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Cultivation of Cassava (*Manihot Esculentus* C.) With Selected Legumes for Growth, Yield and Economic Advantages as Climate Change Mitigations

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ABSTRACT

Cassava (*Manihot esculentus* Crantz.) is a monoecious perennial shrub that is extensively cultivated as an annual crop in tropical and subtr++=opical regions for its edible, starchy, tuberous roots. It is ideal for intercropping with short-duration crops, which are often harvested before the cassava canopy closes. Thus, intercropping cassava, especially with legumes, is an important way for poor farmers to provide additional crop yield during the early growth stage. Moreover, the incorporation of legumes into cassava-based cropping systems may offer one of the most feasible ways of enhancing protein intake and nutritional security of farming households. Accordingly, a 1-year field study on cassava intercropped with three legumes (haricot bean, mung bean, and soybean) in southern Ethiopia was conducted to determine the effect of intercropping on the growth, yield, and economic advantage of the cassava. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The results revealed that there were significant (P<0.05) differences for cassava plant height, leaf number, stem width, number of storage roots per plant, storage root weight, dry matter, and root yield due to cassava legume intercropping. Cassava- haricot bean intercropping increased root yield by 28% as compared to cassava-mung bean (21%), and cassava-soybean (18 %), respectively. And it can improve land-use efficiency by 31% as compared to cassava-soybean and cassava-mung bean intercropping. The partial budget analysis also revealed that cassava planted with haricot bean gave the highest economic benefit of 199,250 Birr ha-1. Further researches on relative planting time of legumes with cassava and soil fertility variation under sole cassava and intercropping systems are important for improving productivity of growers under the study area.

INTRODUCTION

Background of the Study

Cassava (*Manihot esculentus* Crantz.) is categorized under Euphorbiaceae family (Olsen and Schaal, 1999). It is a monoecious perennial shrub having variable height ranging between 1 and 5 m (Bernardo and Hernan, 2012). Tropical America is believed to be the center of origin for cassava and then introduced into Africa in the Congo basin by the Portuguese around 1558. Cassava extensively cultivated as an annual crop in tropical and subtropical regions for its edible starchy tuberous roots (MoC, 2014). Today, this starchy tuber is a dietary staple in much of tropical Africa and is rich in carbohydrates, calcium, vitamins B and C, and essential minerals.

Recently, the world cassava production stands at 291 million tons, with leading countries like Nigeria, Congo, Thailand, Indonesia ranked 1st, 2nd, 3rd and 4th respectively with production in the Africa (177 million in 2017) regarded as the world largest cassava growing region and unarguably Nigeria remained the highest producer of cassava in the world with about 59 million tonnes in 2017 (FAO, 2017). In Africa cassava production increases in order to promote local available food products to limit wheat import from foreign countries (FAO, 2016). According to the report of FAO (2016), Africa produces 155.6 million tons of cassava, which is more than half of the world production of the same year that is 276.5 million tones.Cassava is a long duration crop (9 - 18 months) and characterized by its tolerance of drought, capacity to produce considerable yield in degraded soil, resistant to insect pests and diseases, tolerance of acid soils and flexibility in planting and harvesting time (Bernardo and Hernan, 2012). It is ideal for intercropping with short duration (2 - 3 months) crops, which are often harvested before the cassava canopy closes. Accordingly, solar radiation, water and some nutrients that would be wasted during early growth stages of long-term crops can be utilized by an associated crop growing between the rows. The relative tolerance of cassava to droughts and even short term flooding make it an excellent crop to resist the negative impacts of climate change. It is thus important in several ways: to combat hunger in a changing climate, as a backup source of food when other crops fail, as a result the status of cassava cultivation transformed from subsistence farming to an industrialized system that processes cassava into a wide range of products, including starch, sago grains, flour, chips, animal feed, and, potentially, biofuel in some cassava growing areas (Thresh, 2006). In Ethiopia, it is mainly cultivated by poor farmers on smallholding plots of land and act as a food security crop and a source of household income. It is increasingly becoming a source of industrial raw material for production of starch, ethanol, waxy starch, bio-plastics, glucose, bakery and confectionery products, glue among others (Tesfaye *et al.*, 2013).

