed in the elementary plots of each block and under blocks according to the schematic combination mode in **Figure 3**:

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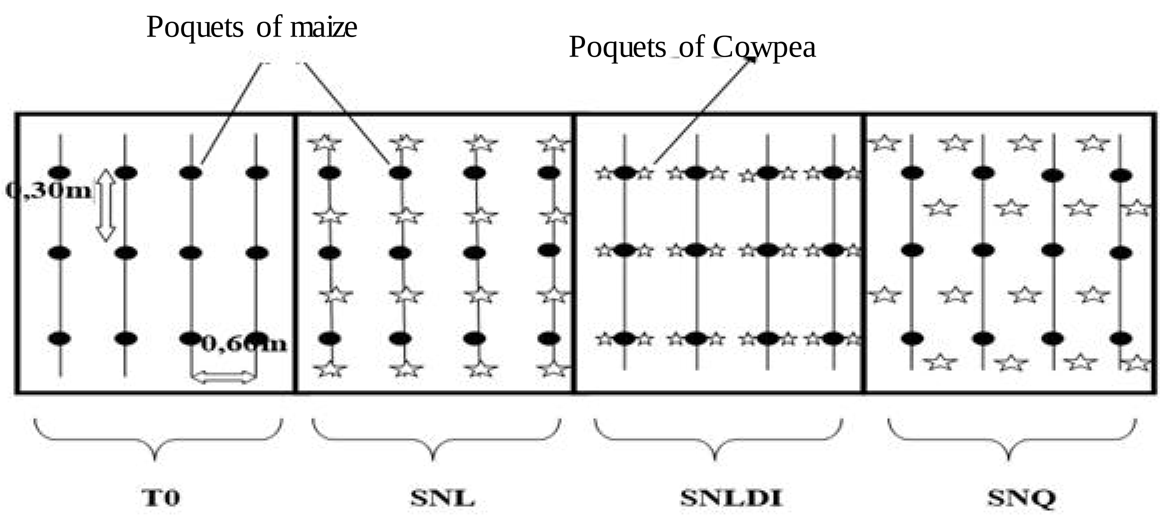

Fig.3: Maize and cowpea semi points in the association system

- **T0**: *maize seed in pure culture*
- **T1-SNL**: *corn-semi-cowpea seed interposed*
- **T2-SNLDI**: *semi-cowpea corn seed in double interbedded line*
- **T3-SNQ**: *semi-stale corn seed staggered*

There were 16 semi points when cowpea is sown in intercalated line (SNL) and quinconce (SNQ), or 16 cowpea plants per line for a density of 208 plants per elementary plot. In addition, when cowpea is sown in a double interspersed line (SNLDI), there were 32 plants on each line equivalent to a density of 416 plants/30m2. All of these plots benefited from fertilizer inputs and insecticide treatments. The study was conducted during two growing cycles covering the growing seasons of 2017 and 2018. During these two seasons, the semi intervened on the demonstration plots of the two villages in the periods from August 12 to 16, 2017 and July 10-15, 2018.

Agronomic data collection

On each of the two demonstration plots, monitoring of the height growth and development of maize plants on the elementary plots was carried out in a participatory manner with the members of the beneficiary groups for 02 months. During this period, observations were made every 15 days from the 30th day after semi (JAS); i.e. at the 30th; 45th and 60th JAS out of 12 plants randomly selected by elementary plot equivalent to 36 plants per treatment.Growth and development parameters described by Mbaye et al. (2014) and Barro et al. (2016) in the case of similar studies, were used to characterize the vegetative behavior of plants from the three maize seeds. During the culture phase, the variables measured were the height of the plants, the number of leaves produced per plant, the circumference of the collar stems at 10 cm from the soil, and the grain yield per unit area.

Statistical analysis

Comparison of the averages of the agronomic parameters tested for seedling density, variety and measurement dates was achieved by variance analysis (ANOVA) at the 5% probability threshold. When a significant difference is noted between the factors considered for a given trait, the test of the smallest significant difference (ppds) HSD of TUKEY was performed. All these statistical tests were carried out using STATISTICA 7.1 software. In addition, the evaluation of association performance was carried out by calculating the Surface Equivalent Rate (TSE) or Land Equivalent Ratio (LER) for each component of the association. When the value of the LER is greater than or equal to 1, the combination is more advantageous than pure cultivation. Otherwise, when the value of the LER is less than 1, the association is less advantageous than pure cultivation (Ghosh, 2004). This method is based on the formula of Mead and Willey (1980) described as following::

LERm= $\frac{YLm}{YSm}$

YLm : maize yield in combination,

YSm : corn yield in pure culture,

LERm : LER of maize.

III. RESULTS

Effects of the corn variety and the study site on plant growth parameters over the two growing seasons.

