Agronomic performance of the maize-cowpea association on maize yield and yield components (*Zea mays* L.) in a real culture situation in northern Côte d'Ivoire.

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Abstract

The present study was conducted to design with members of two food producer groups, but / cowpea-related cropping systems that improves maize yield and soil fertility. In the open fields, four (4) association modalities corresponding to maize in pure culture (T0); corn + cowpea in intercropped line (SNL); corn + intercropped double-row cowpea (SNDLI) and stag fed corn + steak (SNQ) were tested with an improved and local corn variety in three blocks with three replicates. The results show that the variety of maize and the modalities of association did not have a significant effect on maize yield and yield components at any time of the study site. Nevertheless, there was a non-significant increase in length, girth, grain number and grain mass per ear, and grain yield per unit of surface in the improved maize variety compared to the local variety. The results also indicate that SNL association modalities tend to further favor increased yield parameters and maize yield per unit area followed by SNDLI treatments compared to pure maize crop. The promotion of SNL intercalated and double-line corn-cowbed combinations could be considered in the peasant environment, as they do not significantly compromise the yield of the main crop.

Keywords — *association modality, yield, performance component, Côte d'Ivoire.*

I. INTRODUCTION

Like cotton, cashew and mango, northern Côte d'Ivoire is a large maize and groundnut production area. Indeed, since the 1970s, access to new means of production (plough beef, tractors, fertilisers) that allows the system of cotton supervision has promoted in its northern part, the emergence of new systems of corn production and peanuts in monoculture and larger areas (> 2 ha) [1]. Today, demand from livestock and poultry feed industries and the introduction of new high-yielding varieties are increasing the intensification of maize cultivation, which is a source of food and income for the people. However, with the high land and population pressure observed in the dense Korhogo area, farmers are forced to make the most of the available land [1, 2]. As a result, natural and artificial fallows, traditionally practiced to restore soil fertility, are becoming less and less available [1,3]. To compensate for this soil degradation and declining crop yields, producers are using mineral fertilizers. However, the purchase price of these agricultural inputs makes them economically inaccessible to producers and compromises their adoption by low-income households that make up the majority of producers [1,4]. Faced with this situation, recourse to new alternatives is necessary. The aim is to sustainably increase the production of maize, which is mostly grown in monoculture, by combining it with legumes whose effectiveness is already proven in the fixation of nitrogen from the air and in improving soil fertility [2, 4 ; 5-12]. To do this, the research question that arises in the current regional context, is the corn-cowpea association mode that can promote an improvement in yield. Therefore, this study was undertaken to determine the corn-cowpea association modalities that would reduce the competition between maize and cowpeas and, consequently, promote an improvement in yield.

II. MATERIAL AND METHOD

A. 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 (Fig 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 [13]. According to [14], 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 [13]. 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.

