Effect of intercropping sesame (Sesamum indicum L.) and cowpea (Vigna unguiculata L.) on their agronomic performance under rainfed conditions in Bambey, Senegal.

Abstract :

In a context of crop diversification and land scarcity, there is currently no practice of intercropping sesame with cowpea in Senegalese cropping systems. The aim of this experimentation is to investigate the effect of intercropping sesame with this traditional crop of Senegal's groundnut-growing region, The study was carried out during the 2021 and 2022 rainy seasons in Bambey, in the north-central part of Senegal's groundnut-growing region. It focuses on a single factor : intercropping, with three (3) treatments : sesame as a single crop (T1), cowpea as a single crop (T2) and a sesame-cowpea intercrop (T3). A randomised complete block design (Fischer blocks) with three (3) replicates is used. The variables measured mainly concerned growth parameters, yields and their components, which were used to calculate biological indicators such as LER, LEC and the percentages of land area saved (%LS). For each variable, the effects of the factor were analysed using analysis of variance (ANOVA) and means were compared using the LSD test at the 5% significance level with XLSTATS software version 2024.4.0. The results show that in the sesame–cowpea intercrop, both crops achieve the same yield levels as in their respective monoculture. A LER of 1.94 indicates higher sesame productivity and a 48% of land save. Intercropping sesame with cowpeas is beneficial and provides a solution and an adaptation strategy to land constraints. However, it would be useful to determine the combinations and spacing between crops with the newly approved sesame varieties, which have more promising morphological characteristics and could help to increase sesame productivity.

Keywords : sesame, cowpea, intercropping, biological indicators, Senegalese groundnut-growing region.

Introduction

Diversification of agricultural activities enables farmers to adapt to market volatility and/or climatic disturbances (Delaunay *et al.*, 2019). The issue of food insecurity (Andres and Lebailly, 2013), combined with the issue of land pressure on arable land, is acutely felt. In Senegal, intercropping sesame with cowpea could offer an alternative for sustainable and diversified agricultural production.

Sesame is a cash crop that provides those who grow it a substantial income, thereby helping to fight againt poverty. Its cultivation is the subject of growing enthusiasm, driven by several factors, notably the political will to establish sesame as a sustainable diversification option, its suitability for cultivation across almost the entire national territory, its early maturity, virtually non-existent barriers to entry with affordable seeds, relatively easy cultivation, low risk profile, immediate marketability, etc. (USAID, 2008). Sesame has become an alternative for several growing areas, not only because of its modest water and fertiliser requirements (Purseglove, 1982) and its drought resistance, but above all because of the desire to diversify away from the single cash crop (groundnut). It makes it possible both to enhance marginal land and to balance the farmer's work schedule, enabling them to earn, at little cost, a valuable additional income (CIRAD-GRET, 2002). This means that sesame can be grown while exploiting land currently occupied by cowpeas, groundnuts and millet. According to Hess and Dodo (2004), sesame also acts as a trap plant for Striga hermontica. Furthermore, as an erect, herbaceous annual plant, it increases water retention and soil aeration for the subsequent crop, and helps control cotton root rot and root nematodes (Naturland, 2000 ; Langham *et al.*, 2008). However, studies concerning the intercropping of sesame with other species have not been carried out to date in Senegal ; almost all plots (95 per cent) are monocultures. Plots with crops association are marginal (5 p. cent). (DAPSA, 2019).

This lack of information and knowledge regarding the use of sesame in intercropping highlights the relevance of this research topic in a context where land scarcity, due to pressure on land resources, is a limiting factor. The overall objective of this experiment is to contribute to the improvement of sustainable agricultural practices in Senegalese production systems, particularly amongst small scale farmers. Specifically, the aim is to study the potential benefits of intercropping sesame with cowpeas. This experiment is to evaluate the performance of sesame and cowpeas when intercropped compared with the corresponding monocultures.

1. Materials and methods

1.1. Experimental site

The experiment was carried out in the Bambey department, Diourbel region, in the north-central part of the groundnut-growing basin, between latitude 14°41’38 N and longitude 16°28’12 W.