Tables 1 and 2 show, respectively, the average height, number of leaves produced and circumference at the

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collar during the growth of plants from the three maize varieties during the 2017 and 2018 crop seasons. These tables show that the variety of maize has significantly affected (p -0.0001) all of these parameters 30; 45 and 60 JAS regardless of the growing season.The results also show that the average values of these parameters increase over time and with variety, highlighting significant differences (P -0.0001) from 30 JAS. At the Kolokaha demonstration site, there was no significant effect of the maize variety on the number of leaves produced and the circumference at the collar of the corn plants 30; 45 and 60 JAS whatever the growing season. On the contrary, during the two growing seasons, there was a significant difference in the height of maize plants from 30 JAS. In fact, during this period, plant height is significantly higher in the Komsaya (season 1: 74.28 cm; season 2: 75.02 cm) compared to EV87 (season 1: 65.229 cm) and local (season 1: 60.625 cm; saiso n 2: 61,231 cm) which, moreover, have statistically identical values. However, although there is no significant difference, there is a slight increase in plant height in the EV87 variety compared to the local variety regardless of the growing season. This trend of evolution of plant height is the same after 45 and 60 JAS. In Sohouo, the plants behave in the same way for this variable regardless of the variety and the growing season 30 JAS. On this site, the difference between plant height occurs from 45 JAS up to 60 JAS. On these dates, the height of the plants is higher than the improved Komsaya variety compared to the other two varieties during the 2017 and 2018 growing seasons.The results also reveal that in Sohouo, the variety of maize did not significantly influence the circumference at the collar of corn plants 30; 45 and 60 JAS. In addition, data from Tables 1 and 2 show that maize plants grow faster on the Kolokaha demonstration plot compared to those grown in Sohouo regardless of variety and growing season.

Influence of cowpea seeding density and study site on corn plant growth and development parameters during both growing cycles

Tables 3 and 4 show, respectively, the average values of the growth and development parameters of maize plants based on seeding density. These tables show that cowpea seeding density had no significant effect on height, number of leaves produced and plant collar circumference regardless of date of measurement, study site and growing season.Nevertheless, on the Kolokaha demonstration plot and during the first growing cycle, there were 30 JAS, a trend of stunting of maize plants of 0.4% and 1.02%, respectively in low (SNL) and high (SNLDI) cowpea compared to a non-significant 3.08% increase in SNQ treatments compared to pure-grown maize plants.From this date, the sNL maize plants begin a slight growth in height with a non-significant increase of 3.48% and catch up with those of SNQ 45 JAS treatments up to 60 JAS compared to the reference treatment.

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Table 1: Corn plant growth and development data 30 and 45 days after semi depending on variety and study site

Cycles	Var/Site	Measurement dates (days)					
		30			45		
		H	NF	DC	H	NF	DC
1	**Varkom_Kol**	74,28 ± 13,46^{a}	9,33 ± 1,47^{a}	1,21±0,21^{bc}	192,292 ± 30,20^{a}	11,514 ± 1,12^{ab}	2,65 ± 0,63^{ab}
	VarEV87_Kol	65,23 ± 12,32^{b}	9,38 ± 1.33^{a}	1,17±0,20^{c}	169,395 ± 36,56^{b}	10,972 ± 1,48^{b}	2,49 ± 0,59^{b}
	VarLoc_Kol	60,63±10,52^{bc}	8,99 ± 1.48^{a}	1,21±0,017^{bc}	164,222 ± 32,19^{b}	11,597 ± 1,28^{a}	2,59 ± 0,62^{ab}
	Varkom_Soh	57,17 ± 11,93^{cde}	7,80 ± 1,31^{bc}	1,25±0,23^{ab}	111,715 ± 25,18^{e}	8,569 ± 1,51^{cd}	2,20 ± 0,40^{cd}
	VarEV87_Soh	57,06 ± 15,86^{cde}	7,67 ± 1,39^{bc}	1,23 ± 0,23^{abc}	104,889 ± 25,82^{ef}	8,176 ± 1,36^{de}	2,19 ± 0,39^{cd}
	VarLoc_Soh	52,88 ± 15,92^{e}	7,14 ± 1,29^{d}	1,19 ± 0,20^{bc}	94,882 ± 22,84^{f}	7,993 ± 1,83^{e}	2,12 ± 0,34^{d}
2	**Varkom_Kol**	75,02 ± 13,60^{a}	9,43 ± 1,49^{a}	1,22 ± 0,22^{abc}	196,17 ± 30,85^{a}	11,51 ± 1,12^{a}	2,80 ± 0,46^{a}
	VarLoc_Kol	61,23 ± 10,63^{bc}	9,08 ± 1 ,50^{a}	1,22 ± 0,22^{bc}	167,53 ± 32,81^{b}	11,60± 1,28^{a}	2,788 ± 0,51^{b}
	Varkom_Soh	58,31 ± 12,17^{cd}	7,95 ± 1.34^{b}	1,30 ± 0,18^{a}	145,230 ± 32,73^{c}	8,912 ± 1,57^{c}	2,357 ± 0,32^{c}
	VarLoc_Soh	53,93 ± 16,24^{de}	7,28 ± 1,31^{cd}	1,24 ± 0,20^{abc}	123,347 ± 29,69^{d}	8,313 ± 1,91^{de}	2,255 ± 0,36^{cd}
	ANOVA						
	F	48,078***	62,833***	4,161***	183,423***	168,922***	47,656***
	P	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001

