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Effects of Common Bean Varieties and Densities Intercropped with Rice on the Performance of Associated Components in Kaffa and Benchi Maji Zones, Southwestern Ethiopia

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Keywords: *economic feasibility, land equivalent ratio, gross monetary value and productivity.*

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Effects of Common Bean Varieties and Densities Intercropped with Rice on the Performance of Associated Components in Kaffa and Benchi Maji Zones, Southwestern Ethiopia

Mitiku Woldesenbet [α] & Getachew Mekonnen [σ]

Abstract- Intercropping of cereals and legumes is important for sustainable food production in the tropics aimed at minimizing risks associated with monoculture. A field experiment was conducted at kuja site in Guraferda Woreda of Bechi Maji zone and Gojeb site in Ghimbo woreda of Kaffa zone, southwestern Ethiopia, during 2016 cropping season to determine the effects of the density and varieties of common bean intercropped with rice on growth, yield components and yield of the associated crops and productivity of the system. Rice variety 'NARICA-4' was intercropped with three varieties of common bean (Red Wolaita, Awash Melka and Nasir) in a factorial combination of *three* population densities of 25% (62,500 plant ha^{-1}), 50% (125,000 ha^{-1}) and 75% (187,500 plants ha^{-1}) of the recommended population density along with sole crops of the respective varieties of common bean and rice in randomized complete block design with three replications. The results of the study showed that days to 50% heading, days to 90% maturity, were significantly affected by common bean density. The shortest days to 50% heading (95.58 days) and the shortest days to 90% maturity (120.33 days) of the associated rice were recorded at 75% planting density of common bean and significantly increased with the decrease in density of common bean to 25%. The plant height of rice was significantly affected by the main effect of variety, density and their interaction. Accordingly, the highest plat height (78 cm) was observed when Nasir variety was intercropped with rice at 75% planting density. It was observed that either the main effect or the interaction of common bean varieties and planting densities were not significant on the grain yield and harvest index of rice. Though it was not significant, the highest grain yields (3042 and 2855 kg ha-1) were obtained from intercropping Awash Melka variety at 50% planting population, respectively. It was observed that the highest dry biomass (12556 kg /ha) of the rice was recorded when intercropped with common bean at 25% planting density and both parameters decreased significantly with increase in planting density of common bean to 75%. The main effect of common bean varieties had significant (<0.05) effect on dry bio mass and highly significant ($p<0.01$) effect on days to 90% maturity, leaf area index, plant height, number of seed per pods hundred seed weight and harvest index of common bean. The shortest days to 90% maturity (83.6 days) and the highest plant height (53.00 cm) were recorded for the Nasir variety. Conversely, the highest plant height (57.33cm) and the highest number seeds per pod (4.7) were recorded in responses to 25% planting density and significantly increased as the bean planting density increased to 75%. The highest grain yield (1842 kg /ha) was recorded for variety Awash Melka at 75% planting density. The highest total LER of 2.38 and GMV of 30,883 ETB/ha were recorded when rice was intercropped with bean variety Awash Melka at planning density of 75%. Therefore, based on the above agronomic and economic evaluations, rice (100%) intercropped with common bean variety Awash Melka at planting density of 75% of the common bean can be recommended for intercropping of rice with common bean in the study area. However, the experiment has to be repeated across over seasons with consideration of farmers preference of the common bean varieties to reach at conclusive recommendation.

Keywords: economic feasibility, land equivalent ratio, gross monetary value and productivity.

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I. Introduction

Poor soil fertility management, poor crop husbandry and effects of climate change are the major challenges and contribute for low crop productivity. Agro-ecological intensification of land use is a prerequisite for increased agricultural productivity, natural resource conservation and sustainable development (CCRP, 2009). The limited land areas are facing pressure to meet basic demands, such as food, since most growers own very small plots of land, especially in Africa (Rezaei-Chianeh *et al.*, 2011). In view of this, there is need for increased production in small areas through intercropping, which utilize common limiting resources better than the species grown separately, as an efficient resource use method (Ghosh *et al*., 2006; Sobkwicz, 2006).