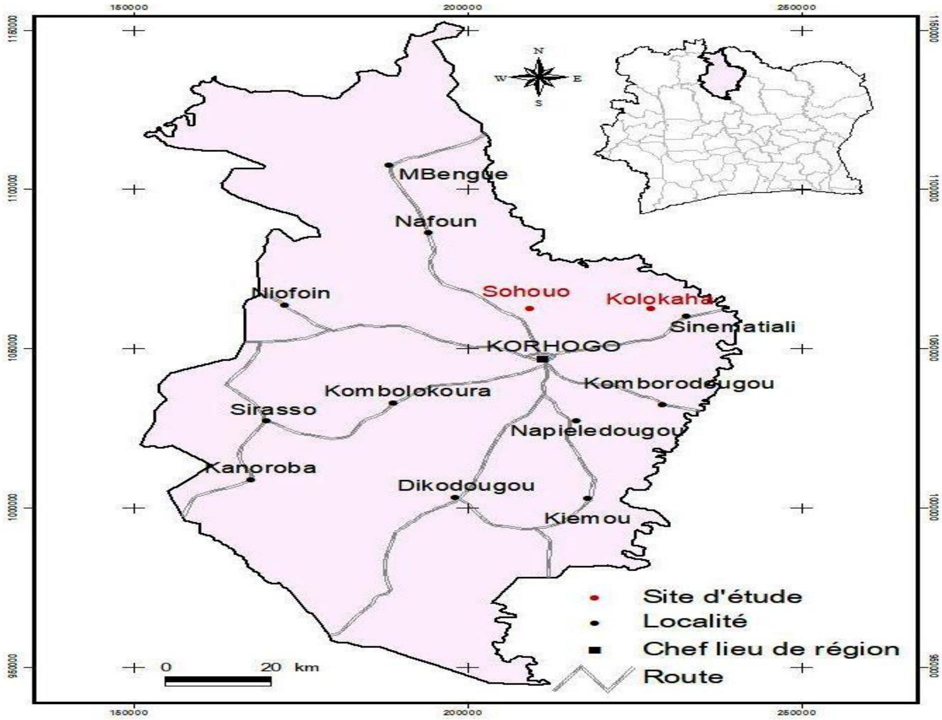

Fig 1: Map showing the location of the study areas.

B. Plant material

The plant material used consisted of two varieties of maize, namely the selected Komsaya variety and the local variety provided by farmers with or without local cowpea seed purchased from the Korhogo market. Seeds of the improved Komsaya variety are characterized by yellow-orange-coloured grains of a tooth. 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 annual rainfall ranging from 800 to 900 mm/year. According to farmers, seeds of the local variety can produce between 02 and 03 t/ha. For cowpea, the seed is characterized by a 75-day cycle. Its potential grain yield is 1.5 t/ha and adapts well to areas with annual rainfall ranging from 400 to 800 mm of water.

C. 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 subsequently gridded into three blocks and each block consists of two sub-blocks subdivided into four 30 m^2 elementary plots measuring 6 m long and 5 m wide. Each of the sub blocks within a block is dedicated to one of the varieties of maize. The interline between the elementary plots within the block is 2 m and from 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 m^2 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 (Fig 2):

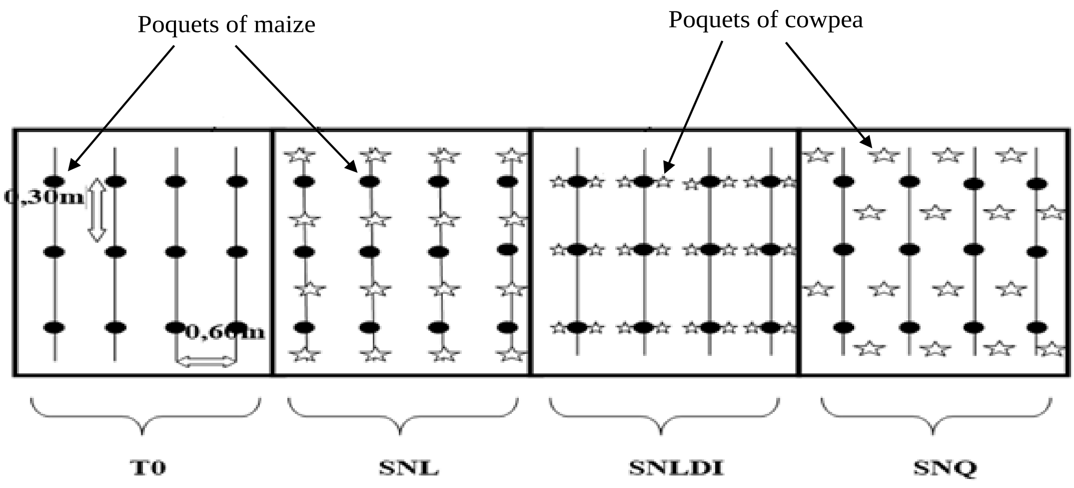

Fig 2: Maize and cowpea semi points in the association system

- **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/30m^2. All of these plots benefited from fertilizer inputs and insecticide treatments. The study was conducted during the 2018 growing season, during which the semi occurred from July 10 to 15, 2018.

