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Influence of Three Types of Legumes (Groundnut, Cowpea, Soybean) on the Agricultural Yield and Monetary Income of a Crop Association in a Forest Region of the DR Congo

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ABSTRACT

The field experiment on the influence of three legumes (groundnut, cowpea and soybean) on the agricultural yield and monetary income of an association of six crops (cassava, plantain, sweet potato, maize, rice and/or groundnut, cowpea, soybean), was conducted during two successive cropping seasons in a forest region of the DRC (Bengamisa). The results show that: - The crop association with cowpea numerically improved the agricultural yield of the components, the overall agricultural yield of the association and induced a better overall LER compared to the association with groundnut and soybean. - The crop association with groundnut, on the other hand, yielded a much higher gross margin of $2645.4/Ha, compared to the gross margin achieved by the association with cowpea ($1872.4/Ha) and that with soybean ($1847.6/Ha). - In the crop associations in this environment, cowpea is considered to be a factor in improving crop yields, while groundnuts are considered to be a factor in improving cash income.

I. Introduction

For a long time, the increase of yield in agricultural systems was always based on the use of varieties with high genetic potential, very uniform, supported with pesticides and chemical fertilizers. This attitude has favored the erosion of biodiversity, simplification and homogenization of the environment, to ultimately create artificially simplified agro-ecosystems (Ater and Hmimsa, 2016; Lecomte and Sarrazin, 2016).

Therefore, in the future, the design of sustainable cropping systems will have to rely on agrobiodiversity management, so as to take advantage of the complementarity of the adaptive and functional characteristics of the different species present, so that biological phenomena interact in improving soil fertility, reducing pest pressure on crops, and regulating climate (Duru et al., 2015; Gaba et al., 2015; Reboud and Malézieux, 2015).

From this point of view, crop systems associating legumes represent today scientific issues worthy of interest (Le Roux et al. 2008). Indeed, associated crops, particularly grain legumes and cereals, are often characterized by higher and more stable yields and more efficient use of soil and resources than pure crops (Clerc et al. 2015. P 2; Chapagain and Riseman 2014; Corre-Hellou et al. 2011; Lithourgidis et al. 2011).

In the forest regions of the Democratic Republic of Congo, the practice of combining crops is the most widespread. Combinations can include up to ten crops on a plot of land, usually less than one hectare in size. In these combinations, annual, multi-annual and seasonal crops are frequently found, including: cereals, root and tuber crops, fruit crops, market garden crops and legumes. This reduces the risk of very low incomes in the event of climatic accidents (Esuka et al., 2019).

In the Bengamisa region, the results of surveys conducted on crop associations report the coexistence of three food legumes, namely groundnuts, cowpeas and soybeans, occurring with average values of sowing density ratios of about 5% and for 15% frequency (Esuka et al. 2020).

Therefore, there is a low presence of legumes in crop associations in this environment and yet elsewhere, farmers are all aware of the importance of legumes both in food and in agricultural production. It has even been proven in some environments that 97% of the associations included at least one species of grain or forage legumes (Thiébeau et al., 2010 a, Verret et al. 2019).

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In addition, it should be noted that the different crop associations in this region are distinguished according to the number and types of crops used and the seeding rate ratios applied to each. These elements can have a different influence on both agricultural yield and income generation.

With this in mind, the present study seeks to assess the influence of each of these three legumes (groundnut, cowpea and soybean) on the yield and income of a cassava, plantain, sweet potato, maize and rice crop association.

II. Setting, Materials and Methods

This study was conducted in the village of Batshusthe, in the Abata group, one of five groups in the Bamanga sector, whose chief town is Bengamisa. The climate is of the Af de Köppen type. Average temperatures range from 24 to 25.5°C. The average annual rainfall is between 1600 - 1700mm. The rainfall pattern shows a double periodicity with maxima in October and May, minima in January and July (Lofinda 2015). The soils are generally acidic with low base saturation and well drained (Esuka and Kahindo 1993).

The study material involved cassava (variety Obama), plantain (variety Libangalikale), rice (variety Nerica 4), maize (variety Samaru), sweet potato (variety Elengi), groundnut (variety JL24), catalogued by the National Seed Service (Senasem, 2012).

The field experiment was carried out successively during two cropping seasons and involved a randomized complete block design, including three treatments and four replications, with plots of 7m x 15m, separated from each other by 1.5m aisles. These treatments are:

T1: Cassava 40% + Banana 20% + Sweet potato 3% + Maize 19% + Rice 19% + Groundnut 19 %

T2: Cassava 40% + Banana 20% + Sweet potato 3% + maize 19% + rice 19% + cowpea 19 %

T3: Cassava 40% + Banana 20% + Sweet potato 3% + maize 19% + rice 19% + soya 19%.

But also, in order to evaluate the potential efficiency of the crop association compared to the pure crops, a control trial was conducted during two successive cropping seasons, with plot sizes similar to those of the associated crops.

The technical itinerary focused on preparatory work, including land delimitation, clearing, stumping, and soil preparation; sowing and planting, weeding, replanting, hoeing, ridging, weeding, staking, and harvesting in a staggered manner, as each crop reached maturity.

It should be noted that the crops were planted according to the following cultural scheme:

- On the twin rows; the cultivation of cassava and on the single rows; the plantain.
- On the 4 m strips; rice, maize, sweet potato and/or groundnut, cowpea and soybean.
- A green manure crop, in this case cowpea, was planted as a catch crop on the strip after the harvest of rice, maize, sweet potato and/or groundnut, cowpea and soybean in the first season, and then mowed during its growing season, before flowering, in order to maintain soil fertility.

In the second cropping season, rice, maize, sweet potato and/or peanut, cowpea and soybean were intercropped with cassava and plantain in the 4m strip between them.

Finally, agricultural yields, Land Equivalent Ratio, gross products, gross expenses or real expenses and gross margins or agricultural cash income were calculated.