The bulk of agricultural output in Ethiopia comes from 13.3 million small scale subsistence households, each owning, on average about 0.93 ha of land and produces a number of different food and cash crops (CSA, 2008). Tef, maize, wheat, rice and sorghum are among the cereal crops used to be the staple food crops and target of most of the food security programs in Ethiopia (CSA, 2014). Rice was introduced and evaluated initially at different areas of Ethiopia such as Gambella, Pawe, and Fogera in the late 1960s.

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However, attention was not given to rice research prior mid 1990s. Since 1990, seven upland rice varieties including two NERICAs (New Rice for Africa) have been released. The average productivity of these varieties ranges from 2.5 to 4 t/ha on farmers fields (Wolelaw, 2005). Ethiopia has different rice agro-ecologies that can grow rain fed upland rice, rain fed lowland rice, and irrigated rice with a total potential land mass of 1 million hectare (Sewagegne, 2011). However, this yield is very low as compared to the world production due to different constraints among which soil fertility problem is the first.

The current trend in global agriculture is to search for highly productive, sustainable and environmentally friendly cropping systems (Crew and Peoples, 2004). With increasing economic and environmental costs associated with fertilizer use, the need for low-input agro-ecological systems is rising (Meighen and Marney, 2012). Traditional agriculture, as practiced through the centuries, has always included different forms of intercropping (Lithourgidis *et al.*, 2011). As in most tropical countries, in Ethiopia, traditional cropping systems are based on resource poor farmers' subsistence requirements, and are not necessarily the most efficient ones (Tesfa *et al.*, 2002). In southwestern Ethiopia, small scale farmer uses a combination of crops grown on the same land in such a way that cereals, pulses, and oil seeds are represented. However, this cereal-legume intercropping study was not scientifically justified for rice in southwestern Ethiopia, though the area is potential area for rice production. Therefore, this study was initiated with the objective of determining the effects of the varieties and densities of common bean intercropped with rice on performance of the components.

II. Materials and Methods

a) *Description of the Study Site*

The experiment was conducted in two locations namely, Ghimbo district Gojeb site in Kaffa Zone and Guraferda district Kuja site in Benchi Maji Zone, Southwestern Ethiopia, during 2016 main cropping season. These sites were selected because of that they are the most potential areas of southwestern Ethiopia. The study sites at Gojeb and Kuja are located at 8° 06´ N, 36°29´ E, 1490 m.a.s.l. and 9° 07´ N, 37° 35´ E, 1238 m.a.s.l., respectively. The rainfall pattern of these areas is characterized by bimodal distribution with small rainy season *belg* (March-June) and main rainy season *meher* (July-November).

b) *Description of Experimental Materials*

An improved variety of rice named as *NERICA-4* (WAB-450-IB-P-9/1), which is currently grown extensively by the model farmers in the study areas, was used as a test crop. The variety was released in 2006 by the Pawe Agricultural Research Center for its high yield and promising agronomic performances (MoARD, 2007).

c) *Treatments and Experimental Design*

The treatments consisted of planting of rice at the density of 100% of sole population with three common bean varieties (Red Wolaita, Awash Melka and Nasir) at the density of 25% (62500 plants ha^{-1}), 50% (12500 plants ha^{-1}), and 75% (187500 plants ha^{-1}). The sole rice was planted at spacing of 70 cm between rows by drilling. The sole common beans were planted at spacing of 40 x 10 cm (250000 plants ha^{-1}), respectively. For intercropping, common bean was planted inside rice rows at intra-row spacing of 7 cm, 11 cm and 21 cm representing 75%, 50% and 25% of sole population density of common bean, respectively. The experiment was laid out in a Randomized Complete Block Design (RCBD) in factorial arrangement in three replications. There were sole crop rice and the three common bean varieties.

