

Effect of Delayed Cassava Planting on Yields and Economic Returns of a Cassava-Groundnut Intercrop in the Democratic Republic of Congo

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Abstract Cassava intercropping is a common practice in sub-Saharan Africa. In terms of growth pattern, canopy development and nutrient demand, grain legumes are well suited for intercropping with cassava. Due to the inter-specific competition for growth resources, the relative planting time of the component crops has been considered as one of the important management practices for intercropping system productivity. Little information exists on the effect of cassava planting time on yields and economic returns of a cassava-legume intercrop. This study investigated the effect of relative planting times of cassava on yields and economic returns of a cassava-groundnut intercrop. Researcher-managed, field trials were installed in Bas-Congo Province in two consecutive seasons using four different planting times of cassava after the groundnuts. The results indicated that cassava planting time did not affect both grain and biomass yields of groundnut. When cassava was planted 3 weeks after the groundnuts, cassava storage root yields were significantly ($P = 0.029$) decreased by 48 to 60 % (9.3 to 11.3 t ha⁻¹) over cassava planted at the same time as groundnut. The net revenue of cassava planted 3 weeks after the groundnut was significantly ($P = 0.002$) decreased by about 70 % over that of cassava planted at the same time or 2 weeks after the groundnuts. Maximum net revenue of \$ 1877 ha⁻¹ with a benefit-cost ratio of 2.42 was reported in the treatment of cassava planted at the same time. Benefit-cost ratio was favourable for the pure cassava (3.2 to 3.8) but not favourable for the pure groundnut. Cassava intercropping with groundnut had significantly ($P = 0.019$) lower profits than the pure cassava. The results suggest that cassava should be planted at the same time or not later than 2 weeks after the groundnuts to maximize yields and economic returns in a cassava-groundnut intercrop.

Keywords: BCR, grain yield, intercropping, MRR, relative planting time, storage root yield

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1. Introduction

Intensive agriculture together with rapid population growth and limited nutrient inputs have resulted in declining soil fertility that leads to a gradual decline in per capita food production in sub-Saharan Africa [1]. In order to maintain soil fertility and crop yields, intercropping which has been a common practice of small-holder farmers is one of the existing options in crop production. Intercropping system is the cultivation of two or more crops in the same space during the same season which uses environmental resources efficiently better than the crops grown separately [2,3,4]. Besides improving soil

fertility [5,6] and stabilizing higher yield [7], the benefits associated with intercropping are reducing risk of crop failure [8], decreasing disease severity [9], controlling weed pressure [10,11,12] and achieving more efficient utilization of environmental resources relative to the pure cropping system [13,14,15,16].

Cassava-based farming systems are particularly prevalent as cassava is one of the major staple foods widely grown in most sub-Saharan Africa countries [17]. Cassava, a widely-spaced, long duration crop is often intercropped with short duration crops such as cereals and grain legumes. Among intercrops, legumes have been considered to be compatible crops for intercropping with cassava [18] as they supply a sustainable amount of nitrogen (N) into lower input agro-ecosystems [19].

Besides the advantages of transferring some N to the present crop and some residual N to the following crops [20], legumes grown in intercropping conserve the other nutrients through the return and crop residues decomposition [21]. Leguminous plants are also well suited with cassava in terms of nutrient demands since they need mostly phosphorus (P) and can get some required N from the nitrogen fixation through soil bacteria *Rhizobia* in their root nodule [22] whereas cassava extracts more potassium (K) for storage in root production and N for leaf production [23,24]. According to [8] intercropping of cassava with legumes (cowpea, soybean, groundnut and common beans) could increase land equivalency ratios as compared to the pure crop. For instance, land equivalency ratios were increased by 50 to 73 % in the cassava-cowpea intercrop [25] and 10 to 58 % in the cassava-soybean intercrop [26]. Several authors have also reported that intercropping with legume crops did not show a significant effect on cassava yield relative to the pure cassava cropping system in a cassava-cowpea intercrop [27,28], a cassava-cowpea/groundnut intercrop [28] and a cassava-mungbean intercrop [29]. Among the various legume plants, groundnut (*Arachis hypogaea* L.) is one of the recommended legume crops for intercropping with cassava [31]. Intercropping with groundnut increases the productivity (land equivalent ratio of 1.27 to 1.85) [32]. The economic benefits could also be achieved by intercropping with groundnut under both rain-fed and irrigated conditions in the cassava-groundnut intercrop in Asia [33]. Cassava intercropping with groundnut also resulted in a positive response of cassava storage root yield and net income [34] as well as decreasing the soil erosion over the pure cassava stand [35,36].

