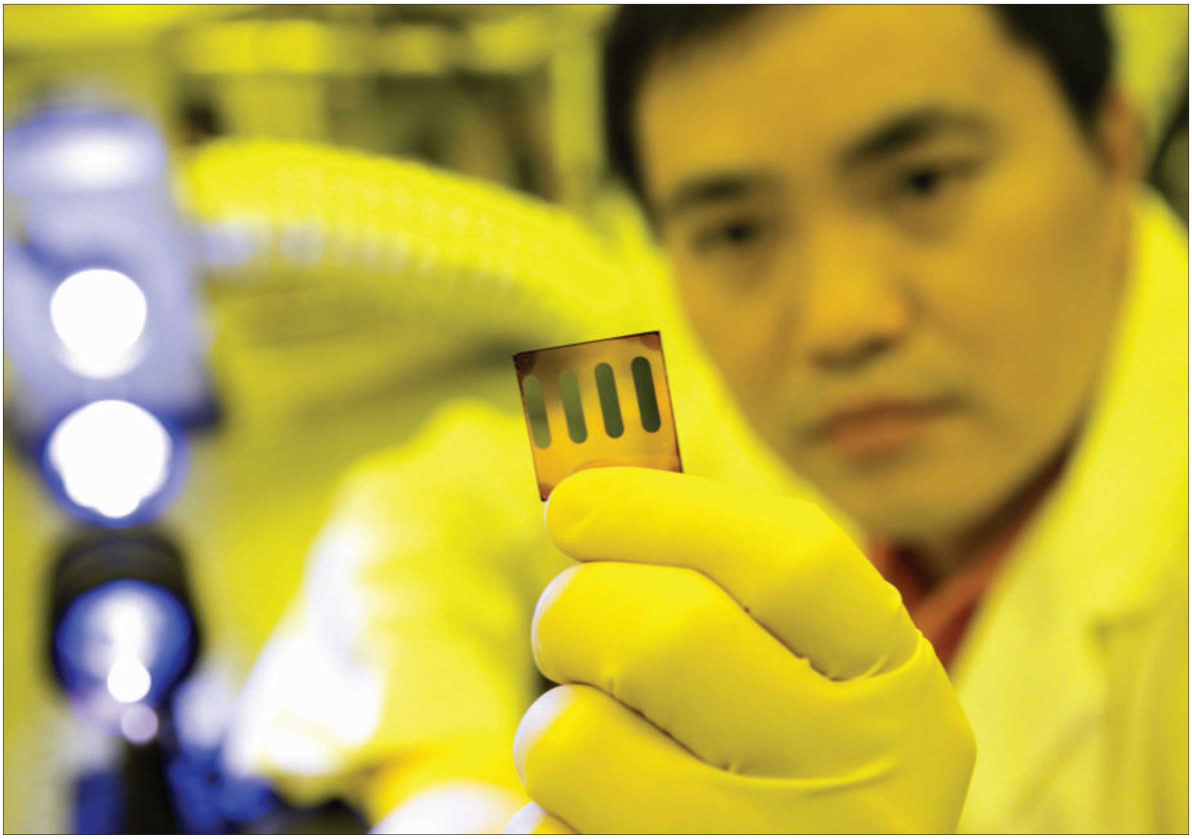

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Research Article
Effect of Cultural Precedents of Leguminous (Groundnuts, Cowpeas and Soybeans) on Maize Production (*Zea mays* L. Poaceae) in Ferkessedougou North of Côte d'ivoire

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Abstract
Background and Objective: To address the low rate of adoption of cover leguminous by farmers, the research advocates the use of food legumes in maize productivity. These leguminous have the threefold advantage of improving soil fertility and diversifying the farmer's diet and income sources. This study to assess the contribution of food leguminous to maize production was carried out in Ferkessédougou in Northern Côte d'Ivoire. **Materials and Methods:** Four previous crops consisting of groundnuts, cowpeas, soybean and natural fallow were planted using a 4-repeat Fisher block system in the first phase of the study. Then, in the second phase, the corn variety (EV-8728) was planted on the 4 previous crops. **Results:** The results showed that groundnuts produced the highest amount of dry biomass (10.62 t ha^{-1}) while soybean produced 2.67 t ha^{-1}. Weed presence was lower with the previous groundnut (0.76 t ha^{-1}) compared to soybean at 1.17 t ha^{-1}. The best results on plant height (163 cm) and grain yield (6.3 t ha^{-1}) of maize were obtained with the previous groundnut. However, yields were lower with previous soybean (3.17 t ha^{-1}) and natural fallow (3.05 t ha^{-1}). **Conclusion:** Groundnuts set the best precedent for maize production. It produced the best dry biomass and reduced weed proliferation. It has led to an improvement in plant height and maize yield.