D. Agronomic data collection

On each of the two demonstration plots, the harvest was carried out by block and by elementary parcel (Fig 3). The ears harvested were removed from their husks before being packed in 50 kg bags to be weighed. Then twelve (12) ears were taken by treatment to constitute the different samples. A total of forty-eight (48) corn samples were collected per study site, or sixteen (16) samples per block, equivalent to four (4) samples per sub-plot. Each sample was packaged in a plastic bag, and labeled with mentions of the treatment. For safety, and to minimize the risk of tearing during transport, the bags containing the samples were doubled. Field samples of maize were transported to the laboratory. Each corn cob has been identified by ear: the number; Block, subblock and treatment. On each ear, the length, girth and weight of the ear were measured. After the seeding, the number and mass of grains of each corn cob were determined. In addition, all the collected ears were dried by block and elemental plot in the villages by the women of the two beneficiary groups and then scinged. This was used to determine after weighing, the grain yield of corn per unit of surface.

E. Statistical analysis

Comparison of yield parameter averages and yield per unit of surface depending on seedling density and variety 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 the STATISTICA 7.1 software.

III. RESULTS AND DISCUSION

A. Results

a) Effect of variety and density of cowpea on yield components of maize.

Table I shows that the variety factor did not have a significant effect on maize yield parameters at any time of the study site. However, there was a non-significant increase of 5.19%; 3,86 % ; 9,78 % ; 13.18% and 12.32% respectively of length, girth, epi mass, grain number and grain mass per ear at plant level of the improved variety relative to the corresponding values obtained at the local variety. It is the same in Sohouo, where we observed a performance of plants of the improved variety for all of these parameters respectively of 6.88%; 5.91%; 12%; 8.86% and 19.03% compared to those of the local variety. The observation of the data in Table 1 also indicates that the three association modalities tested did not have a significant effect on length, girth, ear mass, grain number and grain mass per ear at any study site. Nevertheless, on both demonstration plots, the data collected indicate a trend towards increasing maize yield parameters at the SNL and SNLDI elementary plots against a non-significant regression of these parameters in the Compared to pure maize cultivation of any variety.

(a)

(b)

(c)

(c)

Fig. 3: Agronomic data-taking operation (a- Samples of maize production per unit of surface; collected and identified; b-Vu taking the length and circumference of the c-pup- Taking of the mass and grains of the ear)

TABLE I
Changes in corn yield parameters based on cowpea semi density, variety and study site