On the other hand, agronomic practices such as plant densities, crop arrangement and relative planting times can increase productivity in cassava-legume intercropping systems [37]. Among these practices, the relative planting time of component crop could affect the yields of component crops [38,39,40,41], which has been attributed to the interspecific competition between the component crops for resources [38,42,43]. Delayed growth of cassava was also found in the cassava-groundnut intercrop due to the interspecific competition of resources such as light and nutrients [33]. Generally, labour can be spread more easily if the crops do not require planting at the same time. Thus, the relative planting time of component crops is an important management practice for crop yields and economic returns in the cassava-groundnut intercropping system. Nevertheless, the relative planting time of cassava has not been widely studied and not well documented in the cassava-groundnut cropping systems in Africa. Therefore, this study aimed to investigate the appropriate planting time of cassava to improve crop yields and economic returns in the cassava-groundnut intercropping system in DR. Congo.

2. Materials and Methods

2.1. The Study Area

Field trials were conducted in Mvuazi research station, Zenga (5°26'96" S, 14°53'67" E, 435 m above sea level) of the Bas-Congo province in Democratic Republic of

Congo (DR. Congo). The area receives on average 1300 mm of rain. The rainfall in the Bas-Congo province is bimodal with the first season (1st season) lasting from October to mid-February, and the second season (2nd season) lasting from early March to mid-May, followed by a short dry season (3rd season). The growing period is about 290 days per year. The mean annual temperature is 25°C and the soil was classified as Haplic Acrisols [44]. Some selected characteristics of the top soil (0-15 cm) before sowing data are shown in Table 1.

Table 1. Selected physico-chemical soil properties in Zenga site

Soil parameters	Units	Zenga
Total soil organic carbon†	g kg ⁻¹	31.2
Total N†	g kg ⁻¹	1.13
Available P‡	mg P kg ⁻¹	3.53
pH (H ₂ O)		6.11
ECEC§	cmol _c kg ⁻¹	7.33
Exchangeable K ⁺	cmol _c kg ⁻¹	0.23
Exchangeable Ca ²⁺	cmol _c kg ⁻¹	4.23
Exchangeable Mg ²⁺	cmol _c kg ⁻¹	1.16
Clay	%	22.1
Sand	%	51.8
Silt	%	26.1

† Combustion method

‡ Olsen P method (determined in a modified Olsen extract at pH 8.5)

§ Effective Cation Exchange Capacity (determined by Atomic Absorption Spectroscopy)

Cassava is the main staple food in the study area, which is grown by all farmer households in the lowlands of Bas-Congo [45]. Farmers mostly intercrop cassava with grain legumes, especially groundnut, cowpea (*Vigna unguiculata* (L.) Walp.), common beans (*Phaseolus vulgaris* L.) and soybean (*Glycine max*). The cumulative rainfall during the experimental period in Zenga site is shown in Figure 1.

