OPEN ACCESS
Global Journal of Research in Agriculture & Life Sciences
Volume 02| Issue 02 | March-April | 2022
Journal homepage: https://gjrpublication.com/journals/
Review Article

Impact of cropping association on the growth and productivity of Castor bean (*Ricinus communis L.*) grown in fields in the high plateau area of western Cameroon

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Submission Date: 15th March 2022 | **Published Date:** 08th March 2022

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Abstract

Our study was conducted in West Cameroon; respectively in the high plateau area in Dschang from April to December 2021. A completely randomized experimental device with three repetitions of three treatments was used: in monocrop (Castor bean), then in crop association (Castor bean-Feb 192 and Castor bean-Ecapan 021). Castor bean growth and production parameters were evaluated. The comparison of the performances of the cropping systems was made on the basis of the Land Equivalent Ratio (LER). The results show that the growth and productivity of Castor bean are influenced by the crop association, the edaphic and climatic characteristics (sandy clay soil and tropical climate) of the study area. The yield of Castor bean seeds in crop association is 4.26% and 3.28% higher than that of Castor bean in monocrop respectively for the treatments. Ricin-Ecapan and Ricin-Feb 192. The castor bean is significantly ($p<0.05$) in cultural association with the Ecapan variety of bean. The LER varies from 1.02 in the Castor bean-Ecapan crop association system to 1.01 in the Castor bean-Feb 192 crop association.

INTRODUCTION

For several millennia, human activities, and in particular agriculture, have led to the gradual transformation of a large part of the earth's surfaces (Burel and Garnier 2010). Following demographic and economic transitions, societies seem to follow a sequence of different land use patterns. This results in landscapes more or less marked by the imprint of agriculture in the form of intensive production systems (Foley et al., 2005). Intensive agriculture is an agricultural production system characterized by the high use of inputs, which seek to maximize production through labour or the use of various inputs. It is sometimes also called productivism agriculture. It is based on the optimum use of chemical fertilizers, herbicide treatments, fungicides, insecticides, growth regulators, pesticides. This mode of production weakens (see endangers) the environment. Many problems related to (Burel and Garnier, 2010). According to estimates compiled by the Food and Agriculture Organization (FAO), by 2050 food production will need to increase by 60% to feed a world population of 9.3 billion. Several dimensions: we must produce more to feed more mouths, ensuring a balanced diet for all and respecting the environment more. This requires agriculture that consumes less energy, less water, and preserve water and soil quality. But the changes will also come from our consumer choices and behaviours. (FAO, 2022). To contribute to meeting the multiple challenges of the sector, legumes establish symbiotic relationships with soil micro-organisms (Rhizobium's) capable of fixing atmospheric nitrogen through root nodules, and thus provide the plant with part of its nitrogen needs. Associated with crops that do not fix nitrogen, such as castor bean with legumes, sets up a process of niche complementarity for the nitrogen in the environment. This technique has shown its performance in organic farming, where the addition of nitrogen is less frequent, because it is more expensive (Bedousset et al., 2010).

The castor bean *(Ricinus communis* L.) is an oilseed plant with an oil content between 40 and 60% Derogoh et al 2020; Derogoh et al 2021; Tchuenteu et al., 2021). Castor bean oil is widely used for its lubricating and medicinal properties. In industry, Castor bean oil is used to make soaps, lubricants, hydraulic and brake fluids, paints, dyes, coatings, inks, cold-resistant plastics, waxes and polishes, nylon, pharmaceuticals and perfumes (Duke, 2003).

The Castor bean yield depends on the genotype, but is also on the environmental conditions of cultivation and the type of cultivation practices (Koutroubass et al., 1999). In this regard, with a view to diversifying the supply of SODECOTON oil mills; Tchobsala et al. (2008) list 16 local Castor bean accessions in North Cameroon; Djonbada

(2009) cultivates these local Castor bean accessions in the cotton-growing area of Cameroon and finds that the Motso 1, Motso 2 and Ndoutourou Castor bean accessions have the best seed yields. Tchuenteu et al. (2013a), study the variability of Castor beans grain yield in the Sudano-Guinean and Sudano-Sahelian zone of northern Cameroon and report that Castor bean plants could be grown satisfactorily from both study areas. Also, these authors study the effects of intercropping systems of Castor bean with maize and common bean in the Sudano-Guinean zone of Cameroon and report that the legumes are known to fix atmospheric nitrogen, thereby enriching soil fertility and helping to meet plant N requirements (Manna, 2008). In addition, the work of Derogoh et al. (2018) revealed that certain legume species such as beans perform better in intercropping than cowpea and soya bean.