The climate is characterised by two seasons : a dry and a rainy seasons. The dry season lasts nine months, from October to June. Bambey is located in the isohyetic zone ranging from 300–600 mm, with a short rainy season lasting from three to four months (mid-June to mid-October). Rainfall is also often unequally distributed, with a peak in August. The cumulative rainfall recorded at the station during the experiments in 2021 and 2022 was 529 mm over 38 days and 533.2 mm over 52 days, respectively.

Maximum temperatures ranged from 27.5°C to 41°C, and minimum temperatures ranged from 19.6°C to 29.9°C during these rainy seasons.

Relative humidity in the Bambey area varies somewhat, with a minimum ranging from 31% to 66.61%. August and September are characterised by maximum relative humidity ranging from 84.06% to 100% during 2021 and 2022.

1.1.2. Soil

The soil at the trial site has the following physical and chemical properties: 86% sand, 6% silt and 8% clay, with a pH of 6.7 ; an organic matter content of 5.9 $g.kg^{-1}$ and a cation exchange capacity (CEC) of 5.3 $mol.kg^{-1}$ (Trail *et al*., 2016).

1.1.3. Vegetation

The vegetation in the area is characterised by a wooded steppe. The main species found there are : *Azadirachta indica*, *Adansonia digitata*, *Tamarindus indica*, *Faidherbia albida*, *Acacia raddiana*, *Balanites aegyptiaca* and *Ziziphus mauritiana*. The shrub layer consists mainly of *Guiera senegalensis*, *Combretum micranthum*, *Euphorbia balsamifera* and *Acacia adansonia*. The herbaceous layer is very sparse, with species such as *Cenchrus biflorus*, *Zornia glochidiata* and *Cassia obtusifolia*, in addition to *Cyperaceae* (Fall, 2005).

1.2. Plant material

The experiments were carried out on two (02) species, sesame and cowpea, whose characteristics are set out in Table 1.

1.3. Experimental design

A randomised complete block design (Fischer blocks) with three (3) replicates was used over two years (2021 and 2022). The crop combination is the single factor, with three (3) treatments : sesame as a sole crop (T1), cowpea as a sole crop (T2) and a sesame–cowpea association (T3). Sesame and cowpea are sown as sole crops and in combination (intercropping). The experimental unit consists of a 9 m² (3 m × 3 m) plot. The plots are spaced 1 m apart and the replicates 1.5 m apart. The replicates and plots, surrounded by a 1.5 m wide strip, are arranged over a total area of 210 m² (Figure 1).

The plot of sesame grown as a pure crop consisted of 5 rows, each with 9 planting pockets spaced 0.6 m×0.3 m from each other (i.e. 45 plants, corresponding to a density of 50,000 plants.ha^{-1}) (Figure 2). The pure cowpea plot has 9 rows, each with 9 seed holes sown at a spacing of 0.3 m × 0.3 m (i.e. 81 plants, corresponding to a density of 90,000 plants per hectare) (Figure 3). The intercropped plot contains 5 rows of sesame and 4 rows of cowpea in between (Figure 4).

1.4. Crop management

Crops are managed in accordance with the technical guidelines (from sowing to harvest) recommended for each one. It covers, in particular, soil preparation (seedbed), seed treatment, sowing, thinning, maintenance and plant protection, harvesting, drying, threshing and storage.

- Sesame : 5 to 10 seeds are sown per hole and weeding 15 days after emergence, leaving 2 plants per hole ; a dose of 80 kg.ha^{-1} of NPK 6-20-10 fertiliser and 50 kg.ha^{-1} of urea are applied after weeding ;
- Cowpea : 2 seeds are sown per hole and a dose of 150 kg.ha^{-1} of NPK 6-20-10 fertiliser, equivalent to 135 g per basic plot, is applied from weeding onwards, i.e. 15 days after emergence.

1.5. Measured variables

1.5.1. Sesame measurements

- Plant height : measured regularly every week, from the 35th to the 83rd day after sowing (DAS).