III. Results and discussion

3.1 Results

3.1.1.Agricultural yields

3.1.1.1. Cumulative agricultural yield of two cropping seasons per component and per treatment in crop association

The results relating to the yield of each crop in tons per hectare, in the different treatments, are shown in Figures 1a, 1b, 1c, 1d, 1e, 1f, 1g, 1h and 1i, respectively for rice, maize, groundnut, cowpea, soybean, sweet potato, cassava leaves, cassava roots and plantain

From the observation of the results represented by the figures above, it appears that treatment T2, concerning the association with cowpea, induced a relatively high yield for rice (1.72 t/ha), maize (1.05 t/ha), sweet potato (1.37 t/ha), cassava leaves (4 t/ha), cassava roots (15.1 t/ha) and plantain (8.0 t/ha), sweet potato (1.37 t/ha), cassava leaves (4 t/ha), cassava roots (15.1 t/ha) and plantain (8.2 t/ha), compared to treatments T1 and T3 with groundnut and soybean, respectively.

3.1.1.1. Overall yield of two cropping seasons by crop combination treatment

The results in relation to the overall yield obtained for each treatment for the two cropping seasons are displayed in Figure 2.

The analysis of the results in the figure above shows that the combination of crops with cowpea (T2) resulted in an overall cumulative yield (31.76 t/ha), which is relatively higher than the overall cumulative yield obtained by the combination with groundnut (30.79 t/ha) and soybean (29.72 t/ha).

3.1.1.1. Agricultural yield of components in pure culture during two cropping seasons

The yield results of the different speculations in pure culture are recorded in figure 3.

The results in Figure 3 for cumulative yield (t/ha), for two seasons, under pure cultivation, indicate for rice (5.95 t/ha), for maize (4.38 t/ha), for groundnut (4.25 t/ha) cowpea (1.28 t/ha), soybean (1.26 t/ha), sweet potato (59.6 t/ha), cassava leaves (21 t/ha), cassava roots (30 t/ha) and plantain (30.3 t/ha).

3.1.1.1. Global Land Equivalent Ratio of the agrosystem

The results concerning the global Land Equivalent Ratio, relative to the two cropping seasons, for the different treatments, are shown in the following figure.

The results shown in Figure 4 indicate that the overall LER values for the different treatments are 1.70, 1.76 and 1.67 for T1, T2 and T3 respectively. These values of global LER of the different treatments, higher than the value of the Coefficient of Equivalent Density of 1.20 applied for all the associations, mean that the different treatments of the associated crops produced globally an over - yield compared to the pure crops. However, the crop association with cowpea (T2) seems to have induced a relatively higher over-yield than the association with groundnut (T1) and soybean (T3).

3.1.1. Economic variables

3.1.1.1. Total gross product

The results of the total gross product of the different treatments are presented in Figure 5.

Gross products per hectare were determined by assigning a value to the production (in tons) of paddy rice grains, maize seeds and/or groundnut, cowpea and soybean seeds, sweet potato tubers, tuberized cassava roots, cassava leaves and plantain bunches based on the average local market prices in effect during the marketing period. Thus, the average prices used for each speculation are $610.0 for rice, $200.0 for

maize, $1000.0 for groundnuts, $500.0 for cowpeas, $500.0 for soybeans, $166.5 for sweet potatoes, $28.6 for cassava leaves, $50.0 for cassava tuberized roots, and $78.15 for plantains.

It follows from the results in Figure 5 that the highest gross product value of $3999.0 was obtained in the association with groundnut (T1), compared to the association with cowpea (T2) and soybean (T3) which obtained $3156.8 and $3135.0 respectively.

3.1.2.2. Gross expenses

The gross expenses retained in this study are the expenses of seeds and labor.

3.1.2.2.1. Seed costs

The results relating to the expenses of seeds of the different treatments for the two cropping seasons are included in the figure 6..

The results in the figure 6 show that the highest seed costs were recorded in the groundnut association, compared to the cowpea and soybean association, with $223.6 for Q1, $157.4 for Q3 and $154.4 for Q2 respectively.

3.1.2.3. Labour costs

The results of the labor costs for the different operations during two cropping seasons are recorded in the table 1.

From the results shown in the table above, it should be noted that the labor costs for the various cultivation operations in the first and second cropping seasons were $420.0 and $440.0 respectively. Maintenance operations for cassava and plantain after the harvest of seasonal crops in the second cropping season cost $270.0, while the total cumulative labor costs for the two cropping seasons for all operations amount to $1130.0.

3.1.2.4. Total Gross Expenses

Total cumulative seed and labor costs for all treatments in all seasons.

It can be seen from the results of the figure 7 that the association with groundnut (T1) generated much more expenses, i.e. $ 1353.6, compared to the association with cowpea and soybean.

3.1.2.5. Gross margin

From the observation of the results in the figure 8, it can be seen that the relatively high value of the gross margin was obtained in the association with groundnuts compared to the association with cowpeas and soybeans. The cash income values obtained are in the order of $2645.4 for T1, $1872.4 for T2 and $1847.6 for T3.

3.2. Discussion

From the observation of the results obtained in the present study, the following should be noted:

1) Regarding the influence of the three legumes studied on the agricultural yield of each of the associated crops, the average yield of each component was numerically influenced by each type of legume.

Indeed, it was found that the cumulative average yield values of the different associated crops for the two cropping seasons were relatively high in the plots of the association with cowpea (T2) compared to the plots of the association with groundnut (T1) and soybean (T3).

The yield increases induced by the cowpea association compared to the groundnut (T1) and soybean (T3) associations are in the order of 3% and 2.4% for rice, respectively; 2.9% and 7.1% for maize; 9.6% and 10.5% for sweet potato; 14.3% and 8.1% for cassava leaves; 2.0% and 2.7% for cassava roots; 10.8% and 17.1% for plantain.

2) For the overall crop yield, a similar trend was observed as for the average yield of each component. The highest average value of aggregate yield for both cropping seasons was obtained in the cowpea association plots (T2) compared to the groundnut (T1) and soybean (T3) association plots.

The yield increases induced by the cowpea association compared to the groundnut and soybean association were 3.2% and 7.2%, respectively.

But these cowpea-induced yield increases appear even larger when the individual yields of each legume are subtracted from the final count, which depends on the intrinsic characteristics of each species and variety involved. From this, the readjusted overall cumulative yield increase rates induced by the cowpea association are thus of the order of 6.4% for T1 and 7.3% for T3.

3) As for the comparison of the yields of the crop association compared to pure crops, it was generally found that there was a better efficiency in the use of resources in crop association compared to pure crops.

This was reflected in global Land Equivalent Ratio (global LER) values for all treatments, higher than 1.2; representing the value of the Coefficient of Equivalent Density (CDE) or of the applied land use rate.