Therefore, the present study aims to study the growth and yield of Castor bean plants, in cultural association with two varieties of common bean (Ecapan 021 and Feb 192) grown in the field in the agroecological zone of the highlands of the region of l West Cameroon.

Material and methods

Description of the experimental areas

The field study took place in May 2022 in the multipurpose station of the Institute of Agronomic Research for Development (IRAD) of Dschang, located in the Department of Menoua (West region of Cameroon)

This locality of Dschang is known to have a tropical type climate, heavy rainfall most months, with a short dry season. The average annual temperature in Dschang is 19.7 °C. Annual rainfall averages 4473 mm (Climate data, 2022.)

Biological material

The seeds of the Motso I Castor bean accession, the bean varieties (Feb 192 and Ecapan 021) obtained from IRAD Foumban were used in this study. These varieties were chosen for their early germination, their adaptability to the rainy season and their short reproduction cycle (Table 1). The use of a variety presented with a short reproduction cycle is advantageous for the farmers insofar as they can have several harvests per year if they are cultivated against the season. (Tchuenteu et al., 2013a)

Table-1: Some characteristics of the varieties of sheaths used **(**IRAD, 2013; Tchuenteu et al., 2013a)

Seeds		**Characteristics**
Accession Motso I		Colour type: kidney red Vegetative cycle: 75 days Seed sizes: large seeds Potential yield: 1.5 to 2 tons per hectare
Varieties Ecapan 021		Colour type: Red mottle Vegetative cycle: 75-80 days Yield potential: 2,000 to 2,500 (kg/ha)
Feb 192		Colour type: kidney red Vegetative cycle: 75 days Seed sizes: large seeds Potential yield: 1.5 to 2 tons per hectare

Experimental device

The experimental device consisted of 03 treatments therefore one in monocrop (Castor beans and two in intercropping (common bean-Ecapan 021 and common bean-Feb 192), randomly arranged and repeated in three blocks. Each of the 9 elementary plots had a usable area of 18 m 2 (6 m × 3 m). The total area of the trial was 280 m 2. The

Castor bean plant in monocrop and intercropping was planted in three columns separated by 1 m each. The distance between two consecutive plants within the crop association is 0.5 m between each Castor bean plant.