*In the same column, the averages followed by the same letter are not significantly different to P -0.0001. **H** : height ;**NF** : number of leaves produced per plant ; **DC** : circumference at the collar ; **Var:** variety; **Varkom**: Komsaya variety; **VarEV87**: variety EV87; **VarLo**c: Local variety; **Kol**: Kolokaha, **Soh**: Sohouo.*

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Table 2: Corn plant growth and development data 60 days after semi depending on variety and study site.

Cycles	Var/Sites	Measurement dates (days)		
		60		
		H	NF	DC
1	**Varkom_Kol**	232,673±36,54^{a}	16,12 ± 1,56^{b}	3,232 ± 0,53^{ab}
	VarEV87_Kol	204,969±44,24^{b}	15,361 ± 2,07^{c}	3,122 ± 0,50^{b}
	VarLoc_Kol	198,709±38,95^{b}	16,236 ± 1,79^{ab}	3,217 ± 0,59^{ab}
	Varkom_Soh	117,301 ± 26,44^{d}	9,426 ± 1,51^{ef}	2,37 ± 0,31^{de}
	VarEV87_Soh	112,751 ± 30,66^{d}	9,067 ± 1,35^{f}	2,332 ± 0,41^{e}
	VarLoc_Soh	99,626 ± 23,98^{de}	8,792 ± 1,83^{f}	2,27 ± 0,35^{e}
2	**Varkom_Kol**	241,980 ± 38,00^{a}	16,764 ± 1,62^{ab}	3,362 ± 0,56^{a}
	VarLoc_Kol	206,657 ± 40,51^{b}	16,886 ± 1,86^{a}	3,345 ± 0,61^{a}
	Varkom_Soh	131,377 ± 29,61^{c}	10,558 ± 1,86^{d}	2,640 ± 0,36^{c}
	VarLoc_Soh	111,581 ± 26,86^{e}	9,847 ± 2,26^{e}	2,526 ± 0,40^{cd}
	ANOVA			
	F	385,848***	555,877***	132,133***
	P	<0,0001	<0,0001	<0,0001

In the same column, the averages followed by the same letter are not significantly different to P -0.0001. ***H*** *: height ;**NF** : number of leaves produced per plant ;* ***DC*** *: circumference at the collar ;* ***Var:*** *variety;* ***Varkom****: Komsaya variety;* ***VarEV87****: variety EV87;* ***VarLo****c: Local variety;* ***Kol****:*

Table 3: Corn plant growth and development data based on cowpea seeding density and study site during the two 30 - and 45 JAS growing cycles