The plot size and spacing of the experiment for sole common bean was 4.2 m length, 40 cm inter-row spacing, 10 cm intra- row spacing with a gross plot size of 4.2 m x 0.4 m x 6 = 10.08 m^2 and the central four rows of three meters length (4 rows x 0.4 m x 3 m = 4.8 m^2) were harvested while for the intercrops four rows inside the rice with a plot size of (4 rows x 0.70 m x 3 m = 8.4 m^2) were harvested. Sole rice was planted in 4.2 m length, 70 cm inter rows spacing by drilling and with 6 rows and had a gross plot size of 4.2 m x 0.70 m x 6 rows = 17.64 m^2 and three central rows of three meters (3 rows x 0.70 m x 4.2 m = 8.82 m^2) were harvested both from sole and intercropped rice.

d) *Experimental Procedure*

Land preparation was done in mid June 2016 using daily labour and the rice seeds were sown in rows spaced 20 cm apart by hand drilling at the seed rate of 100 kg ha^{-1}. The sources of N and P were urea (46% N) and triple super phosphate (TSP, 46% P_2O_5), respectively. All P and half of the N fertilizer sources for the respective inorganic N and P_2O_5 treatments were applied at planting. The remaining half of the inorganic N fertilizer was applied at tillering stage by side drilling. Weeds were removed manually three times *i.e.* at early tillering, maximum tillering and booting stages. No insecticide or fungicide was applied as there was no serious incidence of insect pests or diseases. Harvesting was done manually using hand sickles. The harvested product was sun-dried to a constant weight and threshing and winnowing were done subsequently.

e) *Soil Analysis*

Prior to planting, surface (0 - 30 cm) soil samples, from five spots across the experimental fields, were collected in a zigzag pattern, composited, and analyzed for soil physico-chemical properties and the results are depicted in Table 1. The soil physico chemical analysis of the study areas revealed that the soils of the experimental field were clay and clay loam in texture both at Gojeb and Kuja, respectively. The results also indicated that the soil of Gojeb and Kuja are moderately and slightly acidic with pH of 6.31 and 5.66, respectively. The soils have medium organic carbon (1.46) and total N (0.09%) at Kuja and low organic carbon (0.99) and total N (0.06%) at Gjebo. Available P is low both at Kuja (6.30 ppm) and Gojeb (5.90 ppm) (Table 1).

Table 1: Physico-chemical characteristics of soil of the experimental sites

Soil parameters	Districts	
	Gojeb	Kuja
Textural composition (%)		
Sand	22.00	16.30
Silt	25.00	24.80
Clay	53.00	58.90
Textural class	Clay	Clay loam
pH	5.66	6.31
Organic Carbon (%)	0.99	1.46
Total N (%)	0.06	0.09
Available P (mg kg)	5.90	6.30
CEC (cmol/kg)	16.22	23.41

f) Data Collection

i. *Rice Component*

Days to heading were recorded when the ears or panicles were fully visible on 50% of the plants from each plot by visual observation and days to physiological maturity were recorded when 90% of the plants reached maturity in each plot, *i.e*. when grains were difficult to break with thumb nail. Number of productive tillers m^{-2} was counted from two random 1m X 1m areas (5 rows of 1m length) within the net plot area at physiological maturity and the average was recorded as number of productive tiller m^{-2}. Plant height (cm) was determined from measurements of 10 randomly pre-tagged mother shoots from ground level to the top of the spike excluding the awns at physiological maturity. Likewise, the spikes in the pre-tagged 10 plants were collected and the total grains were counted to record the number of grains per spike. Thousand grains were counted in each plot using electronic seed counter from a bulk of threshed grain and their weight was measured using a sensitive balance at harvest and the weight was adjusted to 12.5% moisture content.

The total aboveground dry biomass yield including straw and spikes of plants in a net plot area was measured using spring balance after sun drying to a constant weight. Then threshed and the grain yield per net plot was weighed and adjusted to 12.5% moisture content. Harvest index was calculated as the ratio of grain yield to total aboveground dry biomass and expressed in percentage.

g) Common Bean Component

i. *Phenological and Growth Parameters*

Days to 50% flowering, 90% physiological maturity, Leaf area, Number of primary branches, Dry biomass, Stand count, Number of pods per plant, Number of seeds per pod, Hundred seed weight (g), Grain yield (kg/ha) and Harvest index.

ii. *Productivity and Economic Evaluation of the Intercropping System*

Productivity of the intercropping system was determined by calculating the Land Equivalent Ratio (LER) (Willey, 1979). Land Equivalent Ratio (LER) was a relative land area required as sole crop to produce the same yield as an intercrop system and calculated as

$$LER = \frac{Y_{ab}}{Y_{aa}} + \frac{Y_{ba}}{Y_{bb}}$$

Where Y_{ab} is yield per ha of rice in intercrop with common bean; Y_{aa} yield per ha of sole rice; Y_{ba} were grain yield per ha of common bean in intercrop with rice; Y_{bb} was grain yield per ha of sole common bean. LER values >1.00 indicate an agronomic advantage of intercropping over sole cropping.