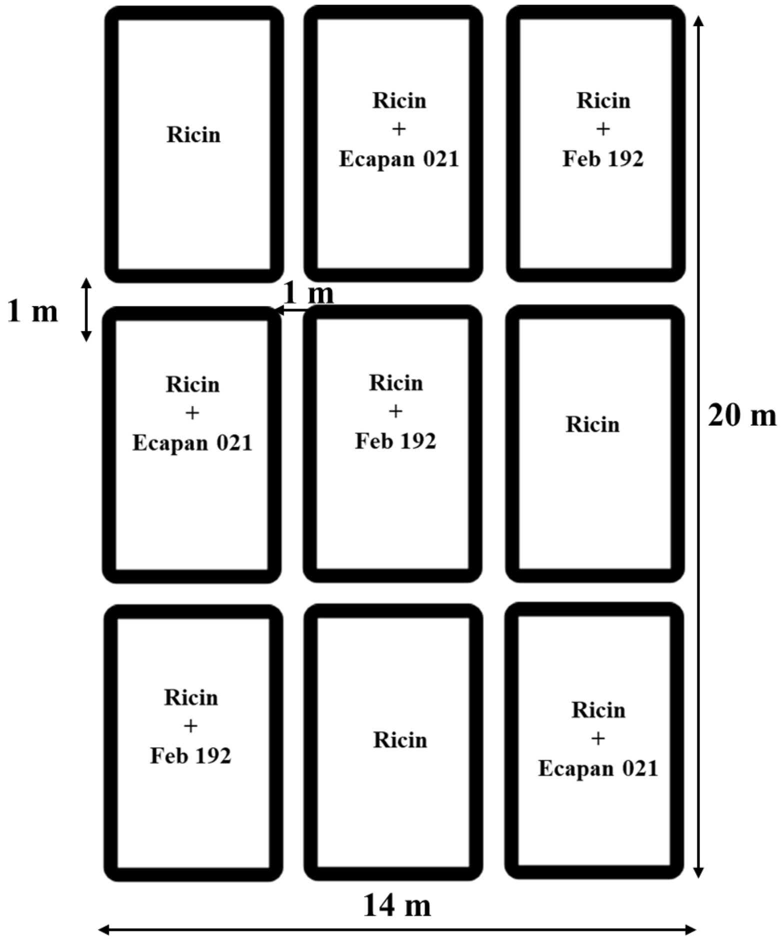

Figure-1: Experimental apparatus

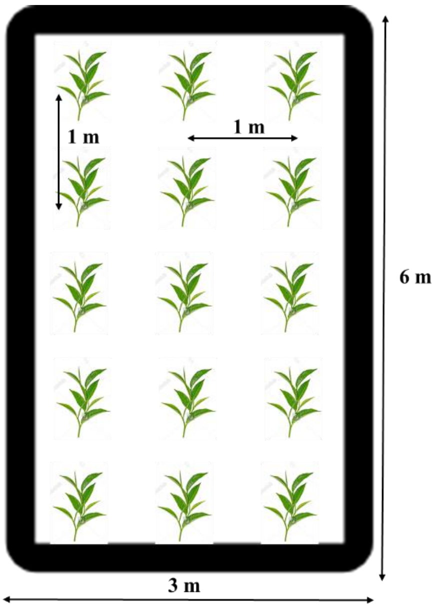

Figure 2: Castor bean plants in monocrop experimental units

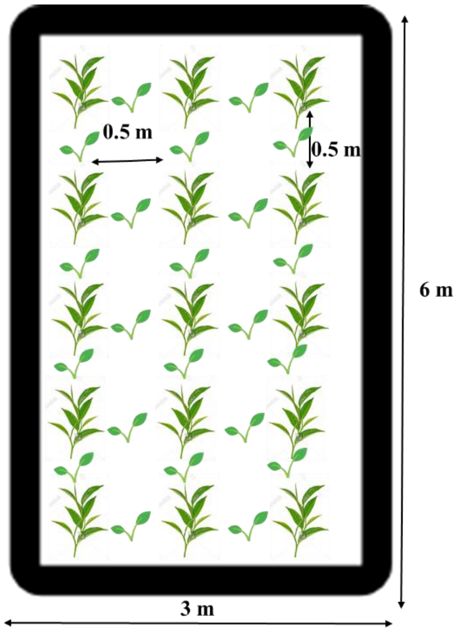

Figure 3: Castor bean and common bean plants in intercropping unit in cultural association

Data analysis and statistics

The soil analyses were carried out at the Soil Analysis and Environmental Chemistry Laboratory (LABASCE) of the University of Dschang-Cameroon according to the international methods recommended by Pauwels et al. (1992). The emergence rate of Castor bean plants was evaluated two weeks after sowing. Plant size and number of Castor bean leaves were assessed on a random sample of 30 plants per treatment at regular intervals of 14 days. At the flowering stage, a random sample of 15 plants per treatment was taken; dry biomass and stem diameter at the collar were measured. At maturity,

$$\mathrm{Rdt(Kg/ha)} = \frac{\mathrm{Mgr(g)}}{\mathrm{NPr}} + \frac{10\,000\ (\mathrm{m2})}{\mathrm{Ds\ (m2)}}\ \mathrm{x}\ \frac{1(\mathrm{Kg})}{1000\ (\mathrm{g})}\ \mathrm{x}\ 100$$

Where Rdt: represents the seed yield, Mgr: mass of seeds, NPr: number of plants harvested and Ds: seeding density (the seeding density is equal to the number of seedlings sown per square meter or on an experimental unit).