The crop is being grown in almost all parts of the country. However, bulk of its production is situated in south, south western and western parts of the country.

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In recent years the average total coverage and production of cassava per annum in Southern region of Ethiopia is 195,055 hectares with the yield of 501, 278.5 tones indicating the average productivity of cassava in the country is not more than 25 ton per hectare (SNNPR, BoA, 2014) which is by far lower than the yield obtained by other tropical countries such as Nigeria which recorded 35 tons per hectare (FAO, 2013). This yield gap is due to lack of appropriate agronomic practices (Feyisa, 2022). Intercropping, which is the simultaneous growth of two or more crop species in the same field area for all or part of their growing period (Willey, 1990; Lithourgidis *et al.*, 2011) is part of nature-based solutions in land management for enhancing ecosystem services (Keesstra, 2018). Moreover, it increase productivity of both associated components of the system(Mao, 2014;Li *et al.*, 1999) by exploiting the full duration of solar radiation (Zhu *et al.*, 2015), thermal energy (Zhang *et al.*, 2008) and water as well as nutrient resources (Mao, 2014; Qin, 2014 Fan, 2016; Ren *et al.*, 2016) in resource-limited ecosystems. Intercropping can also maintain or enhance soil quality, promotes biodiversity, control weed growth, minimize the incidence of pests and diseases, reduce soil erosion and runoff discharge, and increase farming incomes (Sharma, 2017; Zhang, 2017).

Statement of the Problem

Limited availability of land for crop production, decreased soil fertility and declining yield food crops are major concerns to provide nourishment and food insecurity for the increasing population (Premanandh, 2011; FSIN, 2018). Cassava is considered to be a "climate-smart" crop that can yield well in challenging environments. Cassava-based multiple-cropping systems, which represent a diversification of cropping methods have been evaluated and practiced by farmers in developing countries in Africa and Asia. They include the best combinations of crops with different morpho-phenological features that ensure the efficient and judicious use of land, nutrients and water resources. Such cropping systems offer maximum total factor productivity and ecosystem services, besides food production in a sustainable manner. But, selection of an appropriate intercropping system for each case is quite complex as the success of intercropping systems depend much on the interactions between the component crops and the available management practices. This could lead to understand about compatible mixtures. In southern Ethiopia including Arba Minch areas, farmers usually plant cassava in small irregular scattered plots intercropped mainly with various crops including fruit crops such as banana (Eyasu, 1997; Legese and Gobeze, 2013). However, they often undertake intercropping without checking its efficient and compatible mixtures. Thus, comparatively intercropping cassava especially with legumes is important to cassava farmers since it would provide additional crop yield during the early cassava growth stage. In addition, the use of cassava as a food security crop may be limited by extremely low root protein content. Incorporation of legumes into the cassava-based cropping systems may provide one of the most feasible ways of enhancing protein intake and nutritional security of poor farming households. Bantie et al. (2014) reported that most studies in Ethiopia have focused on cereal and legume intercropping while and little attention was given to other root and tuber crops intercropping systems. Therefore there is limited information on inter-cropping of cassava with some of leguminous crops in this area. So the present study is aimed with the following objectives.

Objective

General Objective

To determine the compatibility of companion crops and their effect on the growth, yield of cassava and land productivity

Specific Objective

To know the land productivity of cassava legume intercropping system

To identify the best intercropping in terms of growth, yield and economic advantages

MATERIALS AND METHODS

Description of the Study Area

The research experiment was conducted in the southern regional state, at the Demonstration-farm of Arba Minch University 500 km south of Addis Ababa. It is situated at 6º5" N and a longitude of 37º38" E and at altitude of 1218 m.a.s.l. near Arba Minch town, which is located at 505km from Addis Ababa. The town enclosed by the two rift lakes Abaya and Chamo in the east and south east respectively. As a rift valley area, it is at the foot of the western escarpment. The Demonstration farm found is located at the Arba Minch, located in the Southwestern parts of Ethiopia.