Key words: Maize, groundnut, cowpea, soybean, leguminous, production

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Maize (*Zea mays* L.) is the most widely grown food in the world and the first cereal produced in front of rice and wheat[1]. It presents a great morphological and physiological variability; which favored its cultivation in tropical and temperate regions[2]. World maize production is 1,113,746,667 t in 2017 with a crop area of about 187,959,116 ha and an average yield[3] of 5.6 t ha^{-1}. Maize is the most energetic grass because of its many nutritious assets, namely its richness in starches, proteins and mineral salts[4]. At the economic level, it remains the most important and profitable grain[5]. In Côte d'Ivoire and most of West Africa, maize is mainly used for human consumption where it is the staple of the diet of rural people. It is also used for animal feed (poultry, pigs, cattle) and is used as raw material in some industries, including the brewery, the soap factory and the oil mill[6]. For a long time considered as a simple product of subsistence, the maize is today an agricultural speculation which intensifies in Ivory Coast, because of its economic stakes become more and more important[7]. The second most cultivated cereal in Côte d'Ivoire with a production of 680 000 t for an area of 344 126 ha, maize occupies about 40% of the land sown, with an average yield[3] of 1.9 t ha^{-1}. The maize production system is still traditional (extensive and itinerant type) and often uses "fallow-subsistence" rotation to restore soil fertility[8]. However, high population growth has resulted in a lack of arable land[9]and reduced fallow land, leading to soil degradation and low crop yields[10]. Chemical fertilization (nitrogen fertilizer), which was considered as an alternative, has increased agricultural production. However, it appears inappropriate, as it is costly for farmers and has little regard for environmental balance[11,12]. In this context, leguminous, because of their many advantages (autonomy in terms of nitrogen nutrition, abundant production of plant biomass, weed control), are generally more appropriate[13,14]. It has been proved that cover leguminous such as *Pueraria phaseoloides*, *Crotalaria micans*, *Cajanus cajan*, etc., improve soil fertility[15-17]. However, their adoption in traditional systems remains problematic[18]. This for several reasons among which, the two major ones are:

- The small subsistence farmer is reluctant to invest in soil improvement
- The cultivation of a plant, even if it is a leguminous plant, from which the farmer receives no immediate benefit meets very little favorable echo

In order to overcome the low adoption rate of cover crops by farmers, research recommends the use of edible leguminous such as soy (*Glycine max* L., Fabaceae), cowpea (*Vigna unguiculata* L., Fabaceae) and groundnut (*Arachis hypogaea* L., Fabaceae) in maize productivity (*Zea mays* L., Poaceae). These leguminous have the dual benefit of improving soil fertility and diversifying the farmer's diet and sources of income.

This study is part of studies to improve maize production. It aims to evaluate the effect of previous leguminous crops (soybean, cowpea and peanut) on maize production. It is more specifically a question of determining the best cultural precedent for maize, but also of identifying the one that reduces the pressure of weeds on maize the most.

MATERIALS AND METHODS

The study was carried out at Ferkessédougou from June, 2015 to December, 2016.

Material

General characteristics of the study area: The test was set up at Ferkessédougou in Northern Côte d'Ivoire, between 10°30 and 8°35 West longitude and between 5°55 and 3°30 North latitude (Fig. 1). The climate is tropical sub-humid or Sub-Sudanian in transition[19], with a dry season from November to April and a rainy season from May to October. The shale soils are moderately to slightly desaturated, yellow-ocher in color. The vegetation of the Ferkessédougou region is a wooded Guinean (or sub-Sudanese) savannah, with varying levels containing small pieces of detached forest[20].

Vegetal material: Vegetal material used in this study consists of maize (*Zea mays* L.), Variety EV-8728 and 3 leguminous: soybean (*Glycine max*), Canarana variety, cowpea (*Vigna unguiculata* L.), KN1 variety and peanut (*Arachis hypogea* L.), local variety.