Cycles	DS/Sites	Measurement dates (days)					
		30			45		
		H	NF	DC	H	NF	DC
1	TSN_Kol	66,435 ± 11,92^{ab}	9,624 ± 1,49^{a}	1,193 ± 0,28^{bc}	173,407 ± 35,82^{ab}	11,370 ± 1,28^{ab}	2,651 ± 0,72^{bc}
	SNL_Kol	66,167 ± 12,11^{ab}	9,380 ± 1,37^{ab}	1,235 ± 0,19^{abc}	179,444 ± 36,85^{ab}	11,556 ± 1,28^{ab}	2,745 ± 0,60^{abc}
	SNLDI_Kol	65,759 ± 13,16^{ab}	9,065 ± 1,26^{ab}	1,164 ± 0,18^{c}	169,806 ± 31,61^{b}	11,083 ± 1,22^{b}	2,586 ± 0,54^{cd}
	SNQ_Kol	68,481 ± 16,01^{ab}	8,806 ± 1,49^{b}	1,194 ± 0,19^{bc}	178,556 ± 35,89^{ab}	11,435 ± 1,44^{ab}	2,653 ± 0,57^{bc}
	TSN_Soh	58,324 ± 18,10^{cde}	7,565 ± 1,33^{c}	1,235 ± 0,23^{abc}	106,167 ± 31,07^{e}	8,667 ± 1,84^{cd}	2,246 ± 0,40^{e}
	SNL_Soh	55,963 ± 14,92^{de}	7,370 ± 1,19^{c}	1,215 ± 0,19^{abc}	102,454 ± 23,66^{e}	8,176 ± 1,32^{d}	2,210 ± 0,35^{e}
	SNLDI_Soh	54,935 ± 12,98^{de}	7,648 ± 1,43^{c}	1,220 ± 0,20^{abc}	107,787 ± 30,17^{e}	8,194 ± 1,70^{d}	2,218 ± 0,40^{e}
	SNQ_Soh	53,583 ± 12,28^{e}	7,565 ± 1,47^{c}	1,226 ± 0,19^{abc}	102,231 ± 20,78^{e}	8,037 ± 1,41^{d}	2,230 ± 0,39^{e}
2	TSN_Kol	68,287 ± 12,66^{ab}	9,777 ± 1,51^{a}	1,228 ± 0,28^{abc}	179,917 ± 38,02^{ab}	11,673 ± ±1,09^{ab}	2,811 ± 0,64^{ab}
	SNL_Kol	64,836 ± 12,44^{abc}	9,300 ± 1,42^{ab}	1,265 ± 0,19^{abc}	187,453 ± 33,76^{a}	12,056 ± 1,17^{a}	2,895 ± 0,44^{a}
	SNLDI_Kol	68,371 ± 13,45^{ab}	9,244 ± 1,30^{ab}	1,163 ± 0,18^{c}	175,270 ± 33,11^{ab}	11,801 ± 1,18^{ab}	2,745 ± 0,40^{abc}
	SNQ_Kol	71,009 ± 16,64^{a}	8,697 ± 1,59^{b}	1,229 ± 0,17^{abc}	184,648 ± 33,88^{ab}	11,957 ± 1,28^{a}	2,812 ± 0,40^{ab}
	TSN_Soh	61,186 ± 17,85^{bcd}	7,777 ± 1,30^{c}	1,311 ± 0,20^{a}	145,311 ± 39,56^{c}	9,216 ± 1,98^{c}	2,384 ± 0,36^{de}
	SNL_Soh	54,839 ± 13,21^{de}	7,466 ± 1,17^{c}	1,226 ± 0,18^{abc}	125,919 ± 27,04^{d}	8,566 ± 1,47^{cd}	2,384 ± 0,32^{e}
	SNLDI_Soh	54,768 ± 12,65^{de}	7,508 ± 1,47^{c}	1,260 ± 0,19^{abc}	135,525 ± 33,36^{cd}	8,392 ± 1,92^{cd}	2,291 ± 0,35^{e}
	SNQ_Soh	53,692 ± 12,65^{de}	7,721 ± 1,51^{c}	1,277 ± 0,19^{ab}	130,397 ± 28,28^{cd}	8,277 ± 1,53^{d}	2,321 ± 0,34^{e}
	ANOVA						
	F	17,778***	38,045***	3,12***	99,501***	112,603***	32,814***
	P	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001

In the same column, the averages followed by the same letter are not significantly different to P -0.0001. ***H*** *: height ;* ***NF*** *: number of leaves produced per plant ;* ***DC*** *: circumference at the collar ;* ***Var:*** *variety;* ***Varkom****: Komsaya variety;* ***VarEV87****: variety EV87;* ***VarLo****c: Local variety;* ***Kol****: Kolokaha,* ***Soh****: Sohouo.*

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Table 4: Corn plant growth and development data based on cowpea semi density and study site during the two crop cycles at 60 JAS

Cycles	DS/Sites	Measurement dates (days) 60 H	NF	DC
1	TSN_Kol	209,823 ± 43,34[bc]	15,919 ± 1,79[cd]	3,181 ± 0,71[bc]
	SNL_Kol	217,128 ± 44,59[abc]	16,178 ± 1,80[bcd]	3,294 ± 0,49[abc]
	SNLDI_Kol	205,465 ± 38,25[c]	15,517 ± 1,71[d]	3,103 ± 0,45[c]
	SNQ_Kol	216,052 ± 43,43[abc]	16,009 ± 2,06[cd]	3,183 ± 0,46[bc]
	TSN_Soh	111,475 ± 32,62[e]	9,533 ± 1,84[fgh]	2,336 ± 0,40[ef]
	SNL_Soh	107,576 ± 24,84[e]	8,994 ± 1,32[gh]	2,298 ± 0,34[f]
	SNLDI_Soh	113,176 ± 31,68[de]	9,014 ± 1,70[gh]	2,306 ± 0,36[f]
	SNQ_Soh	107,343 ± 21,82[e]	8,841 ± 1,41[h]	2,319 ± 0,34[ef]
2	TSN_Kol	221,968 ± 46,87[abc]	16,663 ± 1,58[abc]	3,373 ± 0,77[ab]
	SNL_Kol	231,266 ± 41,65[a]	17,209 ± 1,70[a]	3,474 ± 0,53[a]
	SNLDI_Kol	216,235 ± 40,81[abc]	16,360 ± 1,72[abcd]	3,193 ± 0,48[bc]
	SNQ_Kol	227,805 ± 41,82[ab]	17,068 ± 1,86[ab]	3,375 ± 0,48[ab]
	TSN_Soh	131,451 ± 35,78[d]	10,917 ± 2,35[e]	2,670 ± 0,40[d]
	SNL_Soh	113,909 ± 24,46[de]	10,147 ± 1,74[ef]	2,496 ± 0,36[def]
	SNLDI_Soh	122,598 ± 30,18[de]	9,942 ± 2,28[efg]	2,566 ± 0,39[de]
	SNQ_Soh	117,959 ± 25,58[de]	9,805 ± 1,81[fg]	2,600 ± 0,38[d]
	ANOVA			
	F	195,458***	332,944***	80,777***
	P	<0,0001	<0,0001	<0,0001