The rates of excess yields obtained in crop association compared to pure crops are respectively 39.2% for T3, 41.7% for T1 and 46.7% for T2.

From these results, it can be seen that the association with cowpea produced a significantly better yield than the association with groundnut and soybean. These results corroborate those observed on the agricultural yields of both the components and the overall agrosystem.

4) With respect to cash income, it is clear that, contrary to the agricultural yield and the Land Equivalent Ratio, it is the association with groundnuts that allowed for a high cash income, compared to the association with cowpeas and soybeans. The calculated gross margins include $2645.4 for Q1, $1872.4 for Q2, and $1847.6 for Q3.

The rates of increase in income generated by the association with groundnut (Q1) are 41.3% compared to the association with cowpea (Q2) and 43.2% compared to the association with soybean (Q3).

In light of the results described above, it should be noted that:

- Cowpea in association improved the agricultural yield of the components and the overall agricultural yield of the association, compared to the association with groundnut and soybean. It also significantly induced higher yields than the pure crops, compared to the combination with groundnut and soybean. Cowpea compared to other legumes in competition can be considered as a factor of yield improvement.

These results can be explained by the fact that cowpea, at least the variety used, compared to other legumes, produced a large amount of biomass during its vegetative growth. This biomass would be richer in nitrogen and would contribute to the improvement of soil fertility, because the rhizobium leguminosarum, specific to cowpea and wild legumes, would be present in the cultivated soil, since pueraria and mucuna were listed among the plant species that colonized the land before it was cultivated.

- In contrast, the combination with groundnuts yielded a much higher gross margin than the combination with cowpeas and soybeans.

This is despite the high total gross expenses observed for this combination, due to the high seed costs observed, which seem to be closely linked to the costs of groundnut seed. These costs are also dependent on seed quantities per hectare,

which are generally higher for peanuts than for cowpeas and soybeans, at the same 19% seed density ratios for each.

The high total gross expenses of the peanut combination were offset by the gross revenue, which was influenced by both the peanut yield and its field price at marketing.

The groundnut yield in the combination of 1150 kilograms per hectare and its price of $1,000 per ton appears to be more attractive than the cowpea yield of 320 kilograms per hectare and its price of $500 per ton, as well as the soybean yield of 320 kilograms per hectare and its price of $500 per ton.

The gross product of groundnut of $1150 in combination on a one hectare area is numerically far greater than the gross product of cowpea and soybeans in combination and on the same one hectare area. The calculated product for each of these two legumes is $160.

In studies of crop associations, it has been observed by many authors that the yield of cereal-legume seed crops is generally less variable than the average of the corresponding pure crops. It is often higher than the average of the yields of the two crops in monospecific, and more so when the mineral nitrogen available in the soil is low. It is also indicated that all multi-specific cropping systems are significantly better performing both agronomically and economically compared to mono-specific crops. (Bedoussac et al.2015; Agrotransfert, 2016).

Kouame et al. (2020) in a study conducted on the influence of crop association on the nodulation capacity of three legume species: groundnut, cowpea and green soybean found for their part that among the three legumes studied (groundnut, cowpea and soybean), the highest nodulation was observed in groundnut. This could be explained by the difference in cycles between the legumes.

Coulibaly et al. (2017), in their research on the effects of maize-legume associations on maize (Zea mays L.) yield and fertility of a tropical ferruginous soil in western Burkina Faso obtained a cowpea yield of 200 kg/Ha in association, compared to 600-800 kg/Ha in pure culture with fertilization. For our part, the average yield in association was 150 kg/Ha and 170 kg/Ha respectively in the first and second seasons, compared to 530 kg/Ha and 750 kg/Ha in pure culture, without fertilization for the same periods.

IV. Conclusion

The influence of three types of legumes (groundnut, cowpea, soybean) on the agricultural yield and monetary income of a six-crop association was studied in the Bengamisa region of DR Congo.

The crops considered were cassava, plantain, maize, rice, groundnut (and/or cowpea and soybean) and sweet potato. Seasonal crops were planted in 4 m strips between the lines of cassava and plantain.

The soil occupancy rate was 120%, with the following component density ratios: for cassava 40%, for plantain 20%, for sweet potato 3%, for maize 19%, for rice 19% and/or for groundnut, cowpea and soybean 19%.

Based on the results obtained, it is clear that:

- The association with cowpea numerically improved the agricultural yield of the components, the overall agricultural yield of the association and induced a better overall LER compared to the association with groundnut and soybean. Cowpea compared to the other competing legumes can be considered a yield enhancer.
- The association with groundnut, on the other hand, resulted in a much higher gross margin of $2645.4/Ha, compared to the gross margin achieved by the association with cowpea ($1872.4/Ha) and that with soybean ($1847.6/Ha). These high total gross expenses of the groundnut association were offset by the gross product ($1150/Ha), which was influenced both by the yield of groundnuts in the association (1150 kg/Ha), and by their field price at marketing ($1000/ton).

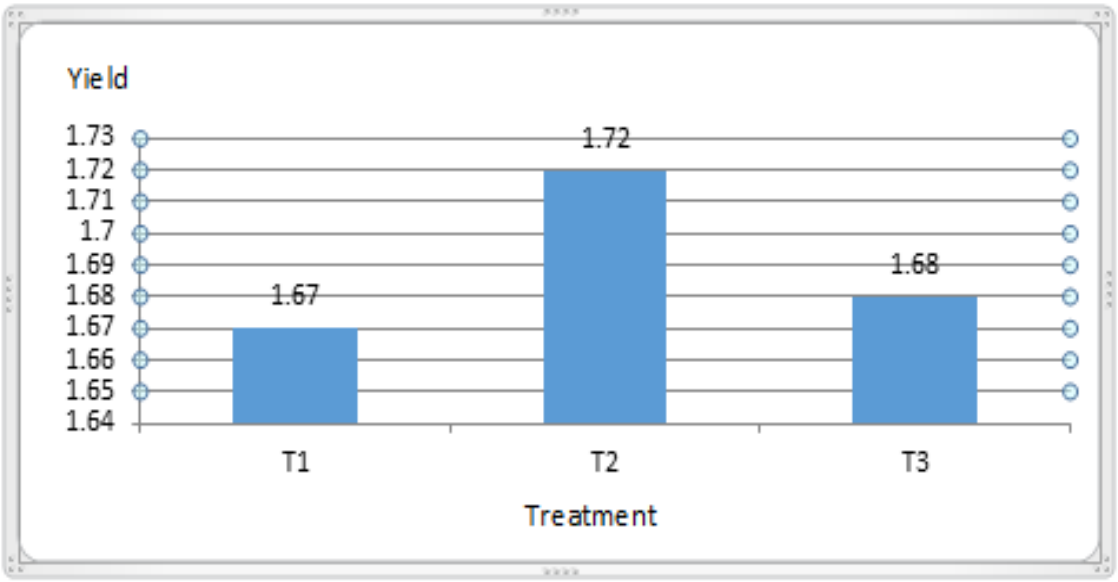

Figure 1a. Riceyield (t/ha)