Climate

Temperature

From the analysis of ten years data, it can be easily conducted that the mean daily maximum temperature ranges from 27.9 0c (February) to 33.8 0c (March) and mean daily range minimum temperature ranges from 12.8 0c (December) to 14.1c in (December).

Rainfall

Ten years rainfall data of the metrological station at Arba Minch University indicated that the maximum mean annual rainfall in the area is about 830.7 mm. The maximum mean month rainfall occurs in the month of April. The distribution pattern of rainfall characterized as bimodal, e.i. have two peaks.

Soil Characteristics

Soil of the research site is alluvial in nature and different characteristics of the soil (0-15 cm) were got analysed by standard methods. The soils are deep, dark in colour and have clay loam soil texture, pH 7.16, organic carbon 1.43 %, total N 0.13 %, Available P as P2O5 - 84.8 ppm and available K 0.41 c mol (+) kg^{-1}.

Table 1: Mean values of selected physico-chemical properties of surface soil

Parameter	Mean value	Rating
Sand (%)	12.0	
Silt (%)	37.3	
Clay (%)	50.7	
Textural class (USDA)	Clay	
PH (1:2.5: soil: water)	7.7	Slightly alkaline (Murphy 1968)
Organic carbon (%)	3.1	High (Tekalign 1991)
Total N (%)	0.26	High (Tekalign 1991)
Available P as P2O5 (ppm)	84.8	Very high (Tekalign 1991)
Available K (cmol / kg soil)	2.63	Very high (FAO 2006)

Own survey, (2021)

Experimental Design and Treatments

The experimental design used for this research was a randomized complete block design with 7 treatments and three replications: Four mono crops, Sole cassava, Sole haricot bean, Sole soybean, Sole mung bean and three intercropped combinations: Cassava + Soybean, Cassava + haricot bean and Cassava + Mung bean. A distance of 1 m and 1.5 m was left between plots and blocks. The size of each plot was 5m length x 4m width ($20m^2$). There were 5 rows per plot for cassava and 12 rows for pluses with spacing of 40 cm x 10 cm. Spatial arrangements of 1: 3 was followed for intercropping according (Aye and Howeler, 2012) methods.

Experimental Materials and Procedures

The experiment was implemented by obtaining released variety of cassava (Qulle) as well as other leguminous crops from Arbaminch Agricultural Research center and the land was ploughed, harrowed till it become ready for planting. Finally seeds of selected legume crops were sown on well prepared plots by their recommended spacing. At the same time cassava stem length of 20 cm cuttings (with 5 - 7 nodes) cut from 60 - 70 cm of 12 months old stems planted on the same land slanting (45^o).

Data Collection

All the desired data of the parameters from the two middle rows of each plot was collected according to the standard scientific procedures.

Growth Parameters

Plant height: Heights of five randomly selected plants were measured by using meter tape from ground level to the apex of the plant and the mean height was expressed in meter.

Number of leaves

All fully matured leaf from five tagged plants were counted and average numbers were considered for statistical analysis.

Stem thickness

From randomly selected plants stem, thickness was measured by using caliper and average number was recorded.

Yield parameters

Storage root number: It was taken by counting the number of tubers from the two harvestable rows in middle hills for each plot.

Storage root weight

This was obtained from the plants of two harvestable rows and the root was weighed by balance and the mean weight expressed in kg.