Chemical inputs: The products used consisted of herbicide and insecticide. Round up (Glyphosate) was used against weeds and decis (Deltamethrin) was applied as an insecticide. Chemical inputs were chosen based on their frequent use in cereal crops and leguminous and also on their commercial availability.

Technical material: The technical equipment consisted mainly of scales to weigh the samples (OHAUS balance (sensitivity 0.01 g) and Naval (sensitivity 50 g), a ruler 3 m long graduated in cm to measure the height of the plants.

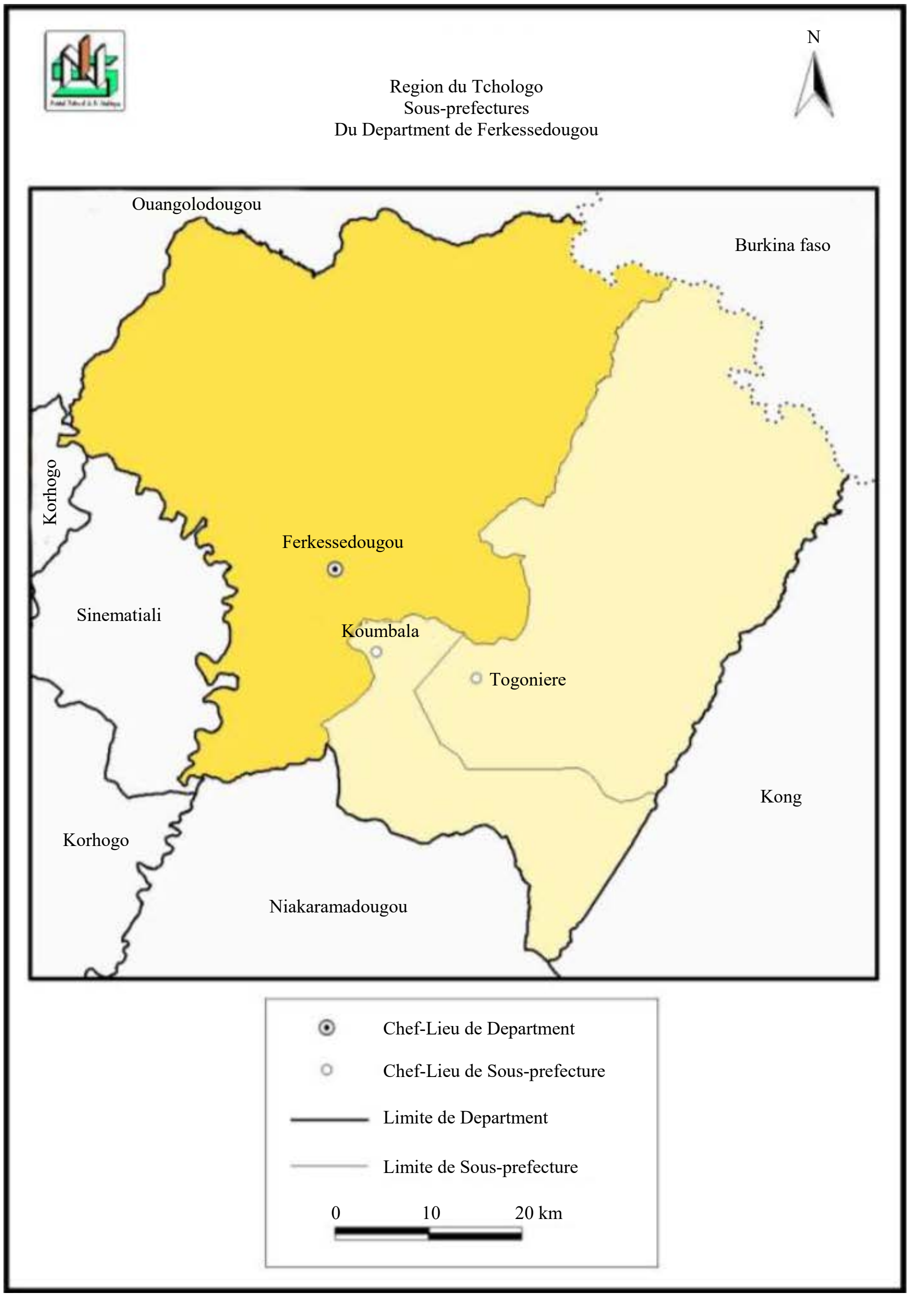

Fig. 1: Presentation of the study area
Source: RGPH[22]

Methods

Preparation of the ground: The land preparation was not the same for the establishment of leguminous and for the cultivation of maize.