- Height of insertion of the first capsule (HIFC) : this measurement is taken at maturity, starting from the collar to the point of insertion of the first capsule. The lower it is, the more likely the plant is to produce capsules.

- Number of capsules (NC) per plant: the count is carried out at physiological maturity.
- Thousand-grain weight (TGW): after the capsules have been dried and threshed, three samples of 1,000 grains are weighed for each plot.

1.5.2. Measurements for cowpea

Only yields per hectare are determined.

1.5.3. Yields and biological performance indicators

- Yields : these are based on the weight of seeds (g) obtained per plot, using formula 1 :

Yield (kg ha^{-1}) = [(Seed weight (g) : 1,000) / (Plot area : 10,000)] *(1)*

In mixed cropping, the yield of the secondary crop (occupying half the plot) is doubled to obtain its actual yield per unit area.

- Harvest Index (HI): for groundnuts, HI indicates the ratio of seed yield to haulm yield. It is calculated using the formula 2:

HI (%) = (Seed yield / Biological yield) × 100 *(2)*

- Land Equivalent Ratio (LER) : the comparison of the performance of cropping systems was carried out on the basis of the Land Equivalent Ratio (LER). The LER is defined as the sum of the partial LERs (yield of species A in a mixture / yield of species A in a pure crop). The LER is interpreted as the area of pure crop required to achieve the same production (same quantity and same proportion) as one hectare of a mixture (Willey, 1985). When the total LER is greater than 1, this means that the mixture has made better use of resources than the pure crops. If the LER is less than 1, the pure crop is more beneficial than the crop mixture. The study of partial LERs (LERp) is another way of analysing the behaviour of species.

- Land Equivalent Coefficient (LEC) : this is the product of the LER indexes for crop (i) and crop (j) and can therefore be regarded as a measure of association or interaction in terms of the strength of the relationship. It helps to determine the biological efficiency of the cropping system in terms of crop compatibility, as it effectively measures the interaction between crops, which is defined as a minimum productivity coefficient (PC) greater than 25 per cent. As indicated by Adetiloye *et al*. (1983), cited by Idoko *et al*. (2018), LEC is determined using the formula 3 :

$$LEC = (Yij/Yii) \times (Yji/Yjj) \quad (3)$$

When LEC is less than or equal to 0.25, the combination is not beneficial. There is inhibition or competition. When LEC is between 0.25 and 1, the combination is beneficial. There is complementarity between the two crops.

- Aggressivity (Agg): it's an important tool for determining a crop's competitive ability when grown in combination with another crop. An aggressivity value of zero indicates that the constituent crops are equally competitive. If both crops have the same numerical value, the sign for the dominant species will be positive and that for the dominated species negative. The higher the numeric value, the greater the differences in competitive ability and the greater the differences between actual and expected yields. The competitive ability value has been calculated using equations 4 and 5 provided by Ghosh *et al*. (2006), as cited by Idoko *et al*. (2018) :

$$\text{Agg. crop (i)} = [Yij / (Yii \times Zij)] - [Yji / (Yjj \times Zji)] \qquad (4)$$

$$\text{Agg. crop (j)} = [Yji / (Yjj \times Zji)] - [Yij / (Yii \times Zij)] \qquad (5)$$

- Percentage land saved (% LS): the percentage of land saved indicates the amount of land saved by intercropping compared to monocropping. This was calculated as described by Willey (1985), cited by Idoko *et al*. (2018), using formula 6 :

$$\% \text{ LS} = [100 - 1/\text{LER} \times 100] \qquad (6)$$

1.6. Statistical analysis

For each measured variable, an analysis of the effects of the treatments under study (ANOVA), as well as a comparison of means using the LSD test at the 5% significance level, were carried out using XLSTATS software, version 2024.4.0.

2. Results

- Summary

The tables below show the global results of the statistical analysis of the variables measured for sesame and cowpea. They cover the results for each year and the averages for the two years of the experiment. The sesame variables related to HIFC, the number of capsules per plant and the weight of 1,000 seeds show significant differences ($P<0.05$; $\alpha=5\%$) between treatments when the results are considered on an annual basis and when the two-year average is taken (Table 2).