The economic evaluation was done using Gross Monetary Values (GMV) as described by Willey (1979). To calculate the GMV of component crops, the prevailing prices at local market (18.00 Birr/kg at Gojeb and 19.50 Birr/kg at Kuja for rice and 8.0 Birr per kg for common bean at Gojeb and 18.00 Birr/kg) were used.

h) Statistical Data Analysis

The agronomic data were subjected to analysis of variance (GLM procedure) using SAS software program version 9.2 (SAS Institute, 2003). Homogeneity of variances was evaluated using the F-test as described by Gomez and Gomez (1984) and since the F-test has showed homogeneity of the variances of the two locations for most of the agronomic parameters, the average data analysis was used for the two locations. The Fisher's protected least significant difference (LSD) test at 0.05 probability level was employed to separate treatment means where significant treatment differences existed.

III. Results and Discussion

a) Rice Component

i. Rice Crop Phenology

The result of this study showed that the main effect of planting density of common bean had a highly significant ($P<0.01$) effect on days to 50% heading and days to 90% maturity of rice crop.

ii. Rice Growth Parameters

The result of this study indicated that the main effects of varieties and planting density of common bean as well as the interactions had no significant effect on leaf area and leaf area index of rice crop. This result is in agreement negatively with the finding of Wogayehu (2005) who reported that the leaf area index of maize was significantly ($P<0.05$) affected by intercrops of the associated bean varieties. Though it was not significant, the highest leaf area (1593 cm^2) of rice was obtained when Nasir variety was intercropped with rice compared to Awash Melka variety (1585 cm^2) and Red Wolaita variety (1424 cm^2) (Table 3). This might be due to less competition between rice and the associated Nasir variety for growth factors as it was early in maturity as compared to the two varieties, and may have required less nutrients during growth than the other variety.

The result of this study also indicated that Common bean variety and planting density had a highly significant ($P<0.01$) effect and the interaction had a significant ($P<0.05$) effect on plant height of rice. As a result, the highest plant height (78 cm) was obtained when rice was intercropped with common bean variety Nasir at planting density of 75% while the shortest plant height (64.7 cm) was obtained when common bean variety Red Wolaita was intercropped with rice at planting density of 25% (Table 2). In general as the planting density of common bean increased, the height of the associated rice increased indicating increased competition from the associated common bean for the limited resources. This result is in agreement with previous studies conducted by Sarma (1994) on *Sesamum indicum* which indicated that in narrow spacing plants compete more for available resources especially for light and result in more height than widely spaced plants. As sesame plants compete for light, high populations grow taller and faster than low populations (Langham, 2007). Unlike to the results of the present study, Demesew (2002) on maize/bean intercropping, Sisay (2004) on sorghum/green gram intercropping and Wogayehu (2005) on maize/common bean intercropping reported that the plant height of the cereal component was not significantly affected by the associated legume components.

Table 2: The average results of the interaction effect of varieties and planting density of commonbean on plant height (cm) of rice intercropped with common bean

	Planting Density of Common bean (PD)			
Common bean Varieties (V)	25%	50%	75%	
Red Wolaita	64.7^{d}	74.6^{ab}	74.7^{ab}	
Awash Melka	74.7^{ab}	71^{bc}	65^{d}.1	
Nasir	72.2^{cd}	69.7^{c}	78^{a}	
Intercrop mean				74.3
Sole rice mean				261.3
	V × PD		Sole vs Intercrop	
$LSD_{(0.05)}$	4.88		NS	
CV (%)	4.7		6.6	

NS= Non-significantly different at 5% probability level; Means followed by the same letters are not significantly different at 5% level of significance according to LSD test.

b) Yield component and Yield of Rice

Form this study it was observed that the number of grains per spike and 100 seed weights (g) were not significantly affected by either the main effects of the varieties and planting density of common bean or their interaction. In agreement to the result of this study, Tilahun (2002) reported non-significant effect of planting densities and planting patterns on maize 1000-kernel weight. Similarly, Wogayehu (2005) reported non-significant effect of the associated bean varieties on thousand-kernel weight of maize.