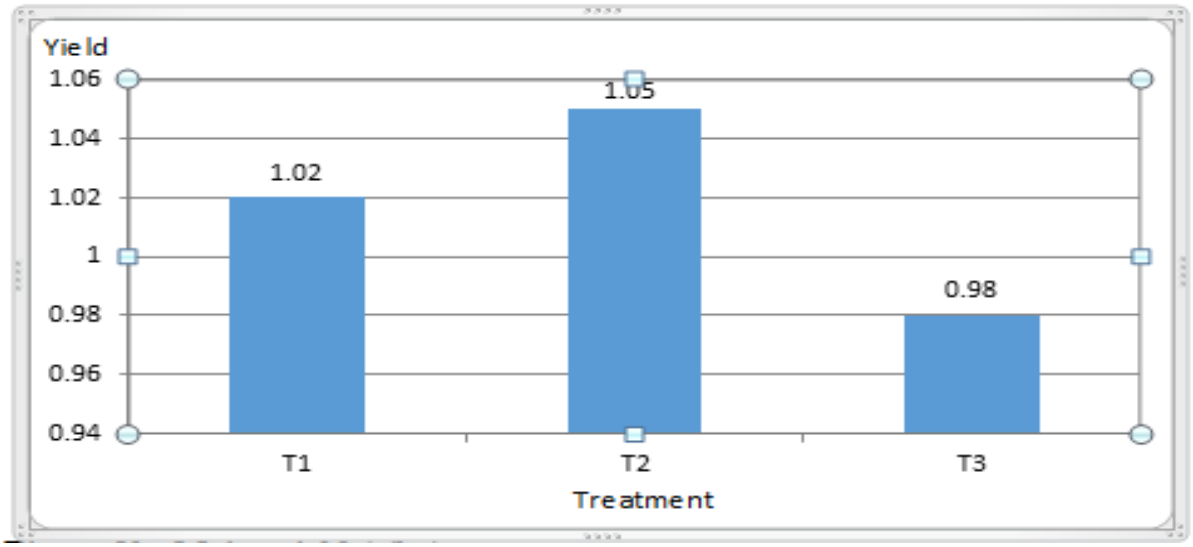

Figure 1b. Maize yield (t/ha)

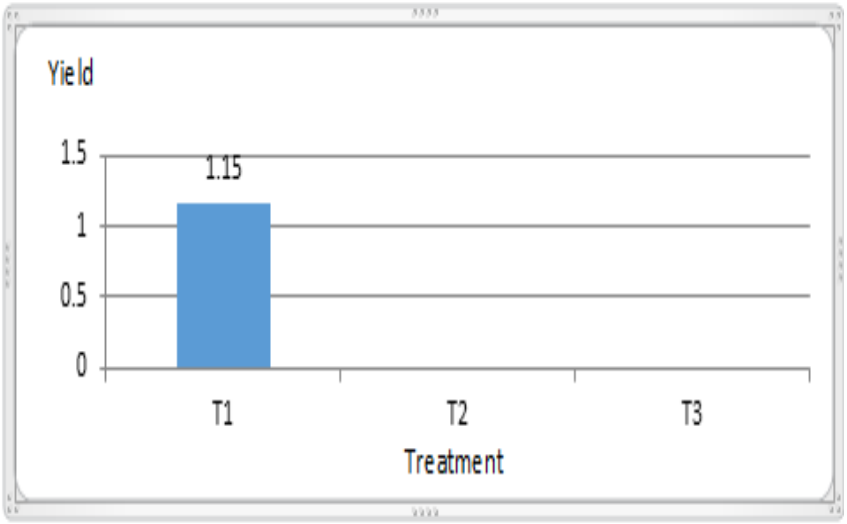

Figure 1c. Peanut yield (t/ha)

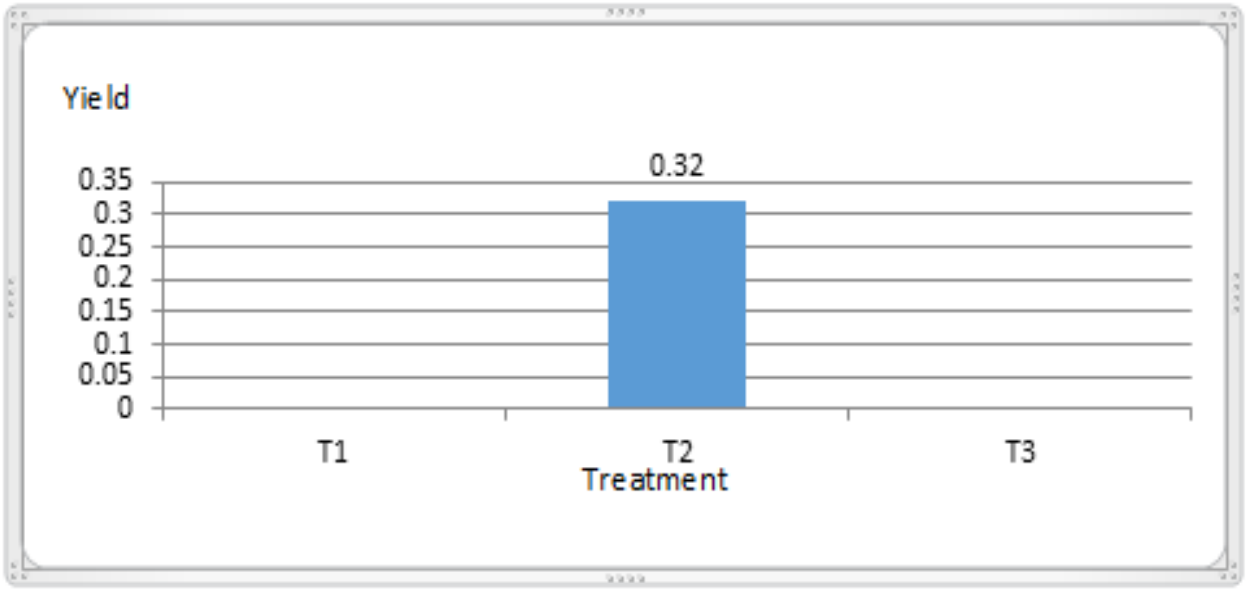

Figure 1d. Cowpea yield (t/ha)