The comparison of the performance of each cropping system was made on the basis of the Land Equivalent Ratio (LER) which is the ratio of the productivity of an area in cropping association to that of an area in monocrop according to this equation:

It is calculated as follows: let A and B be two cultivated plants.

$$\mathrm{LER} = \frac{\text{Rendement de A in association} + \text{Rendement de B en association}}{\text{Rendement de A in monocrorp} + \text{Rendement de B en monocrorp}}$$

If LER=1, there is no difference between the two types of crops
If LER<1, there is a loss of yield in association
If LER >1, there is a productive advantage of intercropping

Data were subjected to analysis of variance followed by Duncan's tests when a significant effect was observed. The statistical software "xlstat 2018" was used.

The correlation between the parameters was evaluated from the correlation diagram, X and Y. each element i is represented by the point of coordinates (Xi,Yi). The set of points forms a cloud of points whose shape makes it possible to characterize the intensity of the relationship.

RESULTS AND DISCUSSION

Physico-chemical properties of the soil of the study site

Table 1 summarizes the physico-chemical properties of the soil of the experimental site of the IRAD station in Dschang (texture, pH, nitrogen and phosphorus)

Table 1: Physico-chemical properties of the soils of the study sites

Texture (%)	Sand=23; silt. = 14; Clay= 64 Textural class: sandy clay
pH	pH water: 5.7 This soil is an acid soil. pH-Kcl: 4.9
Organic carbon (%)	5.40
Material Org. (%):	9.30
Total nitrogen (g/kg):	0.37
Available phosphorus in mg/kgBray II:	11.00
C/N ratio:	15
Exchangeable cations milliequivalents/100g	
Calcium	5.60
Magnesium	3.15
Potassium	1.69
Sodium	0.04
Base sums	10.49
Cation exchange capacity in meq/100 g	
Effective CEC	10.49
S/CECE (%)	100
CEC pH7	34.25
Saturation bases (%)	31.00

Emergence rate of castor bean plants 14 days after sowing (DAS)

Figure 1 shows the emergence rate of Castor bean plants 14 days after sowing.

There is no significant difference between the Castor bean cultivation systems in monocrop and in cropping association on this parameter. The emergence rates of Castor bean are respectively (70.05%, 70.97% and 71.34%) respectively for the treatments (Ricin, Ricin-Ecapan 021 and Ricin-Feb 192).

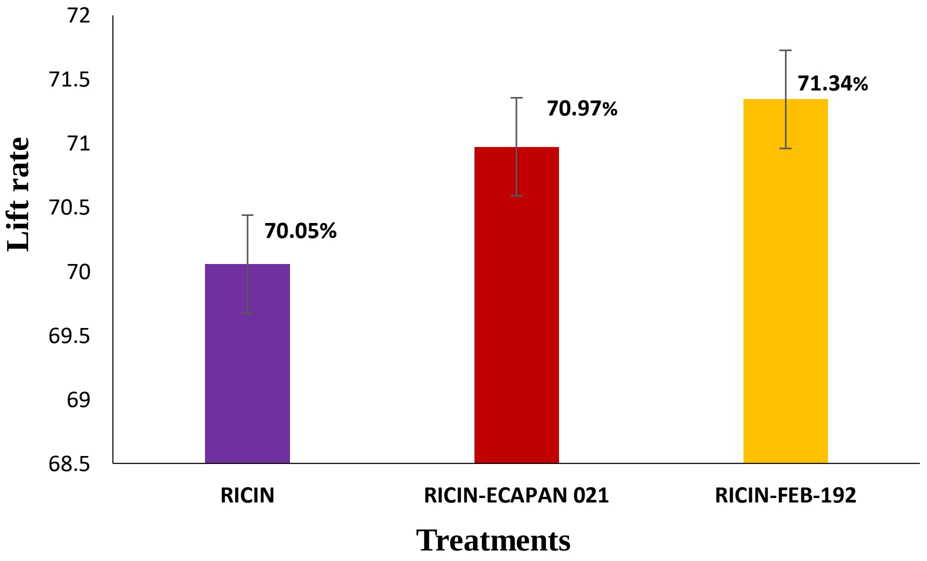

Figure 4: Emergence rate of Castor bean plants

The results obtained in this study on the lifting of castor beans are consistent with the data found in the literature. Indeed, Koutroubas et al. (1999) who studied the adaptability and yield of Castor beans (Ricinus communis L.) in the Mediterranean climate reported that the emergence of Castor bean seedlings varies between 11 and 26 DAS in depending on the year of experimentation and the study area. In addition (TTchuenteu et al., 2013a; Derogoh et al., 2018; Derogoh et al., 2020; Derogoh et al., 2021a; Derogoh et al., 2021b) reported that the emergence of Castor bean plants is observed between 14 and 15 days after sowing and that the average value of this emergence rate is 70.79.8%.