*In the same column, the averages followed by the same letter are not significantly different to P -0.0001. **H** : height ;**NF** : number of leaves produced per plant ; **DC** : circumference at the collar ; **Var:** variety; **Varkom**: Komsaya variety; **VarEV87**: variety EV87; **VarLo**c: Local variety; **Kol**: Kolokaha, **Soh**: Sohouo.*

On the contrary, during the 2018 growing season, there is a trend of SNL and SNQ corn plants growing faster in heights of 4.19% and 2.63% respectively, and a slight growth delay of 2.58% in high density of cowpea semi (SNLDI) compared to pure-grown corn plants (NSTs).The same is true in Sohouo, where the overall trend in maize plants was recorded on all three measurement dates, respectively of SNL, SNLDI and SNQ treatments compared to pure-grown plants (NSTs) regardless of the growing season and the study site. Analysis of the data in Tables 3 and 4 also reveals a significant inter-site difference between the growth and development of maize plants. These tables show that the corn plants at the Kolokaha demonstration site have significantly, the highest average collar circumference values and move higher up on all measurement dates than those grown at Sohouo whatever the growing season.

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Influence of the variety on corn grain yield during the first growing season.

Analysis of histograms in Figure 6 reveals a marked effect of variety on corn grain yield per unit area during the first growing season. The results indicate that in Kolokaha, grain yield per unit of surface area is significantly higher in the Komsaya variety (6.67 kg/30 m2) compared to EV 87 (4.02 kg/30 m2) and local (3.21 kg/30 m2) varieties, which, on the other hand, have statistically of the same production although the EV 87 variety has a slight performance compared to the local variety.This trend in corn yield is identical to that observed in Sohouo although no significant difference was found for this variable between variety. In fact, maize grain production is significantly higher in the Komsaya variety (0.67 kg / 30 m2) followed by the EV87 and local varieties with 0.40 kg / 30 m2 and 0.32 kg / 30 m2 respectively. In addition, Figure 6 shows that corn yield per unit area is significantly higher at Kolokaha than at Sohouo, whatever the variety.

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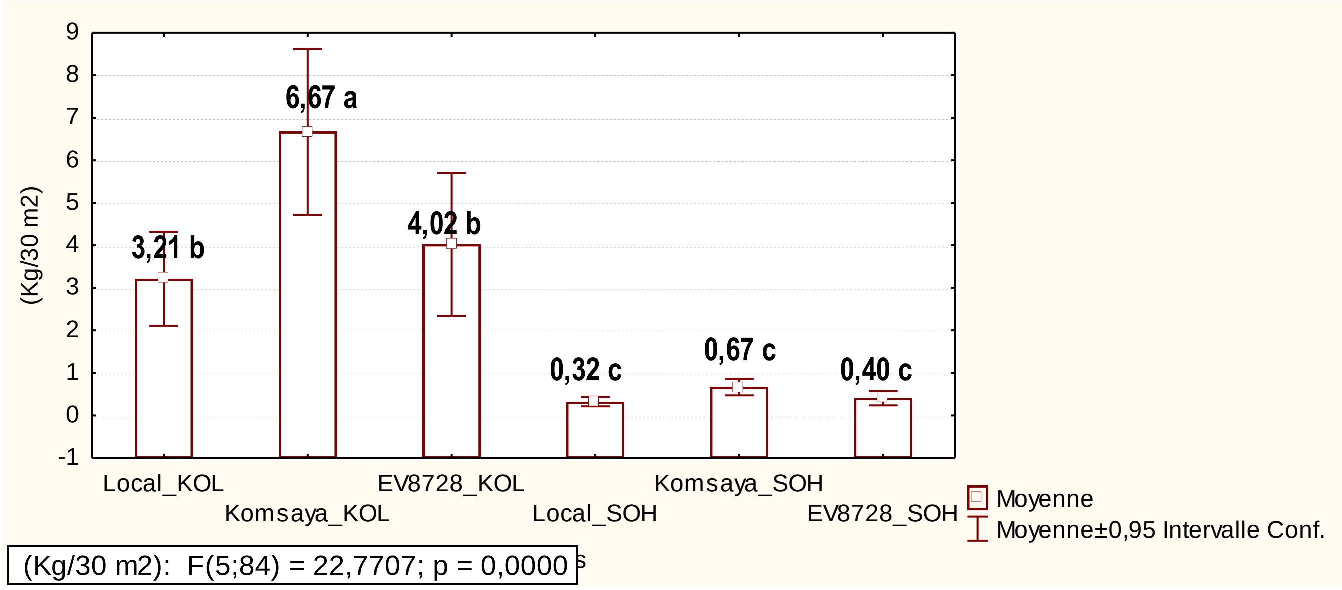