Dry matter content

Root from sample plants from sample rows was collected and washed thoroughly to remove the adhering soil and then the fresh weights was recorded. After that plant parts, properly labeled and then dry in hot air oven at 1050C for 24 hours until constant weights was recorded at successive observation. Finally, dry matter content was determined by the following formula

Dry Matter Content (%)=(Dry Weight)/(Fresh Weight) x100

Storage root yield

Data was taken from each plot in kilogram and converted into yield per hectare in ton by using the following formula:

Yield per hectare = (Yield per plot (Kg) x 10000 $m^{2)/}$ (20 m^2 X 1000(Kg/ton))

Yield of Companion Crop

Grain yield of the pulses was determined at harvest maturity. All the plants from 0.4 m2 quadrat in each experimental plot were cut at ground level. The pods were removed from all harvested plants, dried, threshed and seeds from threshed pods were weighed to obtain grain yield.

Additional Performance Metrics

Land Equivalent Ratio

(LER) was computed using the following formula described by (Willey and Rao, 1980).

LER= La + Lb= (yab/yaa) + (yba/ybb)

Where: La and Lb are the LERs for the individual crops of the system

Yab = Intercrop yield of crop 'a' Yba = Intercrop yield of crop 'b' Yaa = Pure stand crop yield of 'a' Ybb = Pure stand crop yield of 'b'

A LER of 1.0 would indicate that the amount of land required for both crops in the different pattern was the same as that for each crop grown individually. It is also an indicator of complementary of the component crops. This would imply that there was no advantage of intercropping over pure crops. An LER greater than 1.0 would show a yield advantage of intercropping over pure crops, In contrast, when LER is lower than one the intercropping negatively affects the growth and yield of the plants grown in mixtures. It measure of efficiency of mixture relative to monoculture.

Method of Data Analysis

The collected data for growth and yield parameters was subjected to Analysis of variance (ANOVA) by using SAS Software version 9.1.3 and means separation was done using Duncan's multiple range tests at 5% level of significance. The partial budget analysis was also carried out according to (CIMMYT, 1988). The market costs for inputs at planting and prices of outputs at harvesting were used. All costs and benefits were calculated on hectare basis in Ethiopian birr (ETB).

The variable costs considered in the economic analysis included the cost of fertilizer (birr 10.58 kg-1) and application cost of 200 birr ha-1. Finally the yields were adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers could expect from the same treatment. The average open market prices of cassava tuber were estimated to be birr 15 kg-1 at the nearest local market during harvesting time (October 2021).

The net benefit (NB) was calculated as the difference between the gross benefit and the total cost that varied (TCV). Then, marginal rate of return (MRR) was calculated as: MRR (%) = $\Delta NI/\Delta TVC \times 100$, where ΔNI = change in net income; ΔTVC= change in the total cost that varied. A treatment having marginal rate of return (MRR) greater than 100% and with the highest net benefit was considered to be economically best as per the procedure described by (CIMMYT, 1988).

RESULTS AND DISCUSSION

The experiment was conducted to evaluate cassava-based intercropping of selected legumes crops on growth, yield and yield components of cassava. The result revealed that all growth and yield parameters of cassava were significantly ($P \leq 0.05$) affected due to cropping system.

Effect of Legume Intercropping on Growth Performance of Cassava

Plant Height

The analysis of variance on plant height is shown in Appendix Table 1. The effect of intercropping significantly ($P < 0.05$) affected plant height. On basis of the result, among the treatment the maximum plant height (2.4 m) was recorded for cassava planted with soybean and the minimum (1.6 m) was recorded for cassava with haricot bean (Table.1).

Similarly, Ibeawuchi *et al.* (2007) observed the maximum height when cassava intercropped with mucuna but not with lima bean. More recently, cassava soybean resulted in increase in height due to soybean's high biomass production and long maturity (Pypers *et al.*, 2011). Likewise Muoneke and Mbah, (2007) reported cassava plants were significantly shorter in sole than in intercropped farming system. Also reports confirmed that, intercropped maize had a higher maximum daily growth rate than sole maize (Nan *et al.*, 2018). The current result also in contrast to Njoku and Mouneke, (2008), result as they stated cassava-cowpea intercropping did not have a significant effect on cassava plant height. The increased plant height of cassava, intercropped with soybean could be created greater leaf canopy of soybean that greatly reduce intensity of sunlight to main crop. Increased internode elongation, and reduction in leaf production of the intercropped crops, was reported to be typical responses due to increase far-red: red ratio. Similarly, Carr *et al.* (1995) found that intercropping wheat and lentil increased lentil plant height, compared to sole lentil.