It was observed that, the number of grains per spike and 100 seed weights (g) decreased as the planting density of common bean increased from 25% to 75% (Table 1). This might be due to increased competition for growth resources from the associated common bean as its density increased.

The hundred seed weight recorded from intercropped rice was lower than that from sole crop although the difference was not significant (Table 3). In line with this result, Tamado and Eshetu (2002) from intercropping of maize and haricot bean reported that 1000-kernel weight of maize was not significantly affected by the cropping system. On the other hand, Bandyopadhyay and De (1986) attributed the highest sorghum grain yield in intercrops to greater panicle and 1000-grain weight.

Table 3: The average result of main effects of varieties and planting density of common bean on number of grains per spike and 100 seed of rice intercropped with common bean and grown under sole crop

Treatment	Number of grains per spike	100 seed weight(g)
Common bean Varieties		
R + Red Wolaita	16.06	37.1
R + Awash Melka	13.00	38.2
R + Nasir	17.04	39.7
LSD (0.05)	NS	NS
Common bean Planting Density		
R + 25 % B	1.13	42.2
R + 50 %B	1.05	40.5
R + 75 %B	1.05	38.0
LSD (0.05)	NS	NS
CV (%)	17.6	6
Cropping system		
Intercrop	1.23	172.7
Sole crop	1.13	193.3
LSD(0.05)	NS	NS
CV (%)	6	5.8

NS= Non-significantly different at 5% probability level; Means followed by the same letters are not significantly different at 5% level of significance according to LSD test.

It was also observed that the main effect as well as interaction effect of planting density and variety of common bean did not significantly affect the grain yield and harvesting index of rice. This could be due to stronger competitiveness of the rice component as it was planted early at full population as compared to common bean. Amare (1992) also found that intercropping different haricot bean varieties did not significantly affect maize grain yield.

Table 4: The average result of the main effects of varieties and planting density of common bean on grain yield (kg ha^{-1}), dry bio mass (kg ha^{-1}) and harvest index (%) of rice intercropped with common bean and grown under sole crop

Treatment	Grain yield (kg ha^{-1})	Dry biomass (kg ha^{-1})	Harvest index (%)
Common bean Varieties			
R + Red Wolaita	2811	12586	25.41
R + Awash Melka	3042	11968	26.51
R + Nasir	3011	11354	25.32
LSD(0.05)	NS	NS	NS
Common bean Planting Density			
R+ 25 % B	2732	12556^{a}	21.75
R + 50 % B	2855	11224^{b}	25.43
R + 75 % B	2733	11223^{b}	24.35
LSD (0.05)	NS	366	NS
CV (%)	7.6	3.8	7.7

Cropping system			
Intercrop mean	2622	11586	22.63
Sole crop mean	3125	11568	27.01
LSD(0.05)	NS	NS	NS
CV (%)	4.8	6.2	9.8

NS= Non-significantly different at 5% probability level; Means followed by the same letters are not significantly different at 5% level of significance according to LSD test.

However, among the intercropped common bean varieties, rice intercropped with variety Awash Melka gave the highest grain yield (3042 kg ha^{-1}) (Table 4). In agreement with this results of this study, Davis and Garcia (1987), Harwood *et al.* (2000), Tolessa *et al.* (2002) and Tolera *et al*. (2003) reported that planting beans in association had no appreciable effect on the grain yield of maize.

Dry biomass was highly significantly affected by the planting density of the associated common bean and non significantly affected by variety and the interaction of variety with planting density. The highest dry bio mass yield (12556 kg ha^{-1}) was obtained when rice was intercropped with common bean at plant population of 25% and the dry bio mass decreased as the planting density increase to 75% (Table 4). The reduction in dry biomass production in intercropped rice could be due to shading effect of the common bean during the early growth stage and inter-specific competition. Biscoe and Gallagher (1972) reported that the rate of dry bio mass production in crops depend up on the efficiency of the interception of photosyntheticically active radiation (PAR).