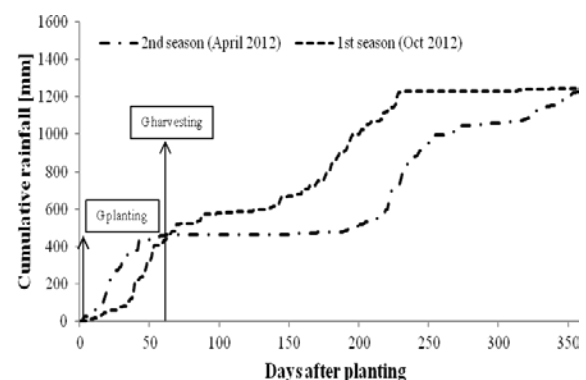


Figure 1. Cumulative rainfall during the experimental period. G refers to Groundnut. Cassava or groundnut planting and harvesting dates are indicated

2.2. Trial Management and Establishment

In April 2011, at the onset of 2nd season, field trials were installed. The field trials were established following a randomized complete block design with three replicates. Plots measured 54 m². In all plots, planting beds of 90 cm width were installed with a spacing of 90 cm between the beds. Two rows of cassava were planted per planting bed. Cassava was planted at a spacing of 90 cm x 90 cm inter- and intra-row, respectively. Groundnut was planted in two parallel lines within the planting bed between the two

lines of cassava. Groundnut was planted at spacing of 30 cm x 20 cm inter- and intra-row, respectively; for both intercropped and pure groundnut stands. Cassava improved variety 'Nsansi' and groundnut improved variety 'JL 24' were used. Main treatments were cropping systems (pure and intercropped cassava), while sub treatments were the cassava planting time. The treatment details are shown in Table 2.

Table 2. Treatment structure for the determination of optimal planting time of cassava in the cassava-groundnut intercropping system during 1st and 2nd seasons in Zenga site

Cropping system	Cassava planting time	NPK fertilizer kg ha ⁻¹
Cassava-groundnut intercrop	same time as the groundnuts	100 (17 N: 17 P: 17 K)
	1 week after the groundnuts	100
	2 weeks after the groundnuts	100
	3 weeks after the groundnuts	100
Pure groundnut	-	50
Pure cassava	1 week after the groundnuts	50
	2 weeks after the groundnuts	50
	3 weeks after the groundnuts	50

At the planting time NPK fertilizer was band applied to the groundnut plants whilst for cassava it was applied per the planting hole. Weed operations were done at 1, 3, 6 and 8 months after planting. Farmers were not allowed to pick cassava leaves during the growing period. The experiment was carried out in two seasons (1st and 2nd seasons of 2012) in Zenga site.

2.3. Crop Measurements

Two months after groundnut sowing, above ground biomass was collected from a 1 m strip within the net plot to determine the biomass yields of groundnut. Groundnut was harvested at full maturity from the net plot (36 m²); when pods had dried, the grains were collected. Biomass and grains were oven-dried (65°C) for 48 h and weighed. Cassava was harvested at 12 months after planting. At harvesting, stem and storage root yields were determined. Subsequently, storage roots were divided into large tradable and small non-tradable storage roots, counted, and sub-sampled for determination of the dry matter (DM) content of the flesh (parenchyma) and peelings.

2.4. Economic Analysis

Economic analysis comprised calculation of total cost and total benefits, and benefit-cost ratios after adjusting the average yields i.e., the average yield was adjusted downward to 10 % to reflect the difference between the experimental yield and the farmer yield (without the researchers' involvement) from the same treatment [46]. Total benefits were estimated using the unit prices for groundnut grain yield and fresh storage root yield of cassava at the local markets in the study site (2.01 USD kg⁻¹ of groundnut grains in both seasons and 0.12 USD kg⁻¹ and 0.1 USD kg⁻¹ of cassava tradable root yields in 2nd and 1st seasons, respectively). Total costs included input costs (seed, cutting and fertilizer) and labour costs (land

preparation, planting, weeding and harvesting) in the different treatments. Groundnut grain price was used for seed since most farmers recycle seed. Cassava stems were valued both as an input (planting material) and as produce at \$ 0.04 m⁻¹. Economic analysis did not take leaf production into account. The price of NPK compound fertilizer was obtained from the local market in the study site (100 USD per 50 kg bag). The labour was valued at a wage of 2.7 USD for a 6 hour working day. An exchange rate of 920 Congolese francs to 1 USD (2012) was used. The benefit-cost ratios of the various treatments were calculated as the ratio of total benefits over total costs and were considered favourable when exceeding 2 invested by the farmer [46]. A sensitivity analysis was conducted for selected treatments. Cassava root and groundnut grain prices were decreased by up to 50 % or increased by up to 150% to determine changes in net benefits.