For previous leguminous crops, clearing of the plot was done with a rotary cutter and the debris was collected outside the plot. Then a first plowing of a depth of 50 cm was made with a plow, followed by a second plowing done with the daba in order to break the clods of earth and to level the ground. Finally, the picketing was carried out to delimit the elementary parcels, the blocks as well as the alleys.

For maize, field preparation after leguminous cultivation consisted of: treating the experimental plot with round up herbicide (glyphosate) at a rate of 4 L ha^{-1}. Then, the dried vegetation was mown by a rotary cutter. Finally, the application of crop residues (leaves) of leguminous on the respective plots was carried out to form a mulch.

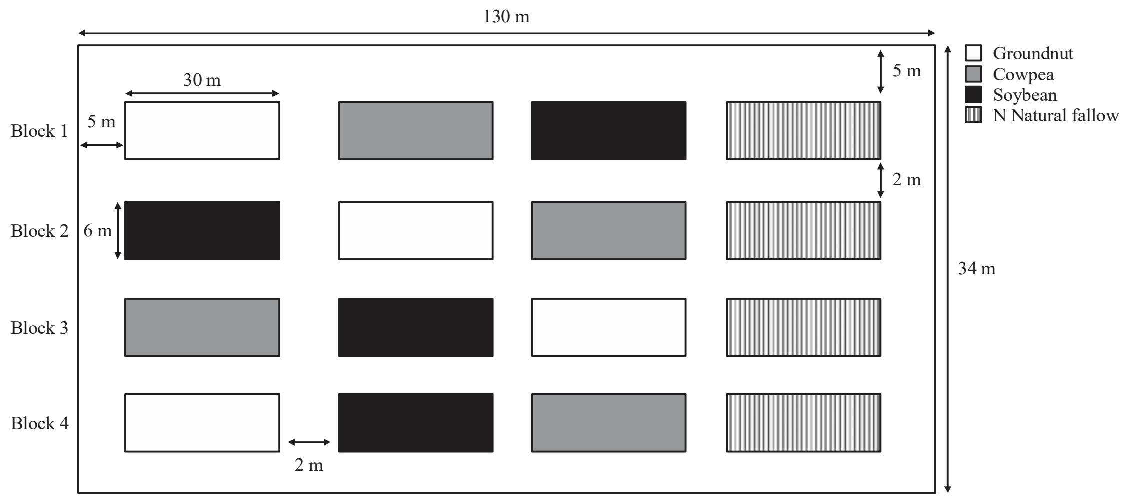

Fig. 2: Experimental fischer block device used for the study of the effect of different previous crops

Experimental set-up and implementation of the test: The experimental setup consists of Fischer blocks with 4 repeats (Fig. 2). Each block contains 4 elementary plots of 180 m^2 (30×6 m) and each plot has 3 observation plots of 4 m^2 each (2×2 m) along a diagonal line. Paths of 2 m are arranged between 2 plots and between 2 blocks. The total area of the plot is 4420 m^2 (130×34 m).

The trial was set up in 2 phases:

- The first phase is that of the establishment of previous crops namely groundnut (A), cowpea (N), soy (S) and natural fallow (JN). Groundnut, soybean and cowpea are randomly placed on the elementary plots in each block. Natural fallow (JN) has been delineated and set up at the end of each block. Groundnuts were sown at a density of 50×15 cm, cowpea at 40×20 cm and soybean at 50×10 cm
- The second phase concerned the cultivation of maize. It was sown on all the elementary plots at the density of 80 cm x 40 cm

Maintenance work: The maintenance work carried out during the trial consisted first of a new sowing at the missing patches 3 days after the emergence of the leguminous and maize. Then, 2 weeks after emergence, the plants were dismarried at 2 feet/pot for leguminous and 1 foot/pot for maize. In addition, manual weeding was carried out when needed for leguminous and at 3 periods for maize, including at demarcation, 15 days after demarcation and at runoff. Finally, an insecticide treatment with Decis (Deltamethrin) at a rate of 1 L ha^{-1} was carried out on all the elementary plots for both maize and leguminous.