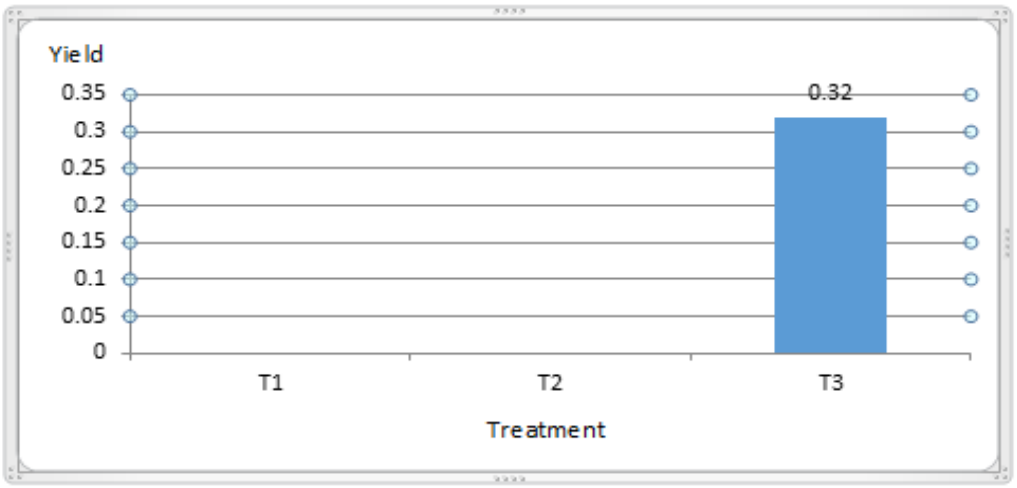

Figure 1e. Soybean yield (t/ha)

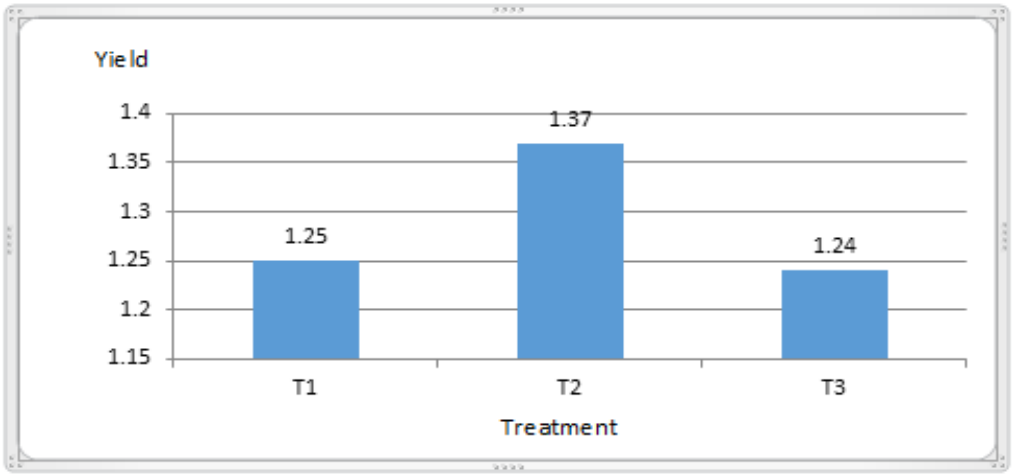

Figure 1f. sweet potato yield (t/ha)

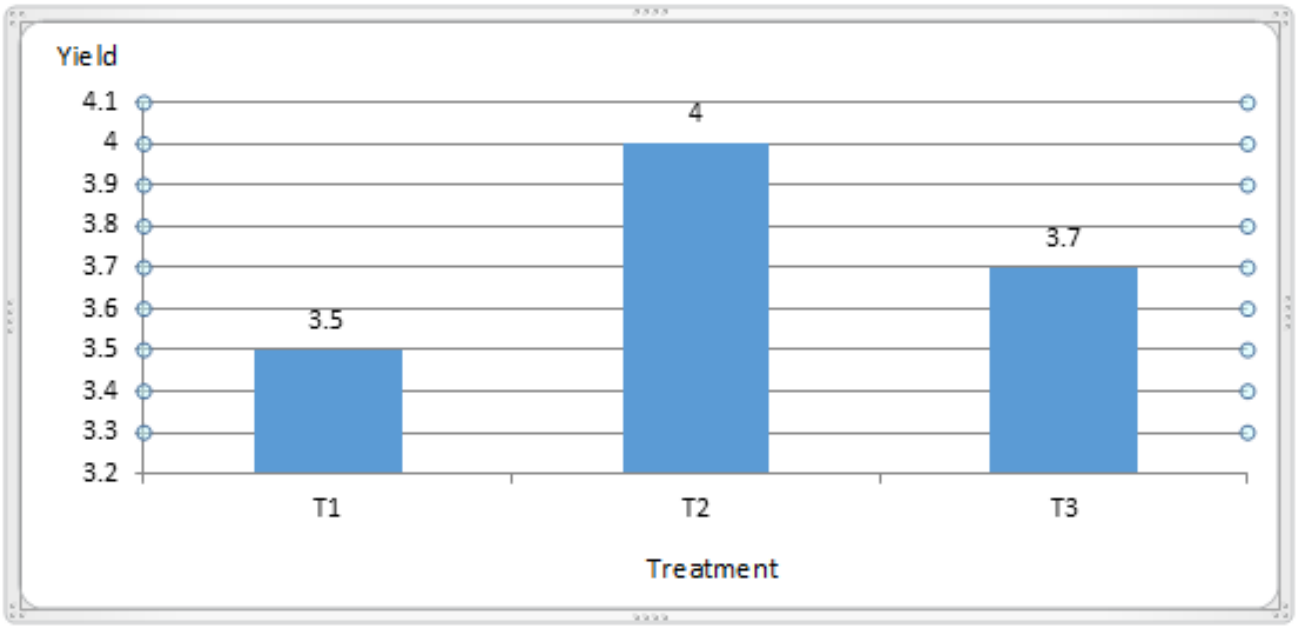

Figure 1g. Leaf yield of cassava (t/ha)