2.5. Statistical Analysis

Analysis of variance was conducted to determine the effects of different treatments using a mixed linear model (MIXED procedure, SAS Institute Inc., 2009). In the mixed model analysis, the treatments of cropping systems and cassava planting time were used as fixed factors and 'replicate' within season were considered as random factors. The effects of the various treatments were compared by computing least square means and standard errors of difference (SED). Significance of difference was evaluated at $P < 0.05$.

3. Results and Discussion

3.1. Groundnut Grain Yields

The relative planting time of cassava had no significant influence on the grain yields of groundnut in the cassava-groundnut intercrop in both 2nd and 1st seasons (Figure 2).

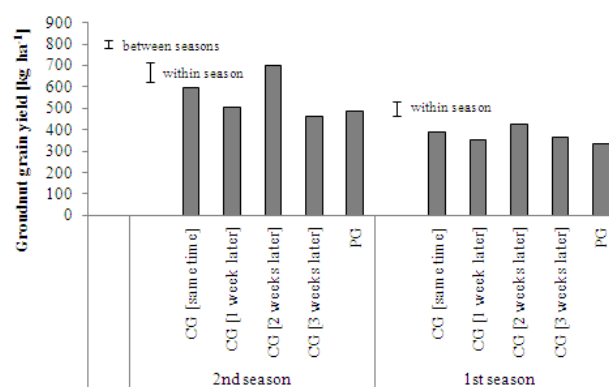


Figure 2. Groundnut grain yields as affected by the relative planting time of cassava in both seasons. Error bars represent standard error of difference (SED) for comparisons of all treatments. CG and PG refer to the cassava-groundnut intercrop and the pure groundnut, respectively

Maximum grain yields (699 kg ha⁻¹ and 426 kg ha⁻¹) were recorded in the treatment of cassava planted 2 weeks after the groundnuts in 2nd and 1st seasons, respectively. The grain yields were only significantly ($P = 0.01$) different between the treatments of cassava planted 2 weeks and 3 weeks after the groundnuts in 2nd season. The grain yield of groundnut was not significantly influenced by intercropping with cassava in both seasons except in

2nd season where a significant ($P = 0.015$) difference on grain yields between the cassava-groundnut and the pure cassava planted 2 weeks after the groundnuts was found. There was a significant ($P = 0.0007$) difference on the groundnut grain yields between the two seasons.

Though there was no effect of cassava planting time on groundnut grain yield in the cassava-groundnut intercrop, other studies [38,39,40,41] have reported the decreased grain yields as a result of relative planting time of the crop. This was attributed to the interspecific competition between the two crops for resources [38,42,43]. When cassava was planted 2 weeks after the groundnuts in 2nd season, the grain yield was higher over the cassava planted 3 weeks after the groundnuts. This could be attributed to higher rainfall in the period of third week than fourth week of April, 2011. The result implies that the intercropping with groundnut had no influence on groundnut grain yield relative to the pure groundnut. Since cassava has a slow early growth [28,47,48,49], resulting in slow canopy formation [50,51] and groundnut matures after attaining maximum canopy development of cassava, there is a competition gap between the periods when each of the component crops is making critical demands for growth resources such as light, water and nutrients [52]. This could also be contributed by different growth habits between the two crops where groundnut is low growing and cassava has an erect type. Conversely, intercropping with cassava had a significant influence on groundnut grain yield in the cassava-groundnut intercrop [18,53]. The 2nd season produced more grain yield, about 28 to 54 % higher than 1st season. This could probably be due to lower rainfall distribution in October, 2011 resulting in relatively lower germination percentage of groundnut (about 21 %) relative to April, 2011. Grain yield of groundnut was lower than the range of yields attained under farmers' field conditions in Africa which were reported by [54] to be an estimated 700 kg ha⁻¹. These low yields could be attributed to high weed pressure, pests and diseases and poor structure of the soil in the study site, at the Bas-Congo, DR. Congo [55]. This might also be due to the insufficient amount of P (8.6 kg ha⁻¹) from NPK fertilizer applied for the groundnut production in Zenga site. Another explanation for this low yield might probably be the insufficient amount of Ca (5 kg ha⁻¹) from NPK fertilizer for groundnut production.