The influence of the edaphic and climatic characteristics of the West Cameroon region on the emergence of Castor bean seeds would be justified by the fact that the sandy clay soil and the tropical climate of the agro-ecological zone of the high plateaus of the region of West Cameroon would favour the emergence of Castor bean seedlings, thus justifying that the emergence rate of these plants depends on environmental and climatic conditions (Derogoh et al., 2018).

Effects of intercropping on the growth of Castor bean plants

Effects of intercropping on height and leaf number of Castor bean plants

Figures 2 and 3 shows respectively the height and number of leaves of castor bean plants according to cropping systems.

Statistical analysis of the data shows that the crop association and the experimentation site do not significantly influence the size of the Castor bean at 56 (DAS) days after sowing. However, the difference begins to be significant ($p<0.05$) between the different cropping systems on the size and number of leaves of Castor bean plants 84 days after sowing. Overall, the curve expressing the growth parameters of Castor bean as a function of time presents a sigmoid: growth increases slowly during the first 70 first DAS, then it increases exponentially between 84 and 189 days after sowing. After this date, the growth of the Castor bean is slowed down and the number of leaves drops.

These results on the size and number of Castor bean leaves are consistent with the work of (Derogoh et al., 2018; Derogoh et al., 2020; Derogoh et al., 2021a; Derogoh et al., 2021b; Tchuenteu et al., (2013a); Koutroubas et al. (1999) who revealed that the height growth of Castor bean follows a sigmoidal curve equation. In addition, these authors reported that the height of Castor bean at maturity varies between 0.79 and 2.3 m depending on the variety of Castor bean used and the study area.

Overall, in this study, the height of the Castor bean was less than 2 m, suggesting that fruit harvesting from the Castor bean accession used would be easy.

Concerning the influence of the crop association at the height of the Castor bean plant, the highest plant height (108.49 ± 1.17 cm) is observed in the Castor bean-Ecapan crop association while the Castor bean in monocrop presents the smallest Castor bean size (97.45 ± 1.23 cm).

The beneficial effects of legumes on heights have been demonstrated (Derogoh et al., 2018; TTchuenteu et al., 2013b Diatta et al., 2019).