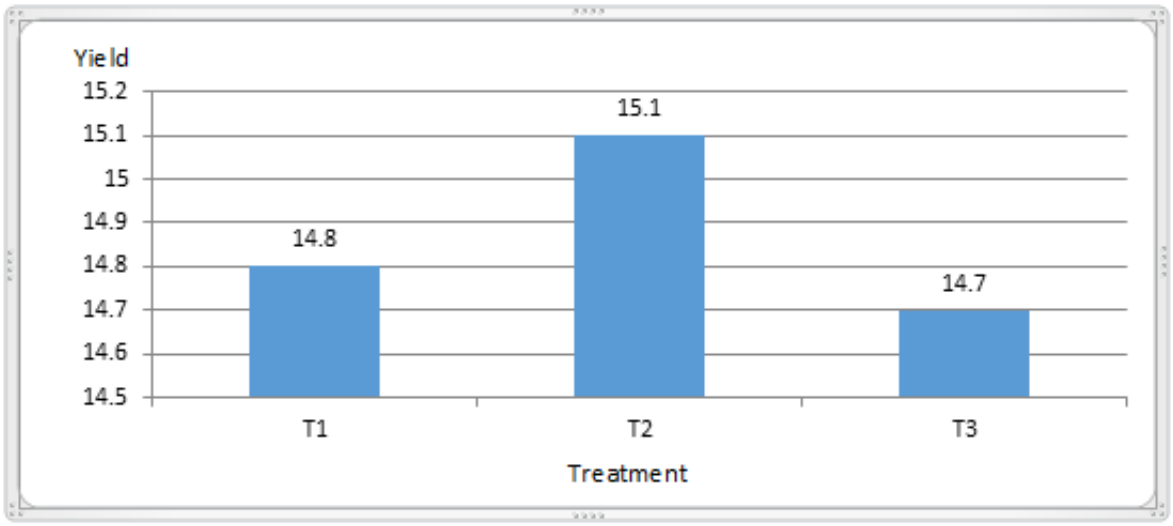

Figure 1h. Root yield of cassava (t/ha)

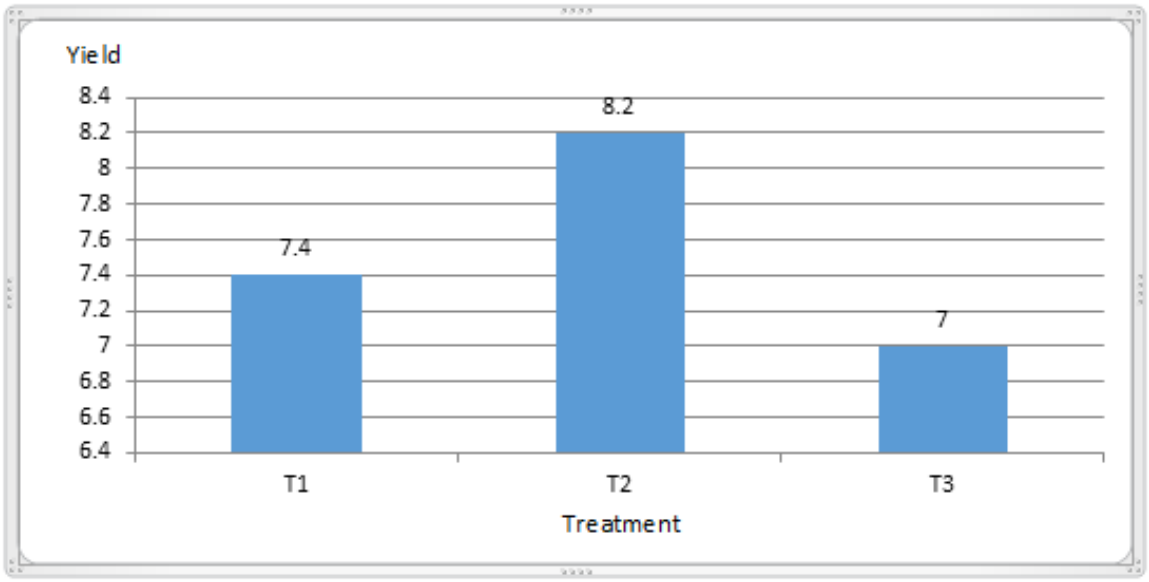

Figure 1i. Plantain bunches yield (t/ha)

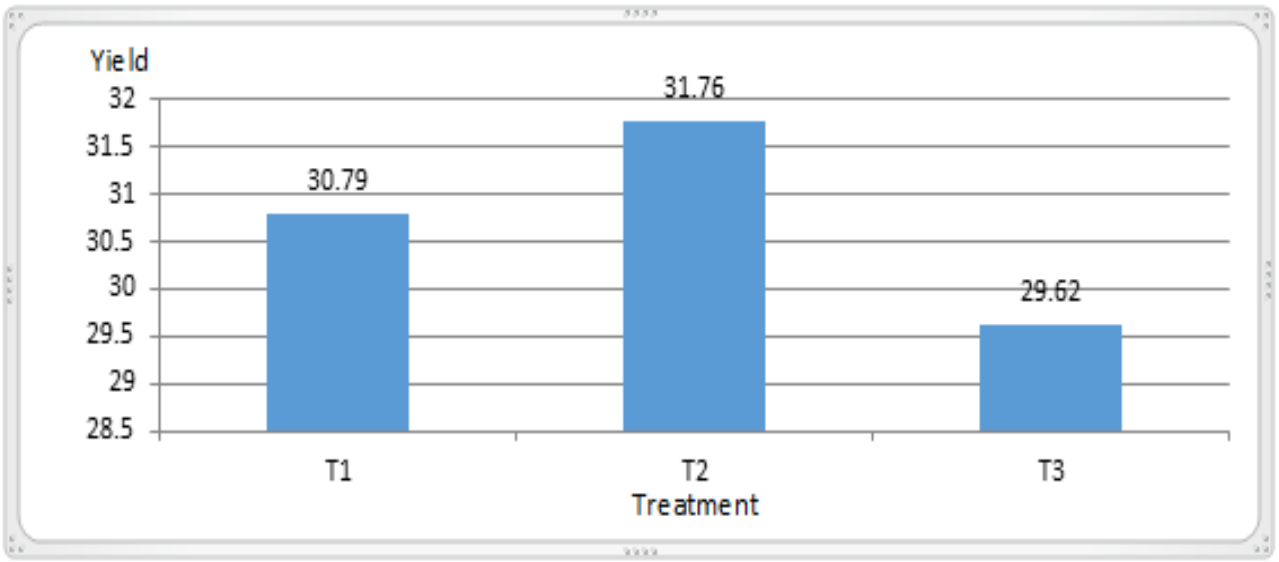

Figure 2. Cumulative overall agricultural yield of the agrosystem by treatment (t/ha) in associated crops