Fig.6: Evolution of maize grain yield during the first growing season

Influence of cowpea seeding density on corn grain yield during the two growing seasons

The results of Table 5 reveal that cowpea seeding density had no significant effect on corn grain yield produced per unit area regardless of the study site and growing season. However, in 2017, there was a downward trend in corn grain yield at each of the two demonstration sites with the seeding density of cowpea in elementary plots grown with improved Komsaya and EV87 against an increase in this parameter at the level of those grown with the local variety. In Kolokaha, the yield decline was 19.24%; 52.17% and 31.52%, respectively, in the SNL, SNLDI and SNQ elementary plots of the improved Komsaya variety and 52.82%; 55.98% and 74.28% at the elementary plots of the EV87 variety compared to pure-grown maize plots. On the Sohouo parcel, the trend decline in yield was 19.41%; 54.37% and 34.95%, respectively, in the SNL, SNLDI and SNQ elementary plots of the improved Komsaya variety and 53.75%; 53.75% and 71.25% in corresponding elementary plots grown with EV87.

Table 5: Corn grain yield per unit area based on density and the study site

Settings	Demonstration plots			
	Kolokaha		Sohouo	
	2017	2018	**2017**	2018
T0_Improved seed_Kom	9,2±5,30^{a}	8,15 ± 3,27^{b}	0,103±0,018^{a}	3,32± 1,81^{a}
T1 _SNL_Improved seed _Kom	7,43±2,18^{a}	8,82 ± 3,37^{b}	0,083±0,018^{a}	3,18± 1,40^{a}
T2_SNDL_Improved seed _Kom	4,40±1,85^{a}	8,45 ± 2,24^{b}	0,047±0,018^{a}	3,68± 2,42^{a}
T3 _SNQ_Improved seed _Kom	6,30±2,00^{a}	6,50 ± 4,09^{ab}	0,067±0,018^{a}	3,47± 2,89^{a}
T0_ Local seed	2,97±2,63^{a}	3,77 ± 1,05^{a}	0,033±0,018^{a}	2,83± 1,42^{a}
T1 _SNL_ Local seed	4,50±0,46^{a}	5,13 ± 1,43^{a}	0,047±0,018^{a}	3,08± 0,96^{a}
T2_SNDL_ Local seed	3,70±3,04^{a}	4,62 ± 3,95^{a}	0,040±0,018^{a}	4,53± 2,26^{a}
T3_SNQ_ Local seed	3,03±0,45^{a}	4,10 ± 1,95^{a}	0,033±0,018^{a}	2,47± 0,67^{a}
T0_Improved seed _EV87	7,27±5,17^{a}		0,08±0,018^{a}	
T1 _SNL_Improved seed _EV87	3,43±1,25^{a}		0,037±0,018^{a}	
T2_SNDL_Improved seed_EV87	3,20±1,67^{a}		0,037±0,018^{a}	
T3 _SNQ_Improved seed _EV87	1,87±0,40^{a}		0,023±0,018^{a}	
ANOVA				
F	2,06	3,07	1,83	0,65
P	0,067	0,01	0,10	0,71

In the same column, the averages followed by the same letter are not significantly different at P <0.05. F: frequency; P: probability.

On the other hand, during the 2018 crop season, there was a non-significant increase in corn grain yields in elementary plots in cowpea-associated crops in both demonstration plots compared to pure-grown plots for each of the two varieties. In Kolokaha, apart from the SNQ elementary plots of the Komsaya maize variety, where there was a downward trend of 20.24%, yield growth was 8.22% and 3.68% respectively in the SNL and SNLDI elementary plots with improved variety and 36.07%; 22.28% and 8.75%, respectively, in the SNL, SNLDI and SNQ elementary plots corresponding to the local variety compared to pure-grown plots.Thus, on the Kolokaha plot, there was a slight performance of corn grain yield in the SNL elementary plots followed by SNLDI for each maize variety compared to the pure-grown elementary plots. In Sohouo, during the 2018 crop season, there was a trend decline in yield of 3.92% and 13.07% respectively in the elementary SNL plots of the improved Komsaya and SNQ variety of the local variety in contrast to a non-increase yield of 11.18% and 4.53% at the SNLDI and SNQ elementary plots of the improved Komsaya variety and 8.83% and 60.07% at the SNL and SNDL parcels of the local variety. In Sohouo, the SNLDI association modality was more efficient regardless of the variety of maize, followed by SNL and SNQ treatments respectively with the local and improved varieties.