3.2. Groundnut Biomass Yields

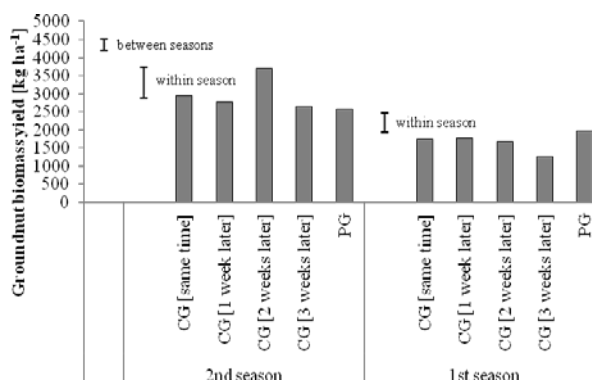


Figure 3. Groundnut biomass yields as affected by the relative planting time of cassava in both seasons. Error bars represent standard error of difference (SED) for comparisons of all treatments. CG and PG refer to the cassava-groundnut intercrop and the pure groundnut, respectively

No significant effect of cassava planting time on the biomass yields of groundnut in the cassava-groundnut intercrop was found in both seasons (Figure 3).

Maximum biomass yields (3700 kg ha⁻¹ and 1775 kg ha⁻¹) were recorded in the cassava planted 2 weeks after the groundnuts in 2nd season and in the cassava planted 1 week after the groundnuts in 1st season, respectively. The intercropping with groundnut at all cassava planting times had no significant influence on groundnut biomass yields relative to the pure groundnut in both seasons. The biomass yield of groundnut was significantly ($P = 0.004$) higher (almost double) in 2nd season compared to 1st season.

Results from this study showed that intercropping with cassava had no influence on groundnut biomass yield in the cassava-groundnut intercrop. It can be assumed that the relative planting time of cassava used in this study might not have reached the interspecific competition for resources such as space, light, moisture, nutrient, etc. In contrast, the relative planting time of colocasia had influence on the biomass yield of rice in the colocasia-rice intercrop [40]. The failure of planting time to affect groundnut yields could be attributed to the slow early development of cassava [28, 47, 48] which might not reach the interspecific competition for resources (space, light, moisture and nutrients) with the groundnut crop. This might also be due to the suitable compatibility of the two crops as intercrops due to the wide maturity gap. This is in line with the previous study in the cassava-cowpea intercrop [28]. Conversely, intercropping with cassava had a significant influence on the biomass yields of Flemingia in the cassava-Flemingia intercrop [36].

3.3. Cassava Storage Root Yields

There was a significant ($P = 0.037$) effect of the relative planting time of cassava in both seasons (Figure 4).