Measured parameters: For each treatment, the parameters studied were evaluated at the observation plot level for both leguminous and maize.

Leguminous parameters

Dry biomass: The aboveground biomass (stem, leaves) of leguminous mowed at harvest was dried. Then, the weight was determined using the "NAVAL" brand electronic scale and extrapolated to the hectare.

Seed yield: The seeds removed from the pods of dried leguminous were weighed and weighed in the scale. Then, the seed yield was determined by the following equation[21]:

$$\text{Seed yield}\left(\text{t ha}^{-1}\right) = \frac{\text{Dry weight of seeds (kg)}}{\text{Observation surface (m}^2)} \times \frac{10000 \text{ m}^2}{1000} \quad (1)$$

Maize parameters

Dry weed biomass: The dry weight of the aboveground biomass (stem and leaves) of weeds mowed during the various weeding operations was determined using the electronic scale (g m^{-2}) and then reported in tonnes per hectare (t ha^{-1}).

Plant height: After the milky grain stage, 83 days after sowing (JAS), the average height of 5 randomly selected plants in the yield squares was determined. The height was measured using a graduated ruler from the base at ground level to the apical end of the stem. The average height of the plants in each treatment was obtained according to the equation:

$$X = \frac{\sum xi}{Ni} \quad (2)$$

Where:
X = Average of the plant heights
xi = Height of plant and
Ni = Total number of plants observed/treatment

Number and weight of ears: The ears harvested from each yield square were counted manually and the average number of ears m^{-2} was calculated. The weight of these was determined by weighing and expressed in t ha^{-1}.

Yield in grains and weight of 100 grains: The air-dried ears (up to 12%) were ginned. Then, for each treatment, the grains were gutted, their weight determined and the grain yield per hectare calculated according to Eq. 1.

Subsequently, batches of 100 grains were counted and weighed using the electronic scale to determine the weight of 100 grains.

Statistical analysis: The Statistica version 7.1 software was used to analyze the data collected. The analysis of variance test (ANOVA) with a classification factor was used to evaluate the effect of each leguminous used in the previous crop on the parameters and on the productivity parameters of maize. In case of significant differences between the averages, the Newman-Keuls multiple comparison test at the 5% threshold (α = 0.05) was performed to classify them into homogeneous groups.

RESULTS

Leguminous parameters

Dry biomass: The dry biomass production of leguminous (groundnuts, cowpeas and soybean) is illustrated in Fig. 3. Variance analysis revealed a very significant difference (p<0.001) between the different leguminous for this parameter. Groundnuts proved to be the leguminous with the highest dry biomass production with a yield of 10.62 t ha^{-1}. This leguminous was followed by cowpea variety KN1, which produced 8.5 t ha^{-1} of dry biomass. Soybean had the lowest dry biomass production at 2.67 t ha^{-1}.

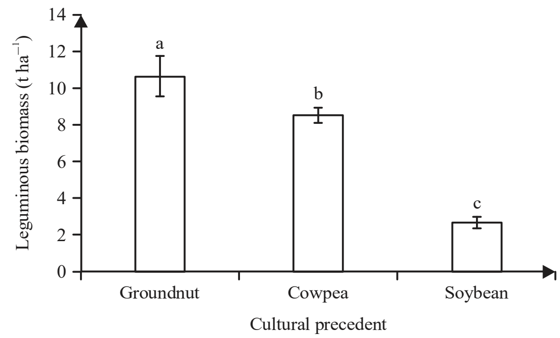

Fig. 3: Dry biomass of food leguminous used as precedents cultural

Bars surmounted by the same letters are not statistically different at the 5% threshold of the Newman-Keuls test

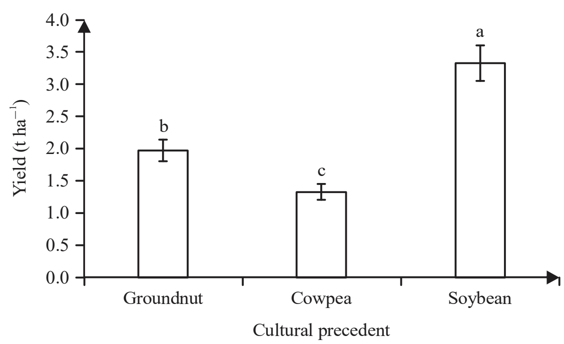

Fig. 4: Seed yield of food leguminous used as crop precedents

Bars surmounted by the same letters are not statistically different at the 5% threshold of the Newman-Keuls test

Seed yield: The results of the statistical analysis on the dry weight of leguminous grains show a highly significant difference (p<0.001) between the three food leguminous used (Fig. 4). Indeed, the dry weight of leguminous grains varied between 3.32 and 1.32 t ha^{-1}. The grain yield of leguminous was higher for soybean at 3.32 t ha^{-1}. Soybean were followed by groundnuts (1.97 t ha^{-1}) and cowpeas (1.32 t ha^{-1}).