Density seedling	Sites	Yield parameters				
		Length ear (cm)	Circumference ear (cm)	Mass of ears (g)	Number of seeds / ears	Mass of seeds of the ear (g)
$T0_{V1}$	Kolokaha	14,51± 2,50^{bcd}	13,69± 0,78^{bcd}	135,22± 30,61^{de}	374,56 ± 104,58^{cd}	112,97± 25,95^{def}
$T1_{V1}$-SNL		14,77± 1,84^{bcd}	13,94± 0,79^{e}	139,01± 29,91^{de}	385,56± 114,19^{cde}	115,95± 34,25^{def}
$T2_{V1}$-SNLDI		14,60± 1,64^{bcd}	13,73± 1,13^{bcd}	135,53± 40,11^{de}	379,25 ± 86,51^{cd}	113,68± 31,39^{def}
$T3_{V1}$-SNQ		14,29± 2,12^{bcd}	13,50± 0,89^{bc}	125,78± 35,77^{de}	349,11 ± 90,21^{bc}	104,34± 27,04^{cde}
$T0_{V2}$		15,45± 2,06^{d}	14,16± 0,73^{e}	146,06± 37,97^{ef}	419,50 ± 109,41^{de}	125,95± 32,79^{ef}
$T1_{V2}$-SNL		15,73± 1,93^{d}	14,66± 0,77^{e}	161,99± 36,30^{f}	458,31 ± 101,10^{e}	137,58± 30,33^{f}
$T2_{V2}$-SNLDI		15,67± 2,39^{d}	14,25± 0,74^{e}	147,06± 38,09^{ef}	427,31 ± 106,37^{de}	126,27± 31,90^{ef}
$T3_{V2}$-SNQ		14,34± 1,88^{d}	13,91± 0,70^{e}	132,82± 33,60^{de}	379,58 ± 92,68^{cd}	112,19± 27,82^{def}
$T0_{V1}$	Sohouo	12,18± 2,37^{a}	12,41± 1,14^{a}	84,76± 44,13^{a}	252,36± 89,82^{a}	71,30± 31,30^{a}
$T1_{V1}$-SNL		13,49± 2,42^{ab}	13,82±1,19^{bcd}	89,98± 38,13^{abc}	269,50± 109,89^{a}	81,61±38,94^{ab}
$T2_{V1}$-SNLDI		12,37± 2,39^{a}	12,79± 1,19^{ab}	86,05± 35,19^{ab}	258,69± 93,93^{a}	76,24± 29,21^{a}
$T3_{V1}$-SNQ		12,05± 1,81^{a}	12,20±1,18^{a}	76,34± 26,83^{a}	243,72± 80,80^{a}	70,65± 22,54^{a}
$T0_{V2}$		13,44± 2,82^{ab}	13,53± 1,19^{bc}	90,80± 48,82^{abc}	274,31± 88,01^{a}	85,12± 37,02^{ab}
$T1_{V2}$-SNL		14,56± 2,44^{bcd}	14,39± 1,48^{e}	106,66± 44,17^{cd}	299,14± 116,79^{ab}	98,97± 42,73^{bc}
$T2_{V2}$-SNLDI		13,62± 2,63^{ab}	14,03± 1,04^{e}	96,78± 42,16^{ab}	288,11± 90,81^{ab}	92,20± 37,02^{bc}
$T3_{V2}$-SNQ		11,92± 2,29^{a}	12,30± 1,14^{a}	83,37± 36,54^{a}	253,47± 95,31^{a}	80,56± 31,550^{ab}
	ANOVA					
	F	12,43	20,06	21,232	19,797	22,952
	P	<0,001	<0,001	<0,001	<0,01	<0,001

In the same column, the averages followed by the same letter are not significantly different ($p > 0.05$) .$T0_{V1}$ = control treatment _ local seed, $T1_{V1}$-SNL = local seed _semis cowpea in single row interposed, $T2_{V1}$-SNLDI = local seed _semis cowpea in interbedded double line, $T3_{V1}$-SNQ = local seed _ seedlings staggered in staggered rows, $T0_{V2}$ = improved seed control, $T1_{V2}$-SNL = improved seed _semis nested in single row interposed, $T2_{V2}$-SNLDI = improved seed _semis niébé in-line double interbedded and $T3_{V2}$-SNQ = improved seed _ seedlings niébé in staggered rows.

In Kolokaha, the cumulative growth rate recorded was 2.40 per cent and 0.60 per cent, then 6.95 per cent and 0.97 per cent respectively in the local variety and improved SNL and SNDLI treatments, compared to a cumulative decline of 4.86 per cent and 7.69 per cent in S NQ of the local variety and improved compared to pure corn cultivation. On the Sohouo demonstration plot, the data showed a cumulative increase in performance parameters of 9.91% and 2.81% and then 11.5% and 4.99% respectively in the SNL and SNDLI treatments of local varieties and improved against a 3.41% and 8.31% in SNQ treatment of the local and improved variety. Thus, the SNL association method tends to further encourage increased performance parameters followed by SNDLI compared to pure maize cultivation.