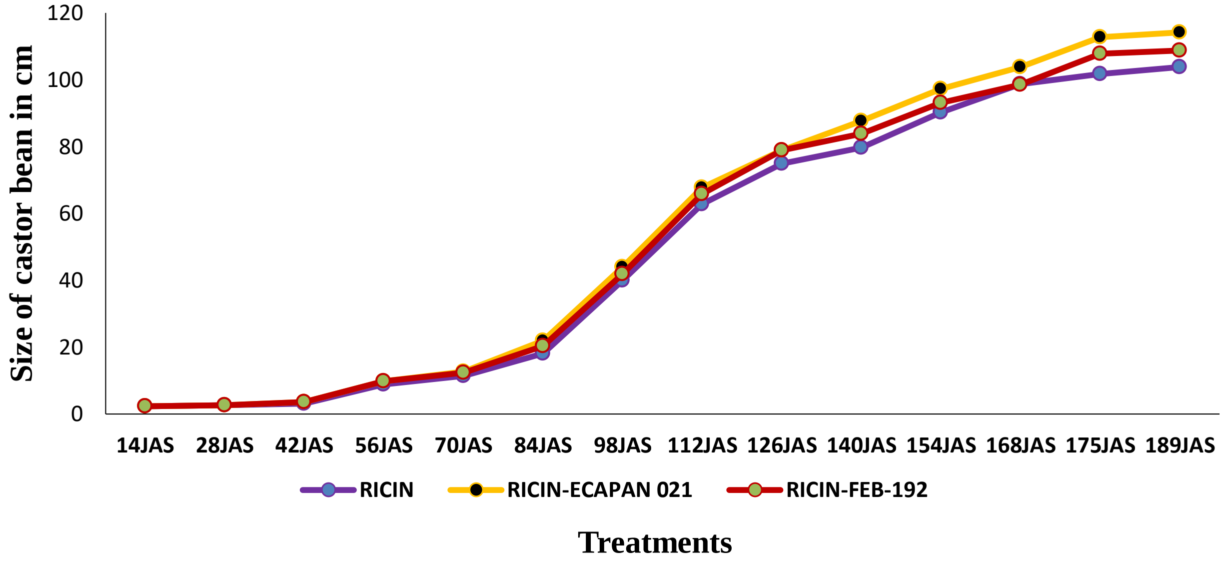

Figure 5: Size of Castor bean plants

Variation in the number of leaves of Castor bean plants

At maturity, the number of leaves per Castor bean oil plant varies from (49.78 ± 1.21) respectively in monocrop and (62.03 ± 1.27) in Castor bean-Ecapan cultural association.

In this study, the maximum number of leaves of Castor bean plants was obtained 175 days after sowing. The increase in leaves can play an important role in limiting sunstroke, increasing soil moisture and reducing erosion. These leaves represent a biomass whose degradation can release mineral elements in the soil necessary for plant nutrition.

In this study, there is a strong and positive correlation between the height of Castor bean and the number of leaves (r = 0.98; p-value = 0.10) and between the number of Castor bean leaves and seed yield (r = 0.89; p-value = 0.30).

Multiple authors Derogoh et al., 2018 ; Derogoh et al., 2020 ; Derogoh et al., 2021a ; Derogoh et al., 2021b ; Tchuenteu et al. (2013a); Koutrobas et al. (1999 reported that Castor bean growth varies with genotype, experimental site and years of experimentation, and that there is a strong and positive correlation between height, number of leaves and seed yield. Indeed, the greater the leaf production, the greater the photosynthetic intensity and therefore the higher the seed yield.

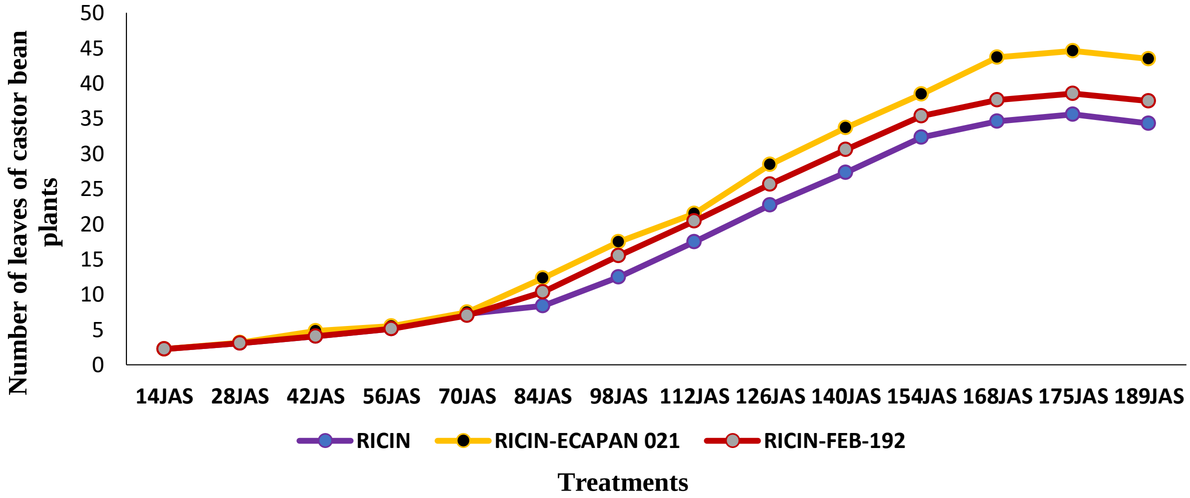

Figure 6: Number of leaves of Castor bean plants

Impact of cropping association on dry biomass and stem diameter of castor bean plants

Table 2 shows the dry biomass and stem collar diameter of mature Castor bean plants (175 days after sowing). In general, the analysis of variance reveals that the Castor bean-Common bean crop association significantly increases ($p<0.05$) these growth parameters studied.