Maize parameters

Dry biomass of weeds: The analysis of variance showed a very significant difference (p<0.001) between the different previous crops for weed biomass. This varied between 0.76 and 1.17 t ha^{-1} with an average of 0.98 t ha^{-1} and a coefficient of variation (CV) of 18.14% (Table 1). The smallest amount of weeds (0.76 t ha^{-1}) was obtained with the previous groundnut. On the other hand, the dry weed biomass was higher on soybean plots (1.17 t ha^{-1}). The cowpea-maize and natural fallow-maize rotations showed intermediate weed dry biomass values of 0.97 and 10.5 t ha^{-1}, respectively.

Height of maize plants: The height of maize plants according to the previous crop, 83 days after sowing (JAS) is shown in Fig. 5. The results revealed a very significant difference ($p<0.001$) at the 5% threshold of the Newman-Keuls test between previous food leguminous crops and natural summer fallow (NJ) for this assessed parameter. The average height of maize plants for all treatments was 146.62 cm. The previous groundnut (A) induced the highest plant heights with an average of 163 cm. To a lesser degree, the maize plants of the natural fallow (JN) and the previous cowpea are at 149.75 and 141 cm, respectively. The lowest plant heights (132.75 cm) were observed with the previous crop soybean (S).

Number and weight of maize cobs: Table 2 shows the number of maize cobs obtained m^{-2} and the weight ha^{-1} of these cobs according to the previous crop. There was no significant difference between treatments for the number of ears ($p>0.001$). However, for the weight of ears the difference was very significant ($p<0.001$) between the different treatments (Table 2). The previous groundnut plot (A) gave the best performance with a yield of 7.65 t ha^{-1} followed by cowpea (N) with 4.92 t ha^{-1}. However, natural fallow (JN) and previous soybean (S) with 3.95 and 3.83 t ha^{-1}, respectively induced the lowest maize cob weights.

Yield in grains: The effects of previous crops on maize grain yield were highly significant ($p<0.001$) and are shown in Fig. 6. The maize plants in the plot with the previous groundnut were the most productive with a grain yield of 6.33 t ha^{-1}. A yield of 4.30 t ha^{-1} of maize grain was obtained with the cowpea treatment (N). The lowest maize kernel yields (3.17 and 3.05 t ha^{-1}) were observed on the previous plots and soybean (S) and natural fallow (JN), respectively.

Weight of 100 maize grains: The previous cultural effect was significant ($p<0.001$) on the weight of 100 maize grains. The analysis of variance followed by the Newman-Keuls test at the 5% threshold made it possible to group the previous crops into two homogeneous groups (Fig. 7). The first group consisted of the peanut-maize and cowpea-maize rotations that induced the highest 100 grain weights with 25.80 and 24.45 g, respectively. The second group was formed by the previous soybean and natural fallow with weights of 100 maize grains of 22.87 and 22.45 g, respectively.

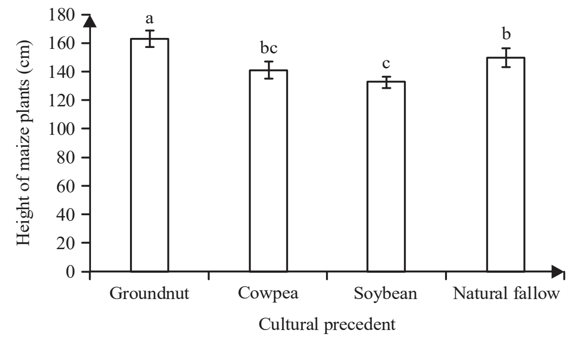

Fig. 5: Heights of maize plants 83 JAS according to the previous crop

Bars surmounted by the same letters are not statistically different at the 5% threshold of the Newman-Keuls test