b) Effect of seedling density of cowpea on maize grain yield per unit area

Table II shows the evolution of maize and cowpea grain yield as a function of density, variety and site of study. This table shows that there was no significant effect of cowpea semi density on corn grain yield per unit area compared to pure cultivation regardless of variety. Nevertheless, there was a trend at each of the two demonstration sites that there was either an increase or a decline in corn grain yield sets in some elemental plots in associated crops. Indeed, at the Kolokaha demonstration site, yield gain was 8.22% and 3.68% at the SNL and SNDLI elementary plots of improved seed and 36.07%; 22.28% and 8.75%, respectively, in SNL, SNDLI and SNQ treatments of the local variety compared to pure-grown maize plots versus a 20% decline in SNQ treatments of improved seed. Thus, at the Kolokaha site, the SNL association method was more efficient followed by SNDLI treatments regardless of the variety of maize. In Sohouo, there was a trend increase in yield of 11.18% and 4.53%, respectively, in the SNDLI and SNQ elementary plots with improved variety and 8.83% and 60.07% in the SNL and SNDLI elementary plots of the local variety against a decline 3.92% and 13.07% respectively in the SNL elementary plots of the improved seed and SNQ of the local seed. By achieving this maize performance in this association system, farmers also benefited from additional cowpea grain production ranging from 2.65 Kg to 4.88 Kg per unit area according to the terms of association whatever the study site. The results in Table II show that the yield of cowpea grain tends to increase with the density of cowpeas.

TABLE II

Changes in maize and cowpea yields obtained per unit area based on semi density, variety and study site.

Parameters	Demonstration plots			
	Kolokaha		Sohouo	
	2018		2018	
	maize	cowpea	maize	cowpea
$T0_{V1}$	$3{,}77 \pm 1{,}05^a$	-	$2{,}83\pm 1{,}42^a$	-
$T1_{V1}$-SNL	$5{,}13 \pm 1{,}43^a$	$2{,}65\pm 0{,}79^a$	$3{,}08\pm 0{,}96^a$	$2{,}78\pm 0{,}83^a$
$T2_{V1}$-SNLDI	$4{,}62 \pm 3{,}95^a$	$2{,}78\pm 1{,}58^a$	$4{,}53\pm 2{,}26^a$	$2{,}92\pm 1{,}65^a$
$T3_{V1}$-SNQ	$4{,}10 \pm 1{,}95^a$	$3{,}05\pm 2{,}18^a$	$2{,}47\pm 0{,}67^a$	$3{,}20\pm 2{,}28^a$
$T0_{V2}$	$8{,}15 \pm 3{,}27^b$	-	$3{,}32\pm 1{,}81^a$	-
$T1_{V2}$-SNL	$8{,}82 \pm 3{,}37^b$	$3{,}87\pm 0{,}25^a$	$3{,}18\pm 1{,}40^a$	$4{,}06\pm 0{,}26^a$
$T2_{V2}$-SNLDI	$8{,}45 \pm 2{,}24^b$	$4{,}65\pm 1{,}25^a$	$3{,}68\pm 2{,}42^a$	$4{,}88\pm 1{,}31^a$
$T3_{V2}$-SNQ	$6{,}50 \pm 4{,}09^{ab}$	$4{,}13\pm 1{,}85^a$	$3{,}47\pm 2{,}89^a$	$4{,}34\pm 1{,}94^a$
ANOVA				
F	3,07	0,92	0,65	0,92
P	0,01	0,50	0,71	0,50

In the same column, the averages followed by the same letter are not significantly different ($p > 0.05$) .$T0_{V1}$ = control treatment _ local seed, $T1_{V1}$-SNL = local seed _semis cowpea in single row interposed, $T2_{V1}$-SNLDI = local seed _semis cowpea in interbedded double line, $T3_{V1}$-SNQ = local seed _ seedlings staggered in staggered rows, $T0_{V2}$ = improved seed control, $T1_{V2}$-SNL = improved seed _semis nested in single row interposed, $T2_{V2}$-SNLDI = improved seed _semis niébé in-line double interbedded and $T3_{V2}$-SNQ = improved seed _ seedlings niébé in staggered rows.