Leaf Number

A significant difference ($p<0.05$) for leaf number of cassava was observed by intercropping with selected legume crops (Appendix table 2). Among the treatment maximum leaf number (217) was recorded for sole cassava and the minimum (60) was recorded for cassava planted with soybean (Table.1).

This implies that increases in canopy coverage and the protracted maturity of soybean leads cassava becomes tall without having much amount of photosynthetic part as compared to sole and other intercropping's. This might be due to the synergistic effect of the two crops was changed into competition for resources such as sun light, nutrient and moisture. In line with this result, Legesse and Gobeze (2013) stated that cow pea and soybean are the legumes not favored by intercropping. Similar finding was also reported by Pypers *et al.* (2011). Partha (2016) reported that sole cropping of cabbage has given maximum values for most of the growth parameters which might be due to no competition from the component crops for available resources. Yewande *et al.* (2014) stated that two cassava varieties under mono crop produced significantly higher number of leaves than when grown under intercropping with legumes. Intercropping cassava with soybean has negative effect on cassava growth and production but

Table 2: The effect of legume intercropping on plant height, leaf number and stem thickness of cassava at Arbaminch during September - December 2020- 2021

Treatments	Plant height (m)	Leaf number /plant	Stem thickness /plant(cm)
Sole cassava	2b[a]	217[a]	17[a]
Cassava + Mungbean	1.8[ba]	120[b]	9[c]
Cassava + Haricot bean	1.6[b]	176[a]	13.6[b]
Cassava + Soybean	2.4[a]	60[c]	6.6[d]
CV (%)	15	15.1	8
LSD	0.6	42	1.3

Where: Means followed by the same letter(s) within a column are not significantly different at ($p < 0.05$)

benefits for soil fertility and long term productivity (Makinde *et al.*, 2007).

Stem Thickness

The intercropping was found significant ($p<0.05$) on mean stem thickness of cassava (Appendix 3). The highest stem thickness (13.6 cm) was observed from cassava intercropped with haricot bean, while the lowest (6.6cm) was obtained from cassava soybean intercropping (Fig.1). This justifies, there is competition period between each of the component crops making critical demands for growth resources in similar way of report by Njo et al. (1986).

Other author, Cardoso *et al.* (2007) reported a 17% reduction in maize stalk thickness due to maize with common bean intercropping. This also corroborated in Olasantan *et al.* (1996). However, Walelign (2008) found that there is no effect of intercropping on maize vegetative growth.

Effect Of Legume Intercropping On Yield And Yield Components Of Cassava

Storage Root Number

The result from analysis of variance revealed that legume intercropping significantly ($p<0.05$) affected storage root number of cassava (Appendix 4). Cassava with haricot bean resulted highest number of storage root (4.6) while cassava with soybean resulted minimum number of storage roots (2.3) and was statically similar with cassava with mung bean (Fig 2). The decreased in number of storage roots with some legume intercropping could be due to competition for growth resources between the component crops which reduced the rate of assimilated photosynthesis in cassava. The current result was similarly reported by Pal *et al.* (1993) as the sorghum intercropped with soybean had shown similar fashion. The other authors, reported same assertion (eg. Mason *et al.*, 1986; Buah and Ogyiriadu, 2017). Our result is in contrast with the report mentioned as the cassava inter-planted with legumes did not influence mean number of roots per plant (Jones and Issaka, 2017).