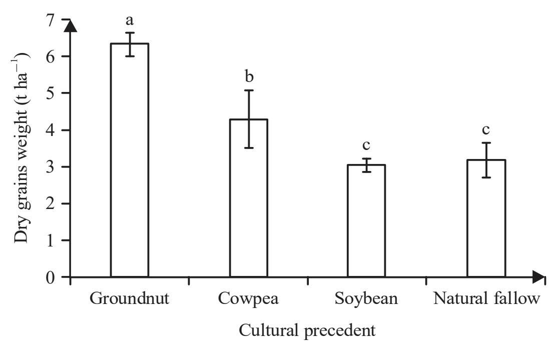

Fig. 6: Dry weight of maize grains (t ha^{-1}) according to the previous crop

Bars surmounted by the same letters are not statistically different at the 5% threshold of the Newman-Keuls test

Table 1: Weight of dry weed biomass (t ha^{-1}) as a function of the previous crop

Cultural precedent	Dry biomass of weeds
Groundnut	0.76 ± 0.047^a
Cowpea	0.97 ± 0.025^b
Soybean	1.17 ± 0.025^c
Natural fallow	1.05 ± 0.064^b
Average	0.98
Probability	<0.001
CV (%)	18.14

Figures in the same column, with the same letter, do not differ significantly from the 5% threshold of the Newman-Keuls test, CV: Coefficient of variation

Table 2: Number and weight of maize cobs according to the previous crop

Cultural precedent	Ears number of maize m^{-2}	Dry ears weight (t ha^{-1})
Groundnut	7.25 ± 0.30^a	7.65 ± 0.22^a
Cowpea	6.50 ± 0.50^a	4.92 ± 0.27^b
Soybean	5.75 ± 0.00^a	3.83 ± 0.06^c
Natural fallow	6.00 ± 0.30^a	3.95 ± 0.20^c
Average	6.37	5.09
Probability	> 0.001	< 0.001
CV (%)	16.06	32.02

Figures in the same column, with the same letter, do not differ significantly from the 5% threshold of the Newman-Keuls test, CV: coefficient of variation

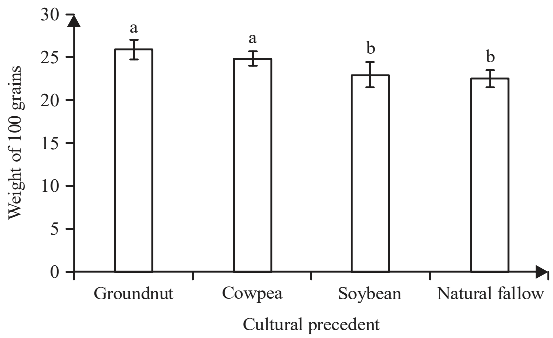

Fig. 7: Weight of 100 grains (g) according to the previous crop
Bars surmounted by the same letters are not statistically different at the 5% threshold of the Newman-Keuls test

DISCUSSION

The results showed that groundnuts produced the largest amount of dry aerial biomass. This shows that this leguminous, used as a cultural precedent for the cultivation of maize, provides a significant amount of residues which, after decomposition by microorganisms, will constitute a source of organic matter that can restore the cultivated soils and enrich them with available mineral elements[23]. According to Ruganzu *et al.*[24], several studies have shown the importance of organic matter in improving soil fertility. Indeed, the decomposition of plant residues, by releasing organic compounds that have a stimulating action on the decomposition of pre-existing organic matter in the soil, considerably improves the level of nutrients in the soil[25,26]. The enrichment of the soil with plant debris could induce significant mineralogical transformations that will affect the availability of certain soil elements[27]. In addition to improving the organic and mineral qualities of soils, leguminous, through high production of dry biomass and good soil cover, help maintain good soil moisture, which is necessary for optimal nodule production, as well as good soil conservation against erosion[28]. These results showed significant effects between different leguminous for grain yield. Indeed, the soybean that produced the highest seed yield was followed by peanut and cowpea. The difference observed between these crops could be due to the genetic make-up of the different leguminous varieties used. But also to the use of nutrients, especially atmospheric nitrogen fixed by them. Soya would therefore have used almost all of this nitrogen for the production of its seeds, unlike groundnuts and cowpeas, which use it to improve maize production. These leguminous used are of particular interest to farmers because they provide them with products for family self-consumption, but also a source of income through the sale of these products[29].