LER values of different cowpea seeding densities

Table 6 shows the LER values obtained from the different seeding densities of the cowpea. During the 2017 growing season, LER values are below 1 when corn seeds of improved varieties are associated with cowpea and greater than 1 in this system of association with the local variety regardless of the study site. On the contrary, during the 2018 crop season, it was observed that LER values are above 1 regardless of the seeding density and maize variety except, the SNQ elemental plots of the improved Komsaya variety at the Kolokaha site and SNL and SNQ resp Komsaya and local varieties in Sohouo.

Table 6: LER values obtained from different cowpea seeding densities

Settings	LER value			
	Kolokaha		Sohouo	
	2017	**2018**	**2017**	**2018**
T1 _SNL_ Improved seed_Kom	0,81	1,08	0,82	0,96
T2_SNDL_ Improved seed_Kom	0,48	1,04	0,46	1,11
T3 _SNQ_ Improved seed_Kom	0,68	0,80	0,65	1,05
T1 _SNL_ Localseed	1,52	1,36	1,42	1,09
T2_SNDL_ Localseed	1,25	1,22	1,21	1,60
T3_SNQ_ Localseed	1,02	1,09	1,00	0,87
T1 _SNL_ Improved seed_EV87	0,47		0,46	
T2_SNDL_ Improved seed_EV87	0,44		0,46	
T3 _SNQ_ Improved seed_EV87	0,26		0,29	

IV. DISCUSSION

Comparison of the three maize varieties according to agronomic parameters

During the two years of testing, the results revealed that corn plants of the improved Komsaya and EV87 varieties grow faster and produce more than local seed plants. This performance of the seeds of the improved varieties is due to the difference between genotype, cultivation techniques and environmental effects (soil quality, temperature, quantity and frequency of rains, relative humidity, etc.). This reflects significant inter-variety variability and is consistent with the work of N'Zué et al., (2004) and Djinabou et al., (2018) which have achieved similar results on cassava varieties in Côte d'Ivoire and southern Benin. This result is also consistent with those of Moussa et al. (2018) which noted this performance in other improved maize varieties in southwestern Niger. These authors unanimously agree that improved varieties yield significantly higher yields than local varieties. Thus, it could be confirmed that the improved seeds Komsaya and EV 87, are genetically stable and effectively suitable for the study area. Our results also indicate that maize plants grow faster on the Kolokaha demonstration plot compared to those grown in Sohouo regardless of variety and growing season. The same is true for corn grain yield harvested per unit area at these two sites during the 2017 and 2018 crop seasons.The underperformance of maize plants observed on the Sohouo plot may be related to its continued strong exploitation as a result of the lack of fertile land available in the cotton basin of the dense

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Korhogo area reported by N'guessan et al., (2019) and N'goran et al. (2018) compared to Kolokaha, which is very little used. As a result, in Sohouo, there has been a general decline in fertility and soil productivity, the plot of which is characterized today by its high sand wealth (78.17 per cent) particularly coarse sand (61.28%) and clay poverty (10.17 per cent) and organic carbon (0.93%) compared to the ground of the Kolokaha plot as evidenced by the results of the work carried out on this project by Gnagne (2019). This negatively impacts the texture and gives the soil of the sohouo plot, poor water retention between rains and a tendency to dry out very quickly and easily lose the fertilizers brought by leaching and joins the observations of N'guessan et al., (2019). Moreover, the results of Gnagne's work (2019) confirmed the low soil richness of the Sohouo plot in mineral elements including nitrogen, potassium, calcium and magnesium and a deficiency of nitrogen compared to phosphorus. In view of the above, low physical and chemical fertility of the soil would be one of the main causes of the poor yield of corn grains obtained in Sohouo compared to that of Kolokaha. For, according to Barro et al., (2016), maize is very demanding in fertiliser and, it is very difficult to get good yields on soils poor in fertilizer elements (NPK, Urea, ...).