Regarding the cowpea variables, such as the weight of 100 seeds and yield (Table 3), no significant differences were observed between the treatments.

- Change in sesame plant height

Intercop significantly reduced sesame plant height between the 42nd and 62nd jas ($P<0.01$, $\alpha=0.05$) (Figure 5).

- Height of insertion of the first capsule (HIFC)

Crop association had overall, a significant effect on the height at which the first capsule appears ($P<0.05$; $\alpha=0.05$) over the two years of the experiment. This averaged 102.4 cm in association, compared with 89.1 cm in sole crop (Figure 6).

- Number of capsules per plant of sesame

Capsule production per plant is significantly higher ($P<0.05$) in the T1 single crop (98) than in the T3 association (74) (Figure 7).

- Yields

The yield of sesame in a single crop (739 kg.ha-1) is equivalent to that in a dual crop (642 kg.ha-1).

The yield of cowpea in a dual crop maintained the same level (908 kg.ha^{-1}) as in a single crop (851 kg.ha^{-1}).

- Compétitivité et productivité

LER of 1.94 indicates higher productivity and a reduction in land use of 48.32 p. cent. In this combination, cowpea proved to be more aggressive than sesame over the two-year trial period (+1.3 and +1.2 respectively) and developed greater competitive ability (CR = 0.6). Cowpea showed a very high complementarity with sesame (i.e. LEC=0.9) (Table 4).

4.3.2. Discussion

Intercrop with cowpea slows down the growth of sesame. Sesame is susceptible to stress between the 42nd and 62nd jas. This period corresponds to the period of accelerated growth. This fast growth increases the height of insertion of the first capsule (HIFC) and reduces the number of capsules, but without significantly affecting yield. Diatta *et al*. (2013) found, for the same variety, an acceleration in sesame growth between the 36th and 48th day, where the treatment applied had a significant effect. In comparison, Bindhu *et al*. (2014) found that intercropping considerably reduced the specific weight and yield of sesame compared with sole cropping. Although the statistical analysis indicates no significant difference in yields between the two systems, a LER of 1.94 reveals higher productivity and a land saving of close to half (48.32 p. cent), similar to the combination of millet and mungbean reported by Trail *et al*. (2016) with a LER of 1.95.

Conclusion

The intercropping of sesame with cowpea provides a solution and an adaptation strategy to the constraints associated with population growth and land pressure. It could be beneficial to farmers by enabling them to save 48% of land without affecting yields. This is achieved thanks to the cowpea's aggressiveness and high competitive capacity.

By keeping the same sowing pattern for sesame as in monoculture, intercropping provides the same level of yield for both crops.

However, this experiment should be repeated with the newly registered sesame varieties, which have more interesting morphological characteristics and could help to increase sesame productivity.

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Species	Variety	Type / Origin	Provenance	Seed color	Growth cycle (days)	Performance at the research station
Sesame	32-15	Non-indéhiscent / Registered in Sénégal / Origin Burkina	CNRA Bambey	Creamy white to yellow	90	1,5 t.ha^{-1}
Niébé	Melakh	Early-maturing, indeterminate growth	CNRA Bambey	White, with a light brown eye	56	Yield : 1 t.ha^{-1} Weight of 100 seeds : 19 g

Table 1. Characteristics of the species

Table 2. Sesame variables

	HIFC (cm)			Number of capsules per plante			Weight of 1,000 seeds (gr)			Yields (kg.ha^{-1})		
	2021	2022	*Aver.*	2021	2022	*Aver.*	2021	2022	*Aver*	2021	2022	*Aver.*
T1 (sole crop)	79,3 a	98,8 a	89 a	89 a	107 a	98 a	3,7 b	4,7 a	4,4 a	685 a	793 a	739 a
T3 (intercrop)	100,9 b	103,9 a	102,4 b	63 b	84 b	74 b	3,8 b	5,0 b	4,2 b	601 a	683 a	642 a
Pr >traitement	0,017	0,179	0,006	0,001	0,008	0,0001	0,16	0,013	0,002	0,313	0,162	0,177
Signification	*	NS	**	**	**	***	NS	*	**	NS	NS	NS

For the same column, values followed by the same letter are not significantly different at the 5%. NS: not significant. * significant, ** highly significant, *** very highly significant.