Table 3: The effect of legume intercropping on storage root number, storage root weight, storage root yield and dry matter of cassava at Arbaminch during September - December 2020- 2021

Treatments	Storage root number/plant	Storage root weightplant(kg)	Storage root yield (t/ha)	Dry matter content(%)
Sole cassava	7[a]	3.1[a]	20[a]	52[a]
Cassava + Mungbean	2.4[c]	1.08[c]	14[b]	30[c]
Cassava + Haricot bean	4.6[b]	1.7[b]	18[a]	41b
Cassava + Soybean	2.3[c]	0.6[c]	12[c]	27[c]
CV (%)	25	20	8	6
LSD	1.8	0.6	2.3	4.5

Where: Means followed by the same letter(s) within a column are not significantly different at ($p < 0.05$)

Storage Root Weight

The storage root weight of cassava was significantly ($P < 0.05$) affected by legume intercropping (Appendix, 5). Based on the obtained result maximum storage root weight (3.1 Kg/plant) registered cassava intercropped with haricot bean and the minimum amount of storage root weight (0.6 Kg/plant) was obtained from cassava with soybean (Table 3). This finding illustrates that, comparing the legumes abilities to suppress weeds that heavily attack at early times which eventually affect negatively the yield components; haricot was able to suppress weeds more effectively than mung bean and soybean. This could be due to haricot ability to grow fast to form a closed canopy and reduction in nutrient drain by weeds. Similarly, Eke-Okoro *et al.* (1999) observed highest cassava storage root yield when intercropped with ground nut relative to other legume crops. Umeh and Umeh, (2015) came to similar conclusions at which intercropped cassava produced

significantly (P < 0.05) different tuber weight.
In contrast, Marcus and Roland (2017) reported that legume intercropping did not show significant difference on mean root weight of cassavaand also, Muoneke and Mbah (2007) stated that weight of fresh tubers per plant and tuberous root yield of cassava were not affected by intercropping.

Storage Root Yield

The intercropping was found significant (p<0.05) on mean storage root yield of cassava (Appendix table 6). The maximum root yield (12 t ha-1) was observed from cassava with haricot bean, that is statistically par with sole cassava and the minimum yield (12 t ha-1) was recorded in cassava planted with soybean (Table 2). The results are in agreement with previous studies on the yield of cassava was not favored by intercropping with cow pea and soybean (Legese and Gobeze, 2013).The findings corroborated the observations of Kingsley and Emmanuel (2021) on cassava-soybean intercrop, in which the intercropped cassava gave minimum mean number of fresh tuber yield. Similar finding was observed by different authors (Gerh *et al.*, 2006; Oguzor, 2007; Buah and Ogyiriadu, 2017; Marcus and Roland, 2017).In line with Ogola *et al.* (2013) reported that yield of cassava in the intercrop may vary with species and cultivar of the component legume. Cassava soybean resulted in greater yield loss of cassava compared with cassava-beans and cassava-groundnut intercrop systems due to soybean's high biomass production and long maturity. Our result is comparable to the findings of Mbah *et al.*, 2003; Pypers *et al.*, 2011; Marcus and Roland, 2017). The authors reported as the yield increment of fresh tuber when cassava grown intercropping with legumes crops. In contrast to present finding Gebisa *et al* (2020) found that cassava-soybean intercropping was increased root yield by 41.7 % as compared to cassava-haricot and also there are reports that confirm yield and yield components of cassava were not affected by intercropping (Polthanee and Kotchasati, 1999).