Weed control is an important aspect that concerns farmers. Previous groundnut plots had the lowest weed infestation rates compared to other treatment plots. This could be explained by the high amount of dry biomass produced by this leguminous. These results are in line with the results of the work of Zegda *et al.*[30] which showed that a significant quantity of de mulch de angler pea slows down the development of weeds in rice cultivation. In addition, Adetimirin and Kim[31] showed that early maize fertilization reduced the level of parasitism in the Striga. For these authors, the role of leguminous is not only to serve as false hosts for Striga, but also to contribute to soil fertility by providing significant amounts of nitrogen. Rotation with maize has reduced the negative effects of the pest. In addition, according to Hasnaoui[32] work, the rotation of maize with leguminous disrupts the growth cycle of weeds and prevents them from adapting to a given cropping system. Similarly, for the latter, this weed control method is not only environmentally friendly, but also reduces the cost of purchasing chemical herbicides, which are costly for farmers.

Groundnuts have greatly reduced the presence of weeds and this would also explain the good growth of maize in the plots of this previous crop. Indeed, the low proportion of weeds in these plots reduces competition between maize and weeds for nutrients, light and water[33]. The higher maize plant heights observed with this leguminous would probably be due to higher nitrogen fixation in groundnut nodules[9]. Indeed, nitrogen is the mineral element that promotes cell multiplication and vegetative growth of crops[24,34]. It also stimulates the active growth of young organs by increasing plant height, stem diameter, number of branches and leaves[35].

The lack of significant difference between treatments for the number of ears of maize of the variety EV-8728 could be explained by the genetic character of the variety. These observations are consistent with those made by Mansour-Gueddes *et al.*[36], who showed that some production parameters are genetic in nature.

The results showed significant differences between the treatments for the dry weight of ears, grains and 100 grains of maize. The best performances obtained in previous groundnuts and cowpeas would result in a higher production of fixing nodules in these leguminous compared to soybean[37]. These authors found a significantly higher number of fixing nodules (262 nodules m^{-2}) in the cowpea variety KN1 than in the soybean variety Canarana (199 nodules m^{-2}). This implies a more intense activity of symbiotic bacteria in the groundnut and cowpea varieties used than in soybean varieties, while the more important symbiotic activity implies a more intense nitrogen fixation and consequently a higher nitrogen release at ground level. Moreover, the decomposition of crop residues from leguminous buried in the soil contributes to its enrichment in organic matter and to the increased mineralization of nitrogen by the action of microorganisms. Nitrogen being the essential mineral element for plant metabolism, its absorption followed by its use leads to the formation of proteins considered as the essential components for the formation of living matter in plants[38-40], by evaluating the effect of groundnut and soybean on maize production, showed that groundnut was the best nitrogen provider, resulting in an 18% increase in maize yield. However, the low yields obtained on the natural fallow plot may be due to the fact that the observed 3 years period was not sufficient to restore the soil fertility necessary for good maize production. In addition, the work of N'Dayegamiaye *et al.*[41] showed that the use of leguminous such as hairs and alfalfa significantly improves soil properties, as well as yields of subsequent crops (maize), which means that these cropping systems are appropriate to increase gains in the medium term. With regard to natural fallow land, our results are different from those of Konaté *et al.*[37], which showed that a three-year natural fallow land had improved growth parameters and upland rice yield in the locality of Gagnoa.

SIGNIFICANCE STATEMENT

The study aims to determine the best legume food crop precedent for corn that most effectively reduces weed pressure on maize. This study has shown that peanut is the best precedent for corn production. It produced a large amount of dry biomass and reduced weed proliferation. It induced an improvement in plant height and maize yield. This study will help the researcher address the low adoption rate of cover legumes by farmers. Cover legumes not only improve soil fertility, but also diversify the farmer's diet and sources of income.

CONCLUSION

This study was undertaken to evaluate the effect of 3 leguminous on maize production (var EV-8728). It has been found that groundnut produces the largest amount of dry biomass. The previous groundnut crop has reduced weeds, but also improved plant height and maize grain yield. On the other hand, the lowest performances were obtained with previous soybean and natural fallow. As this study only covered the variety EV- 8728, these experiments should be repeated with other maize varieties to confirm these results.

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