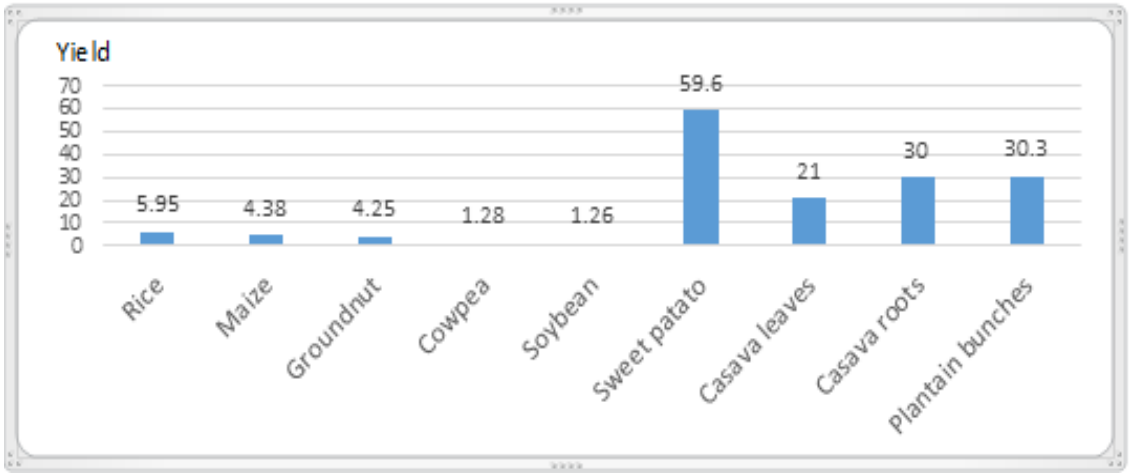

Figure 3. Yield (t/ha) under pure cultivation

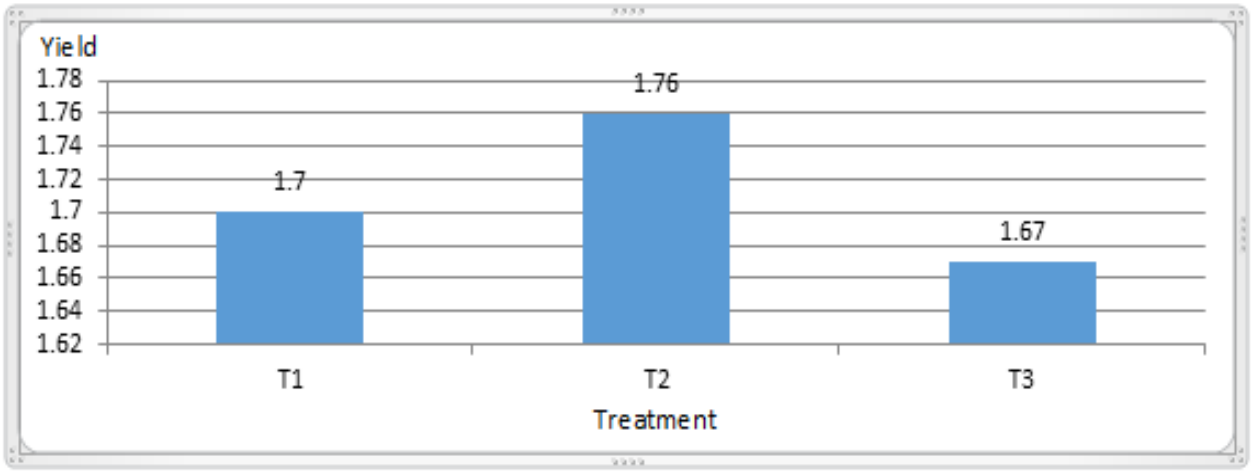

Figure 4. Average values of global LER of the different treatments for the two cropping seasons

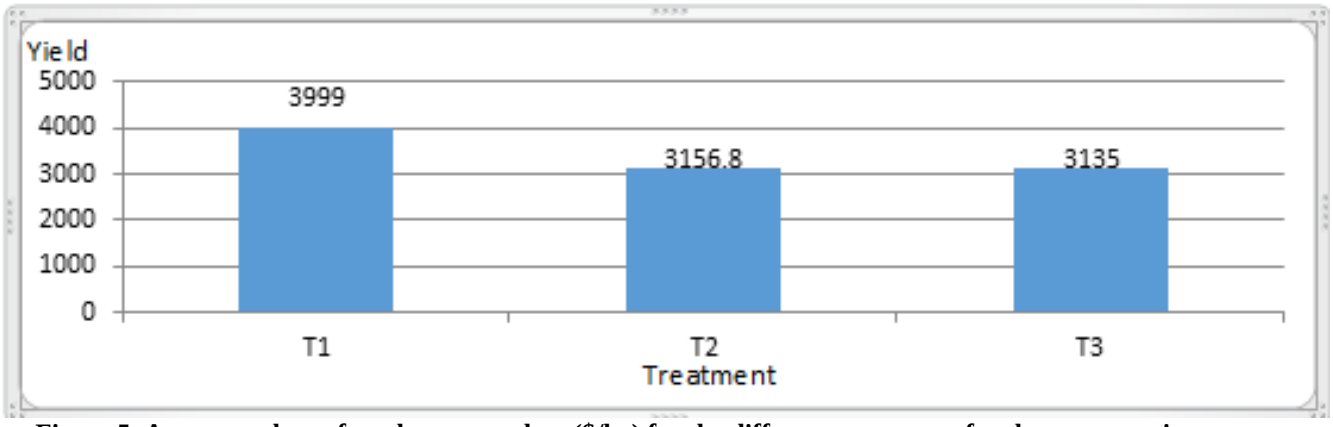

Figure 5. Average values of total gross product ($/ha) for the different treatments for the two cropping seasons