Dry Matter Content

The analysis of variance on dry matter content revealed that, the intercropping significantly (P < 0.05) affect the dry matter content of cassava (Appendix 7)The maximum dry matter (41%) was recorded for cassava planted with haricot bean and the least (27%) was recorded for cassava planted with soybean (Table 2).
Similarly, intercropping highly significantly reduced tuber dry matter of cassava relative to their mono crops (Yewande *et al.*, 2014). The dry matter differences among intercropping treatments might be attributed to differences in inter competition among plants (Beyenesh *et al.*, 2017). Sharing of growth resources among components crops under intercropping can limit growth and accumulation of dry matter where competition exists (Dasbak and Asiegbu, 2009). In contrast Reinhardt (2017) reported that intercropping has the advantage that the grain legumes are harvested before the cassava closes its canopy and neither crop suffers too much from interspecific competition. Silva *et al.* (2016) also reported that dry matter production between the intercropping systems was not significantly different among different cropping systems. Likewise, cassava-soybean intercropping was increased dry matter content by 41.7% and 21.3% as compared to cassava-haricot bean (Benti *et al.*, 2020). The cassava-cowpea and cassava-peanut intercropping systems produced 42 to 250 g m−2 more dry matter than did the sole cropped cassava between 50 and 105 days after planting (Mason *et al.*, 1988). Total dry-matter of intercropped cassava was always less than that of sole cassava (Tsay *et al.,* 1989). Dry matter production of the maize and soybean components in intercrops was lower than their sole crop counterparts (Ennin *et al.*, 2002).

Effect Of Cassava Legume Intercropping On Yield Performance Of Legumes

A significant (P < 0.05) (28430 kg ha−1) yield increment was observed when cassava was planted with haricot bean and it is statistically par with sole haricot bean (Table.3). Whereas, the least yield was recorded cassava intercropped with mung bean and soybean. Mung bean yields (16932 kg ha-1) and soybean (17010 kg ha-1) were smaller than haricot bean yields in both sole and intercropped cases. Other studies came to similar conclusions Pieter et al. (2011) observed the cassava–groundnut intercropping system performed superiorly in comparison with the cassava–soybean intercrop.
The decrease in grain yield was due to competition of environmental factors with the neighboring cassava plants. In line with our finding Gebisa *et al.* (2020) reported that Pure stand of haricot bean provided grain yield of 33.5% over the intercrop of the same crop with cassava The results confirmed the observations of (Legese and Gobeze, 2013) and also comparable to the findings of Ibeawuchi *et al.* (2007) stated that yield of grain legumes was decreased in cassava- legumes intercrop systems in Nigeria. Similarly Adrien *et al.* (2015) described mono crop yields of groundnut were higher but not significantly different from yields of intercrop system with cassava at Congo.

Table 4: Effect of intercropping cassava with grain legumes on yield of legumes at Arbaminch during September - December 2020- 2021

Treatment	Yield (kg ha^{-1})
Cassava + haricot bean	28430^{b}
Cassava + mung bean	16932^{d}
Cassava+ soybean	17010^{d}
Sole haricot bean	29310^{a}
Sole mung bean	17034^{d}
Sole soybean	18672^{c}
CV	8.9
LSD	175

Land Equivalent Ratio Of Cassava Legume Intercropping

The land equivalent ratio recorded for the cassava legume based cropping systems was greater than one (1.0) for all the cropping systems (Table 5). Cassava planted with haricot gave the highest LER of 1.64, followed by cassava planted with mung bean having LER of 1.33 and the lowest LER was recorded by treatments in which cassava was planted with soybean (1.25).

In the present study, the LER was greater than 1.0 in all the treatments, indicating that it is advantageous to grow cassava in association than in pure stands. The results clearly depicts cassava planted with legumes (Haricot bean, Mung bean and Soybean) recorded the highest LER respectively and suggest that it is the best arrangement for cassava-legumes production (Table 2). The intercropping system's better productivity compared to a single crop could be due to the associated crops' complementary and efficient use of resources which are important for growth and development. Several researchers have also obtained LER greater than 1.0 in cassava-legume intercropping. For instance, Taah *et al.* (2021) observed LER of 1.6 for cassava-soybean intercrop, Widiastuti *et al.* (2021) had also reported of cassava- mung bean had higher LER than the monoculture system, chickpea intercropping with cassava appeared to show greater LER (Ogola *et al.*, 2013). Inline with our finding Hidota and Loha (2013) stated that haricot bean intercropping system had a higher LER (1.8), indicating that the system was efficient. Similarly, Islami *et al.* (2011) reported that intercropping cassava with soybean could increase the cassava productivity and farmer income in Entisol East Java compared to the monoculture cassava. This clearly show, in spite of individual yields of associated crops being lower under intercropping, the overall land productivity was greater under intercropping.