In this study, the dry biomass of Castor bean varies from 15.16 ± 0.29 g in monocrop to 37.64 ± 0.33 g in a Ricin-Ecapan crop association.

This study reveals that there is a strong and positive correlation (r = 0.99; p-value = 0.04) between the dry biomass of Castor beans and the seed yield of castor beans.

These results obtained on the dry biomass of Castor bean are in conformity with those of Derogoh et al., 2018; Derogoh et al., 2020; Derogoh et al., 2021a; Derogoh et al., 2021b; TTchuenteu et al., (2013a) who found that the dry biomass of Castor beans grown in the field varies from 0.05 to 0.17 kg depending on the variety of Castor bean used.

In this study, there is a positive and significant correlation (r = 0.35, $p < 0.05$) between the diameter of the stem at the collar and the seed yield of Castor beans.

In this study, the diameter of Castor bean at the neck varies from 0.99 ± 0.42 cm in monocrop to 1.67 ± 033 cm in Castor bean-Ecapan cultural association.

These results obtained on the diameter of Castor beans stem corroborate the work of (Derogoh et al., 2018; Derogoh et al., 2020; Derogoh et al., 2021a; Derogoh et al., 2021b; Tchuenteu et al. (2013a) who report that the diameter of the Castor bean stem varies from 0.79 to 3.3 cm depending on the variety of Castor bean used.

Table 2: Dry biomass and stem diameter at the collar of Castor bean

parameter	Dry biomass (g)	Collar diameter (cm)
Castor	27.92±0.21a	0.99±0.42a
Ricin-Ecapan 021	31.25±067b	1.65±0.25b
Castor-Feb 192	32.69±0.29b	1.67±0.33b

Values in columns followed by the same letter are not significantly different

Effects of intercropping on castor bean production parameters

Number of ears per plant, number of fruits per ear and seed yield of castor bean plants

Number of ears per plant

Table 3 summarizes the data on the number of ears per plant, number of fruits per ear and seed yield of castor bean plants according to the systems in 189 days after sowing. In general, the analysis of variance reveals that the castor bean-bean association significantly increases ($p<0.05$) these production parameters. There is no significant difference between the different castor bean-bean cropping systems on these production parameters. However, the highest values for its parameters come from the Castor bean-Ecapan crop association.

In this study, the number of ears per Castor bean plant varies from 4.32±0.42 in monocrop to 7.22±0.74 in a Castor bean-Ecapan crop association.

This study reveals that there is a strong and positive correlation ($r = 0.99$; p-value = 0.07) between the number of ears per plant and the yield of Castor bean beans.

These results obtained on the number of ears per Castor bean plant corroborate the work of (Derogoh et al., 2018; Derogoh et al., 2020; Derogoh et al., 2021a; Derogoh et al., 2021b; Tchuenteu et al. (2013a) who revealed that the number of ears per **castor bean** plant varies from 2 to 21 depending on the variety of Castor bean used.

The number of fruits per ear

The number of fruits per ear of Castor bean varies from 90.67 ± 2.21 in monocrop to 97.67 ± 0.27 in Castor bean-Ecapan crop association.

This study reveals that there is a strong and positive correlation ($r = 0.99$; p-value = 0.06) between the number of fruits per bunch and the seed yield.

These results were obtained on the number of fruits per castor bean plant corroborate the work of Derogoh et al., 2018; Derogoh et al., 2020; Derogoh et al., 2021a; Derogoh et al., 2021b; TTchuenteu et al. (2013a) who report that the number of fruits per castor bean plant varies from 60.72 to 122.33 depending on the variety of castor bean used.

The seed yield of castor bean plants

In this work, the castor bean seed yield varies from 124.59±1.21 kg/ha in monocrop to 128.82±0.92 kg/ha in the castor bean-Ecapan cropping system.
The results obtained on castor bean yield corroborate the work of Derogoh et al., 2018; Derogoh et al., 2020; Derogoh et al., 2021a; Derogoh et al., 2021b; TTchuenteu et al. (2013a) who report that the yield of castor bean seeds varies from 19.44 to 2500 kg/ha depending on the variety of castor bean used and the experimental site.