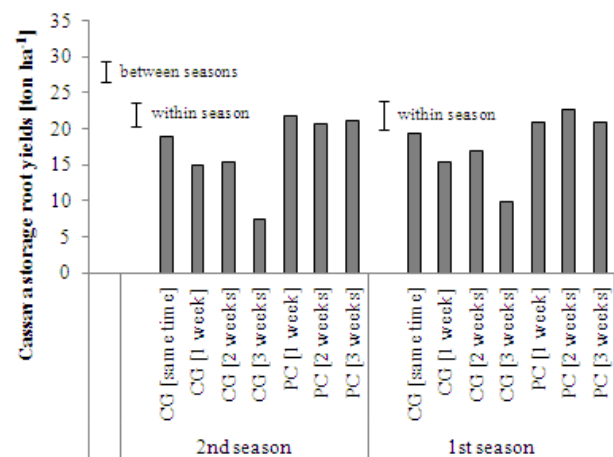


Figure 4. Cassava root yields as affected by the relative planting time of cassava in both seasons. Error bars represent standard error (SED) of difference for comparisons of all treatments. CG and PG refer to the cassava-groundnut intercrop and the pure groundnut, respectively

When cassava was planted 3 weeks after the groundnuts, the storage root yields were significantly ($P = 0.037$ and $P = 0.042$) decreased by 48 % and 60 % (9.3 to 11.3 t ha⁻¹) in 2nd and 1st seasons, respectively, relative to cassava planted at the same time as groundnut. For the pure cassava cropping system, there was no significant effect of cassava planting time on cassava storage yields in both

seasons. The effect of intercropping with groundnut on cassava storage root yields was not observed in both seasons. The storage root yield was only significantly ($P = 0.019$ and $P = 0.001$) decreased by 64 % and 73 % (10.9 to 13.6 t ha⁻¹) in the cassava intercrop 3 weeks after the groundnut as compared to the relative treatment of pure cassava in 2nd and 1st seasons, respectively. There were no significant differences on the storage root yields between the two seasons.

Cassava planted 3 weeks after the groundnut significantly decreased cassava storage root yields as compared to cassava planted at the same time as groundnut in the cassava-groundnut intercrop, probably due to the interspecific competition for growth resources (space, moisture and nutrients) between the two crops [56] and shading by groundnut plants to cassava when cassava was planted 3 weeks after the groundnuts. Cassava yields could be considerably decreased if the intercrop was planted earlier than cassava, creating strong interspecific competition for growth resources at a time when cassava was still a weak competitor [57]. The results indicate that cassava can be planted at the same time or not later than 2 weeks after the groundnut without affecting the storage root yields in the cassava-groundnut intercrop. Intercropping with groundnut had no influence on the storage root yields in the cassava-groundnut intercrop. The yields of the main crop and its intercrop would not be affected by their association where there is a competition gap between the periods when each of the component crops has critical demands for growth resources [51]. This could be due to the fact that groundnut, a short-duration crop (90 days) matured just after the maximum canopy development of cassava and harvested earlier before an increase rate of storage root bulking process in the cassava crop. The results of this study suggest that the presence of groundnut in the cassava-groundnut intercrop had no negative effect on the root yields of cassava when cassava was planted at the same time or not later than 2 weeks after the groundnuts.

3.4. Cassava Stem Yields

In the cassava-groundnut intercrop, the relative planting time of cassava had no significant effect on the stem yields of cassava in both 2nd and 1st seasons (Figure 5).

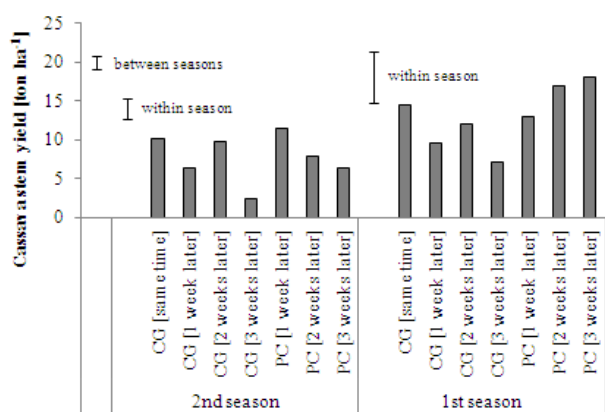


Figure 5. Cassava stem yields as affected by the relative planting time of cassava in both seasons. Error bars represent standard error of difference (SED) for comparisons of all treatments. CG and PG refer to the cassava-groundnut intercrop and the pure groundnut, respectively