Table 5: LER values for intercropping systems at Arbaminch during September - December

Cropping system	Land equivalent ratio (LER)
Sole cassava	1
Sole cassava + mung bean	1.33
Sole cassava + haricot	1.64
Sole cassava +soybean	1.25

Economic Advantage Of Intercropping Cassava With Legumes

The partial budget analysis showed that intercropping cassava with haricot bean and soybean gave the maximum economic benefit of 199,250 and 166,500 birr ha-1 with marginal rate of return of 230 % and 160 %, respectively, while the lowest net benefit (164,420 birr ha-1) was obtained from cassava planted with mung bean (Table 3). The highest economic benefit for the above treatments might be due to the high nutrient uptake under the intercropping was superior to that under the sole cropping system, that forms a conducive environment for the growth and development of intercropped crop which eventually resulting in increased dry matter accumulation and yield. As the number of crops in the mixture increased, the canopies became denser and covered the soil against insolation, enhanced water infiltration into the soil, minimizing heat and water loss by evaporation during the day and inversion of temperature gradient at night eventually leads increment of earth warm activity (Olasantan, 1988). Ogbuenehi and Orzolek (1987) had reported that intercropping where land is scarce would always generate a higher gross monetary return per unit area of land compared to sole cropping. Total gross returns were greater than growing either pepper or cassava in monoculture (Olasantan et al., 2007). Kumer and Yusuf (1991) observed that the highest LER would not always reflect the highest monetary return for farmers that clearly observed in present finding. In contrast Sibomana *et al.* (2020) reported that cassava under intercropping did not prove profitable in terms of net returns and economic efficiency.

Table 6: Economic Benefits of cassava as influenced by intercropping with legumes during September - December 2020- 2021

	TVC	AjY=AvY- (AvY-0.1)	Field price kg1	TR	NI	MRR (%)
C	17,500	12,000 kg	15	180,000	162,500	
C+S	18,000	12,300 kg	15	184,500	166,500	160
C+M	21,580	12,400 kg	15	186,000	164,420	Dominant
C+ H	25,750	15,000 kg	15	225,000	199,250	230

AjY: Adjusted yield; TVC: Total variable cost; TC: Total cost; TR: Total revenue; MRR: Marginal rate of returns; NI: Net income; C: Cassava; C+M: Cassava + mungbean; C+H: Cassava + haricot bean; C+S: Cassava +soybean.

CONCLUSION

Incorporating grain legumes into the cassava-based cropping systems could enhance the overall productivity of the systems in the study area. In this experiment, the haricot bean was found to be a potential plant for intercropping with cassava. When cassava was intercropped, yields were reduced by 12 to 20 t/ha compared to when cassava was grown solely. However, the intercropping system was able to increase the productivity of land with a LER of 1.64 in cassava intercropped with haricot, followed by a LER of 1.23 in cassava with mung bean. The partial budget analysis also indicated that cassava intercropped with haricot beans gave the highest net economic benefit.

Legumes were able to grow faster to form a canopy that suppressed the growth and development of cassava. Therefore, determining appropriate planting time for cassava before sowing legume crops is the future avenue to be addressed. In addition to this, soil fertility variation under intercropping system is needed to be investigated.

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List of Abbreviations

ARC	Agricultural research center
MOA	Ministry of Agriculture
FAO	Food and Agricultural Organization
IFAD	International Fund for agricultural development
SNNPR	South Nation, Nationalities and Peoples Region

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