B. Discussion

On all two demonstration plots, the improved variety's corn plants performed better than those of the local variety. In fact, there was a non-significant increase in length, girth, epi mass, grain number and grain mass per ear compared to the corresponding values obtained at the plant levels of the local variety.

This result is believed to be due to the difference between genotype and confirms the existence of significant inter-variety variability. This is in line with the work of [15] and [16], which have achieved similar results on cassava varieties in Côte d'Ivoire and southern Benin. It also corroborates the results of [17] which found this performance in other improved maize varieties in southwestern Niger. These authors unanimously agree that improved varieties yield significantly higher yields than local varieties. Our results also showed that the three association modalities tested did not have a significant effect on the components of yield and corn grain yield per unit of surface at any time of study site. [9] have achieved similar results in the mil-niébé scheme in Senegal. For, according to [18] and [19], the increase in semi or planting density does not affect the individual performance of the plants, as 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 semi density of the cowpea and the variety. Based on these results, it could be said that the three methods of cowpea association tested are indeed appropriate for maize in associated crops. However, on both demonstration plots, the data collected indicate a trend towards increased yield parameters and corn grain yield per unit of surface at the SNL and SNLDI elementary plots against a non-significant regression of these parameters to SNQ treatment compared to pure maize culture of any variety. The upward trend in yield parameters and the yield of maize grains per unit of surface area observed at the SNL plots followed by SNDLI are consistent with the conclusions of [20] which have shown that the combination of maize/cowpea allows better value of the resources of the environment compared to mono-specific cultures. By highlighting the impact of different dates and densities of cowpea seeding on millet growth and yield in the southern arachidier basin in Senegal, [9] observed that one-line cowpea semi-crop production promotes that production biomass, ears and millet grains. The SNL association method thus appears to be more efficient because of the distance between maize and cowpea plants which reduces interspecific competition for water, light and nutrients. However, it is thought that the semi shift, as recommended by [4], [9] and [21] could lead to better use of soil resources and, consequently, improved productivity of cultures associated with it. However, this result is contrary to those of [5] which observed non-significant declines (p -0.05) in maize yields on associated crop plots compared to pure maize cultivation during two years of testing (2014 and 2015). The same is true for [2], which achieved a decline in yam yields during the evaluation of the performance of food yam-legume associations in central-western Côte d'Ivoire. It joins the work of [6] and [18] who have made similar findings with three varieties of cowpea and plants from savannah tea cuttings (*Lippia multiflora*) tested respectively between three and four semi and planting densities in Côte d'Ivoire. Under the conditions of our experimentation, our results could be correlated with the previous crop that allowed the corn plants to benefit from the back effect of fertilizer brought to the soil during the 2017 crop season marking the first year of the project, as well as nutrients from the decomposition of previous crop residues. According to [5], the biomass supplement from legumes increases insignificantly the total forage production on parcel plots compared to the parcel of pure corn culture. This is an asset in that [5] advocate for environments where soils are poor due to over-exploitation and lack of forage for animals, associations of food crops with legumes to ensure fodder safety (forage production), food security (food production) and improve soil fertility. By achieving this performance at the maize level in this association system, farmers have also benefited from the production of additional cowpea grains, which range from 2.65 kg to 4.88 kg per unit of area depending on the terms of association regardless of the methods of association study site.

IV. CONCLUSIONS

At the end of this work, carried out during the 2018 growing season, it can be remembered that the corn plants of the improved variety performed better than those of the local variety. The results also show that the three association modalities tested did not have a significant effect on yield components and corn grain yield compared to pure cultivation regardless of the demonstration plot. evertheless, it has been observed that the SNL and SNDLI combination modalities tend to induce an increase in yield parameters and maize grain yield regardless of the study site. Ultimately, the promotion of intercropped SNL and intercropped SNDLI intercropped maize-cowpea associations could be considered in the peasant environment, insofar as they do not significantly compromise the yield of the main crop. However, the study of the cowpea semi lag with maize, in the regional context, is encouraged to allow better use of soil resources and therefore an improvement in the productivity of the associated crop.

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