Table 3: Seed yield and yield-related traits of castor bean

Parameter	Ears per plant	Fruit per ear	Seed yield (kg/ha)
Castor bean	4.32±0.42a	90.67±2.21a	124.59±1.21a
Castor bean-Ecapan 021	6.88±0.63a	95.33±1.33b	130.14±1.33b
Castor bean-Feb-192	7.22±0.74a	97.67±0.27b	128.82±0.92b

The values of the bands followed by the same letter are not significantly different

Land equivalent Ratio of cropping association according to intercropping systems

In this study, the LER varies from 1.01 in the Castor bean-Feb 192 combination of 1.02 in the Castor bean-Ecapan 021 combination. These results obtained on LER corroborate the data found in the literature. Indeed, several authors (Derogoh et al., 2018; TTchuenteu et al., 2013b) who revealed that the LER of Legumes in intercropping is greater than 1. In this study, the LERs of all intercropping systems studied are greater than 1, thus suggesting that the castor bean-bean crop association is beneficial in our study area.

The beneficial effect of the castor bean-Ecapan cropping system compared to the other cropping systems studied suggests that this variety of common bean would fix more nitrogen and make it available to the castor bean which requires the nitrogen for its growth; than the Feb 192 variety in our study area, but this needs to be evaluated.

Table 4: Land Equivalent Ratio according to cultural associations

Castor bean -Ecapan 021	Castor bean-Feb-192
1.02	1.01

Discussion

It was observed in this study that the edaphic and climatic characteristics of the West Cameroon region and the castor bean-bean crop association significantly influence ($p < 0.05$) the growth and production parameters. Castor bean oil compared to monocrop. Indeed, the humid climate of West Cameroon and the sandy clay soil, rich in nitrogen, and the acid pH of our study site would be favourable to the cultivation of the castor bean (Table 1). According to Weiss (2000), castor bean plants grow well in a low shade environment where the soil is rich in organic manure, well drained and has an acidic pH. Additionally, Reddy and Matcha (2008) reported that castor bean grows well in nitrogen-rich soils. The cultural association of castor beans with bean seems to increase significantly (p <0, 05) castor bean growth. These beneficial effects of the combination of the growth of castor bean have been demonstrated. Legumes live in symbiosis with the Rhizobium bacterium. These bacteria fix atmospheric nitrogen in the soil, thus helping to increase the nitrogen content of the soil, thus justifying the high productivity of castor beans in association with the common bean. In addition, several authors (Konate et al. 2012; Coulibaly et al., 2012) have reported that the intercropping of Legumes with other plant species improves the yield of plants that cannot fix nitrogen compared to the monocrop. Atmospheric nitrogen in the soil, thus contribute to increasing the nitrogen content of the soil, thus justifying the high productivity of castor beans in association with the common bean. In addition, several authors (Konate et al. 2012; Coulibaly et al., 2012) have reported that the intercropping of Legumes with other plant species improves the yield of plants that cannot fix nitrogen compared to the monocrop. Atmospheric nitrogen in the soil, thus contribute to increasing the nitrogen content of the soil, thus justifying the high productivity of castor beans in association with the common bean. In addition, several authors (Konate et al. 2012; Coulibaly et al., 2012) have reported that the Association of Legumes with other plant species improves the yield of plants that cannot fix nitrogen compared to the monocrop.

Conclusion

This study aimed to evaluate the effect of intercropping on the growth and productivity of castor beans in the agroecological zone of the highlands of the West Cameroon region. Castor bean growth and production parameters were evaluated. The comparison of the performance of each cropping system was made on the basis of the Land Equivalent Ratio (LER). The results show that plant productivity is influenced by the cropping systems and the edaphic and climatic characteristics (sandy clay soil and tropical climate) of the agro-ecological zone of the highlands of the West Cameroon region. The yield of castor bean seeds in crop association is 4.26% and 3.28% higher than that of castor bean in monocrop respectively for the treatments. Ricin-Ecapan and Ricin-Feb 192. The castor bean is significantly ($p<0.05$) in cultural association with the Ecapan variety of bean. The LER varies from 1.02 in the castor bean-Ecapan crop association system to 1.01 in the castor bean-Feb 192 crop association. The castor bean crop association is therefore beneficial for Cameroonian farmers in the West region. By cultivating castor bean oil in association with beans, Cameroonian farmers contribute not only to developing biofuels, but also to preserving food security.

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