The lowest stem yields (2.5 and 7 t ha⁻¹) were recorded in the cassava planted 3 weeks after the groundnuts in 2nd and 1st seasons, respectively. In the pure cassava cropping system, the planting time of cassava had no significant effect on the stem yields in both seasons. No significant difference on the stem yields was found between the treatments of pure cassava and the relative treatments of cassava intercropping with groundnut in both seasons. The result indicates that intercropping with groundnut had no influence on the stem yield of cassava. This might be due to the different growing habits of the two crops while cassava has erect growth and groundnut is low growing. In contrast, the stem yields of petiole were significantly decreased by intercropping with legumes as compared to the pure cassava [58]. Planting cassava in 1st season gave higher stem yields by about 87 % than planting in 2nd season. This difference might be due to higher rainfall in 2nd season than that of 1st season (Figure 1) or weed pressure.

3.5. Economic Analysis

In the cassava-groundnut intercrop, cassava planted 3 weeks after the groundnuts was less profitable as it resulted in a significant ($P = 0.002$) decrease in both total and net benefits (1226 to 1351 USD ha⁻¹) as compared to the treatment of cassava planted at the same time or 2 weeks after the groundnut (Table 3). This reduced benefit was attributable to the negative effect on both cassava root yield and groundnut grain yield.

Table 3. Economic analysis, including total benefits (TC), total costs (TB), net benefits (NB) and benefit-cost ratio (BCR), as affected by the relative planting time of cassava in both seasons in Zenga site

Treatment	TB	TC	NB	BCR
	USD ha ⁻¹			
CG [same time]	3269	1311	1898	2.4
CG [1 week]	2689	1311	1319	2.0
CG [2 weeks]	3143	1311	1773	2.3
CG [3 weeks]	1918	1311	547	1.4
PG [same time]	791	704	87	1.1
PC [1 week]	3015	801	2214	3.8
PC [2 weeks]	2675	801	1875	3.3
PC [3 weeks]	2562	801	1760	3.2
SED (Treatment)	376***		368***	0.4***

SED = standard error of difference. *** = $P < 0.001$. CG, PG and PC mean the cassava-groundnut intercrop, the pure groundnut and the pure cassava, respectively.

When cassava was planted 3 weeks after the groundnuts, benefit-cost ratio (BCR) was unfavorable (BCR less than \$ 2 \$⁻¹) and significantly ($P = 0.0193$ and $P = 0.013$) decreased by 39 to 41 % as compared to the treatments of cassava planted at same time or 2 weeks after the groundnuts, respectively. The BCR was not favourable for the pure groundnut cropping system due to the low grain yields of groundnut. In the pure cassava cropping system, cassava planting time had no significant effect on both total and net benefits. The BCR was favourable (\$ 3.2 to 3.8 \$⁻¹) in all treatments, indicating that the pure cassava cropping system is profitable in the study area. The intercropping with groundnut was significantly ($P = 0.023$) less profitable relative to the pure cassava cropping due to lower revenue obtained from the groundnut crop and

higher cost of production. However, the results of previous studies revealed that the intercropping systems were more profitable than the pure stands in the cassava-groundnut intercrop [18], in the sorghum-groundnut intercrop [59] and in the pigeonpea-maize intercrop [60].

A sensitivity analysis is presented for evaluating the effect of changes in crop prices on the net benefits. Up to the current groundnut grain price (2.01 USD kg⁻¹), net benefits for the PC [1 week later] treatment remained the largest shown in Figure 6.