Table 3. Cowpea variables

	Weight of 100 seeds (gr)			Yields (kg.ha^{-1})		
	2021	2022	*Average*	2021	2022	*Average*
T1 (sole crop)	17,5 a	19,8 a	18,7 a	877 a	825 a	851 a
T3 (ntercrop)	17,0 a	19,4 a	18,2 a	962 a	854 a	908 a
Pr > F (traitement)	0,495	0,239	0,195	0,393	0,770	0,557
Signification	NS	NS	NS	NS	NS	NS

For the same column, values followed by the same letter are not significantly different at the 5%.

NS: not significant.

Tableau 4. Biological indexes of sesame and cowpea

		Yield (kg.ha^{-1})			Land équivalent ratio (LER)		Land équivalent coëf (LEC)		Competitive ratio (CR)		Aggressivity		% Land save	
	Treatment	**2021**	**2022**	Z	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
Sesame	T1 (Yii)	685	793	1	0,88	0,86	-	-	0,4	0,4	-1,3	-1,2	-	-
	T3 (Yij)	601	683											
Cowpea	T2 (Yjj)	877	825	0,5	1,10	1,04	-	-	0,6	0,6	1,3	1,2	-	-
	T3 (Yji)	962	854											
Total					1,97	1,90	0,9	0,89					49,36	47,28
Average					1,94		0,9						48,32	

Z : proportion. Y : yield. ii et jj: sole crop. ij et ji : intercrop.

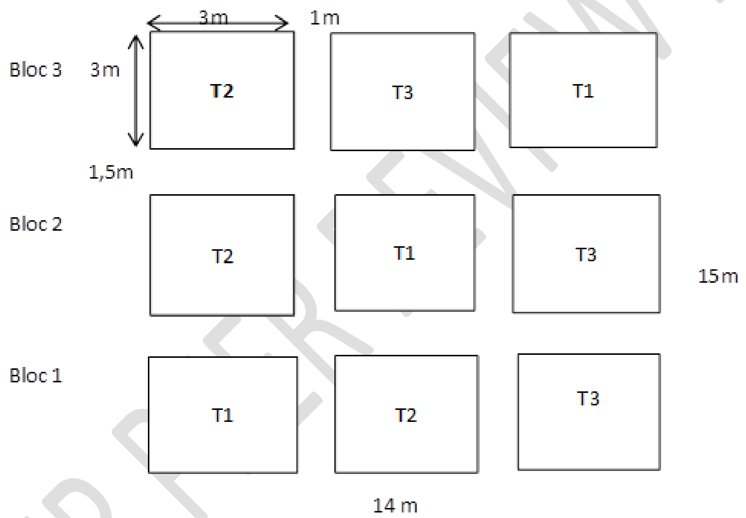


Figure 1. Diagram of the experimental device for cowpea and sesame

Legend : T1 : pure sesame plot, T2 : pure cowpea plot, T3 : cowpea and sesame intercrop.