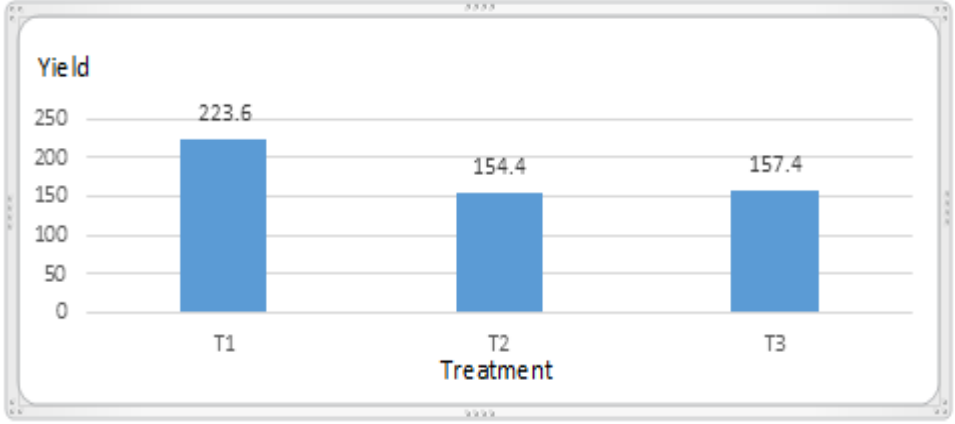

Figure 6. Cumulative values of total seed costs

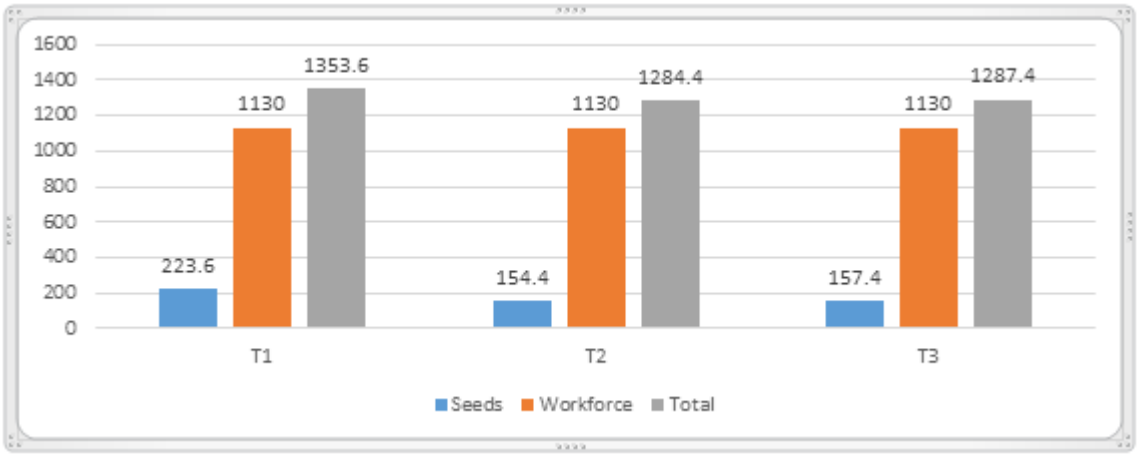

Figure 7 .Total Gross Expenses

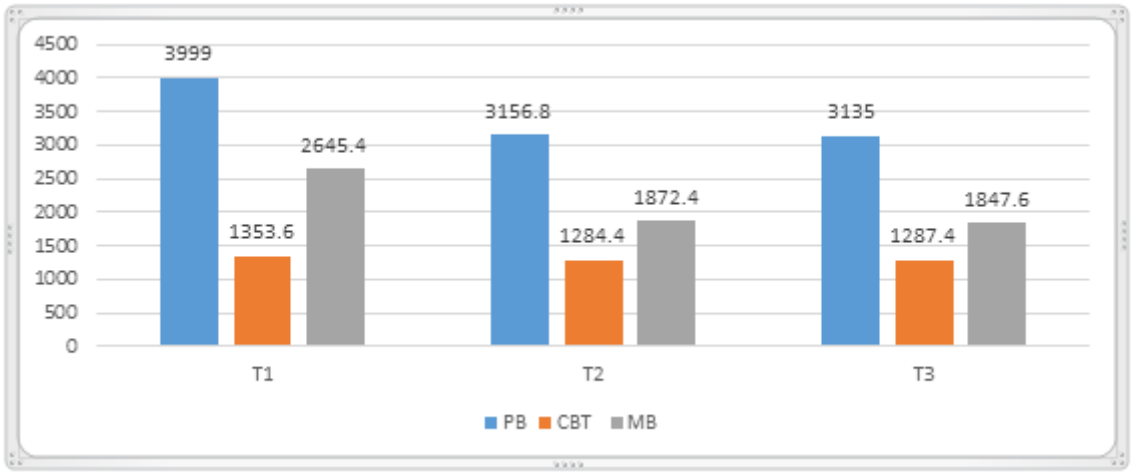

Figure 8 . Gross margin values by treatment ($/ha)

Table 1. Total values of labor costs

N°	Operations	Tache/HJ	PU(§)	CMO S1	CMO S2	CMO APS2	Total/operation
1	Clearing	10x25	1,5	60,0	--------	-------	60,0
2	Stump removal and clearing + seedbed preparation	10x25	2,5	100,0	---------	-------	100,0
3	Preparation of the seedbed	10x25	1,5	----	60,0	-------	60,0
4	Sowing and planting	10x25	1,5	60,0	60,0	-------	120,0
	Green manureseedbedpreparation	10x25	1,5	-------	60,0	-------	60,0
	Green manuresowing	10x25	1,5	--------	60,0	-------	60,0
	Green manuremowing	10x25	1,5	--------	60,0	-------	60,0
5	Weeding (2,1,3)	10x25 ; 20x25	1,5	120,0	60,0	90,0	270,0
7	Harvest	10x25	2	80,0	80,0	180,0	340,0
8	Cumulative total	------	------	420,0	440,0	270,0	1130

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