Effect of cowpea seeding density on corn growth and yield parameters

In order to optimize the maize/cowpea combination, the choice of seedling density remains a crucial step (M'BAYE et al., 2014; Barro et al. (2016) that would better manage arable space (M'Baye et al., 2014) and help improve soil fertility by symbiotic nitrogen fixation in the air (N'goran et al., 2011; Coulibaly et al., 2017). Based on field work, the results indicate that cowpea seeding density had no significant effect on corn grain growth and yield parameters per unit of land regardless of study site and season. These results are in line with those of N'guessan et al., (2010) and Foidl et al. (2001) who observed that the increase in seeding or planting density does not affect the individual performance of the plants, since the density remains below the level of occurrence of food competition between plants. As a result, the corn plants in each of the two demonstration plots behaved substantially in the same way regardless of the seeding density of the cowpea and the growing season. Based on our results, it could be said that the three methods of combining cowpea tested are indeed suitable for maize in associated crops. Nevertheless, looking at our data, we note during the 2017 growing season that the increase in the seeding density of cowpea tends to induce a decline in yield per unit of surface and a delay in the growth and development of corn from elementary plots in associated cultivation compared to pure-grown plants.This result is consistent with those of Coulibaly et al., (2017) and N'goran et al., (2011), which achieved similar results in assessing the performance of food corn-legume swings and yam-legumes in western Burkina Faso and in Central West Côte d'Ivoire. It joins the work of Kouassi et al., (2017) and N'guessan et al., (2010) who have made similar findings with three varieties of cowpea and plants from savannah tea cuttings (Lippia multiflora) tested respectively between three and four seeding and planting densities in Côte d'Ivoire. They also corroborate the findings of Ayaz et al. (2004) reported by Pageau et al. (2006) which, in Canada, observed that the increase in pea stand density reduced the number of grains per pod and the number of pods per plant. Under the conditions of the experiment, our results could be explained by the semi-simultaneous maize and cowpea which favored, in the elementary plots in associated culture, a competition between the plants for the water and nutrients resources. Therefore, the shift of semi, as recommended by Kouassi et al. (2016), M'baye et al. (2014) and Coulibaly et al. (2012) could allow a better use of the resources of the soil and consequently an improvement in the productivity of the associated crops.In addition, our results revealed that the downward trend in corn grain yield and stunting are more pronounced in the seeds of the improved Komsaya and EV87 varieties in associated crops, with an LER value of less than 1 , against an increase in this parameter at the level of those grown with the local variety for an LER greater than 1. This result suggests that the association of cowpea with maize was beneficial only with local corn seed and there was no productivity-saving association in this system with improved seeds.It is thought that climate variability as described by Dekoula et al., (2018a), Dekoula et al., (2018b) and Noufé et al., (2015), may be responsible for the underperformance of plants of improved varieties compared to local seeds. Indeed, the rainfall irregularities observed during this crop ping could be a major handicap to the possibilities of expression of the characters and the recovery of soil moisture by corn plants of improved seeds compared to local seeds that appear to be more drought-resistant. Added to this is the low physical and chemical fertility of the soils of the locality of Sohouo and Kolokaha reported by Gnagne (2019). On the other hand, in the second year of the trial, on each of the two demonstration plots, there was a slight performance of corn grain yield in the associated elementary plots for each maize variety compared to the pure culture with an LER greater than 1. This result could be correlated with the previous crop that allowed maize plants to benefit from the back effect of soil fertilizer as reported by Barro et al., (2016) as well as nutrients from the decomposition of crop residues Previous. According to Coulibaly et al., (2017), the biomass supplement from legumes can increase in a non-significant 10-43% increase in total forage production on the association plots compared to the pure corn plot. This is an asset inthatcoulibaly et al., (2017) advocate for environments where soils are poor due to over-exploitation and where there is a lack of fodder for animals, food crop associations with legumes to ensure forage safety (forage production), food security (food production) and improve soil fertility. Specifically, our data revealed that the performance of corn plants is more pronounced in Kolokaha in the basic Plots SNL followed by SNLDI compared to pure-grown treatment. This justifies the fact that, with a low density of cowpea (SNL), competition between maize and cowpea is reduced while promoting good maize production. On the other hand, the SNLDI association of the high density of cowpea seeding has been more effective in Sohouo, regardless of the variety of maize. It is followed by SNL and SNQ treatments respectively with local and improved varieties. It is thought that the high density of seeding-SNLDI has led to a gain in maize productivity due to the maintenance of sufficient moisture and soil enrichment of the corresponding plots of nutrients, notably organic carbon and nitrogen. Because the functioning and performance of cereal-legume associations depend heavily on the nitrogen availability of the environment (Naudin et al., 2010). Overall, it can be said that maize can be associated with legumes without significantly decreasing its yield. A good control of the density and the semi lag of cowpea can lead to better yields and this would have an advantage in the management of land that is becoming increasingly scarce with population growth.

V. CONCLUSION

The results of this work show that corn plants in the improved Komsaya and EV87 varieties grow faster and produce more than local seed plants. Cowpea seeding density does not significantly affect all growth parameters and corn grain yield per unit area. Nevertheless, during the first year of testing, the increase in cowpea semi density tends to induce a decline in yield per unit of surface and a delay in the growth and development of corn plants in the elementary plots in cultivation compared to pure-grown plants. On the other hand, there was a slight performance of corn grain yield in the associated elementary plots in the second year of the trial. Although the three methods of association are effective, the SNL and SNLDI association models that confirm themselves as the most competitive can, preferably, be recommended to farmers. However, the study of the shift of cowpea with corn could be considered to allow a better use of the soil resources and consequently, an improvement of the productivity of the associated crops.

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