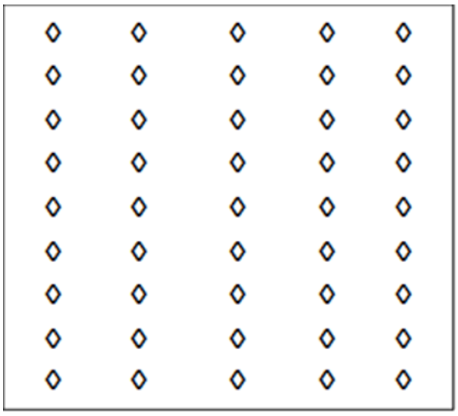


Figure 2. Diagram of a basic plot of sesame sole crop

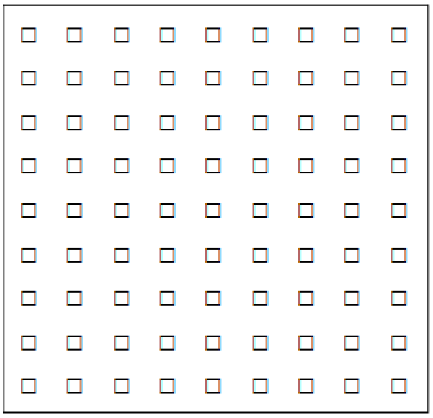


Figure 3. Diagram of a basic plot of cowpea sole crop

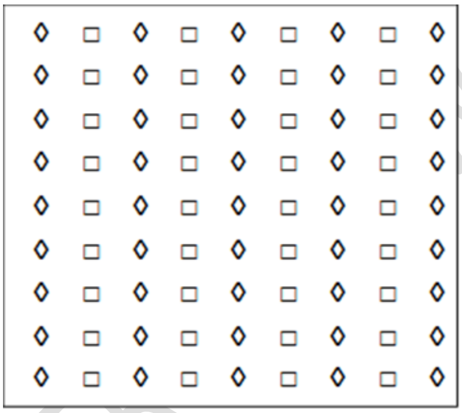
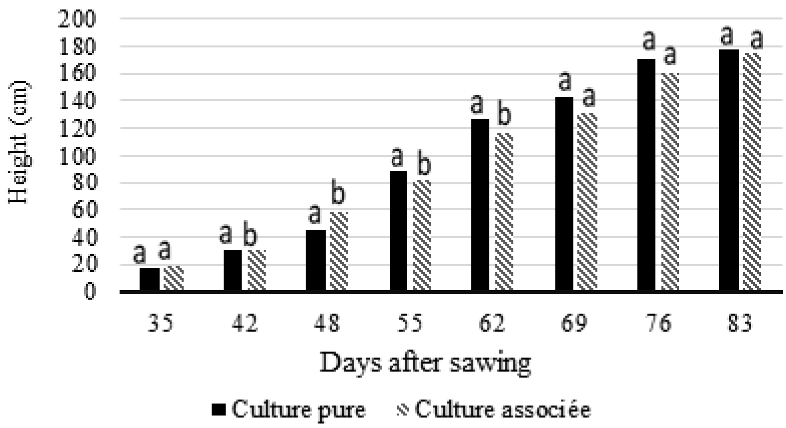


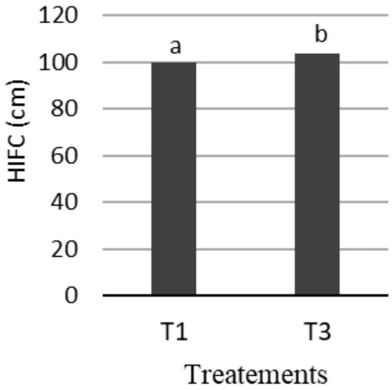
Figure 4. Diagram of a basic plot with of sesame and cowpea intercrop

◊ Sesame line □ Cowpea line



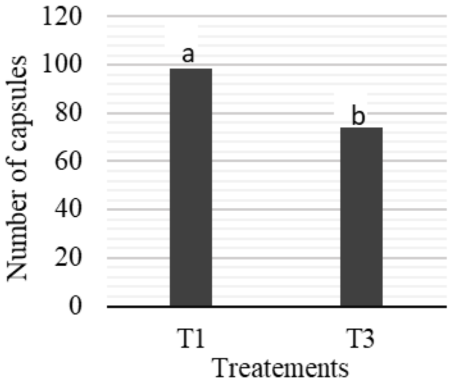
Values followed by the same letter are not significantly different at 5%.

Figure 5. Change in sesame plant height



Values that are not followed by the same letter are significantly different at the 5% significance level.

Figure 6. Height of insertion of the first capsule



Values that are not followed by the same letter are significantly different at the 5% significance level

Figure 7. Number of capsules per plant of sesame