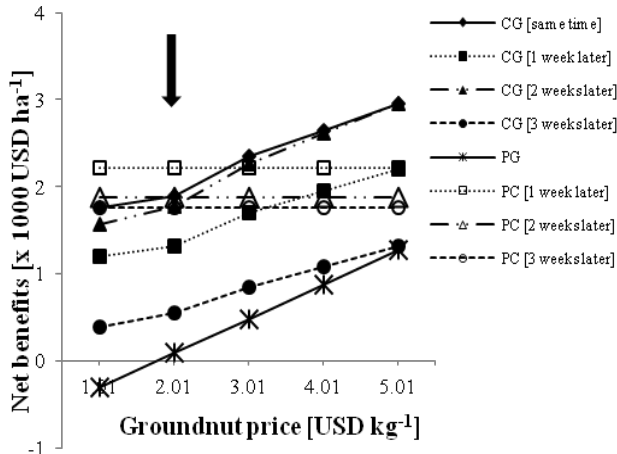


Figure 6. Sensitivity analysis evaluating the effect of changes in groundnut grain on the net benefits. Arrows indicate the current groundnut and cassava prices

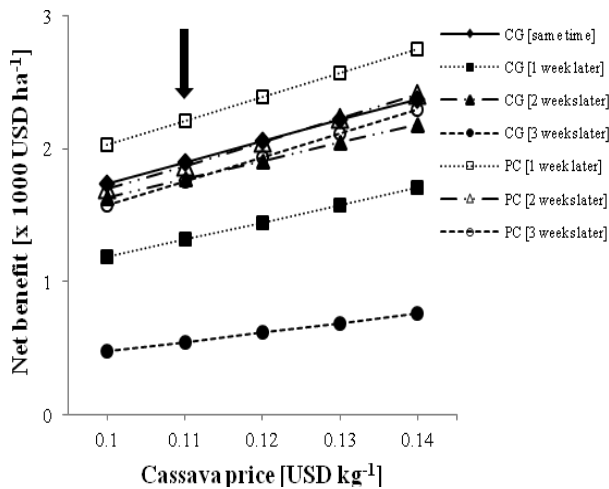


Figure 7. Sensitivity analysis evaluating the effect of changes in cassava root prices on the net benefits. Arrows indicate the current groundnut and cassava prices

When cassava planted at same time or 2 weeks after the groundnuts, net benefits increased (438 to 1778 USD ha⁻¹) if the grain price would change to 4.01 USD kg⁻¹ relative to the pure cassava cropping system. This could be attributed to the additional profits of groundnut in the cassava-groundnut intercrop. A further increase of the grain price (5.01 USD kg⁻¹) would result in an increase of net benefits in the cassava-groundnut intercrop. This indicates that farmer will get a profit by the cassava intercropping with groundnut if the grain price is > 3.01 USD kg⁻¹. However, net benefits remained the lowest when cassava planted later than 3 weeks after the groundnuts in all price changes, indicating that planting of

cassava at 3 weeks after planting was the lowest profit in the cassava-intercropping system due to the low grain yields. In all cassava root price changes, the PC [1 week later] treatment gave the largest net benefit (Figure 7).

Even though cassava price would increase up to 0.14 USD kg⁻¹, the cassava intercropping with groundnut did not result in an increase of net benefits as compared to the pure cassava cropping system. This indicates that farmers should grow cassava alone as there was no additional benefit from the cassava intercropping with the groundnuts.

4. Conclusion

The results of this study show that it is a disadvantage to intercrop cassava 3 weeks after the groundnuts. This is associated with a lower cassava storage root yield, resulting in a lower profit in the cassava-groundnut intercrop. However, the relative planting time of cassava had no significant influence on the yields of groundnut in the cassava-groundnut intercrop. The maximum profit was obtained when cassava was planted at the same time as groundnut. It can be therefore concluded that farmers should plant cassava at the same time or not later than 2 weeks after the groundnuts in the cassava-groundnut intercrop. Based on the present data, farmers should grow cassava alone because the intercropping system does not give the additional benefits under current market conditions.

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