The harvest index of rice was non significantly affected by the main effect of common bean varieties, population and their interaction. In this study, though the difference was statistically non-significant, relatively higher harvest index was recorded from sole crop (27.01%) than the intercropped rice (22.63%) (Table 4). In conformity to this Karikari *et al.* (1999) in Bambara groundnut + maize and Bambara groundnut + sorghum intercropping, reported significantly higher harvest indices for sole maize (0.599) and sole sorghum (0.386) than those in intercrops.

c) *Common Bean Component*

i. *Crop Phenology*

The main effect of common bean varieties and planting density had significantly affected days to 50% emergence, days to 50% flowering and days to maturity.

ii. *Growth Parameters*

The main effect of varieties of common bean was highly significant (P<0.01) on leaf area, leaf area index, and plant height. Similarly the effect of planting density on leaf area index and plant height was highly significant and the interaction effect of varieties and planting density was significant on leaf area.

Common bean variety Nasir has the highest LAI (2.9) while the lowest was for variety Awash Melka (LAI=1.4). The variation in leaf area and leaf index observed due to varieties might be due to the difference in inherent characters of the varieties. Similarly, Wogayehu (2005) found significant difference in the leaf area index of common bean among the intercropped common bean varieties.

With regards to the common bean planting density, the highest leaf area index (2.9) was recorded when common bean was intercropped with rice at planting density of 75% and then the leaf area index decreased as planting density was decreased (Table 5). In line with this result, Sisay (2004) reported the highest LAI (2.321) when green gram was sown at its full rate (100%) while the lowest LAI (0.266) from the treatment containing the lowest rate (20%) of green gram. Although the difference is not statistically significant, higher leaf area index (2.53) of common bean was recorded from sole crop than the intercrop with LAI of 2.20 (Table 5).

Table 5: The average result of the main effects of varieties and planting density of common bean on days to maturity, leaf area index and plant height of common bean intercropped with rice and grown as sole crop

Treatment	Days to 90 % maturity	LAI	Plant height (cm)
Common bean varieties			
Red Wolaita	113.4b	2.5^{ab}	52.56^{b}
Awash Melka	117.3a	1.4^{c}	46.44^{c}
Nasir	83.6^{c}	2.9^{a}	53.00^{b}
LSD (0.05)	0.92	0.87	0.72
Common bean Planting Density			
R + 25%	98.1c	1.5^{b}	53.83^{c}
R + 50%	99.9b	2.2^{ab}	55.75^{b}
R + 75%	101.6a	2.9^{a}	57.33^{a}
LSD (0.05)	0.79	0.75	0.62
CV (%)	0.9	35.8	1.3
Intercrop mean	116.3	2.03	55.64
Sole crop mean	100.0	2.53	55.83
LSD (0.05)	9.05	NS	NS
CV%	1.5 2.3	9.9	5.4

NS= Non-significantly different at 5% probability level; Means followed by the same letters are not significantly different at 5% level of significance according to LSD test.

With regards to the effect of planting density the highest plant height (57.33 cm) was recorded at common bean planting density of 75% and the height was significantly increased as planting density of common bean was increased (Table 5). The reduction in plant height of common bean with increase in planting density of common bean might be due to increased competition for growth resources such as radiation, soil moisture and nutrients with increased population of the intercropping system.

iii. *Yield Components and Yield*

In the present study, the main effect of common bean varieties had a highly significant (P<0.01) effect on number pods per plant, number seeds per pod, hundred seed weight, grain yield and harvest index. Moreover, the effect of planting density was highly significant on the above parameters except on hundred seed weight and harvest index which was non-significant. The interaction effect of varieties and planting density of common bean was significant (P<0.05) on number pods per plant and highly significant (P<0.01) on grain yield of common bean.

The highest number of pods per plant (16.33) was obtained from Nasir common bean variety at planting density of 25% and the lowest number of pods per plant (3.0) was obtained from Awash Melka variety at planting density of 75% (Table 6). In general, the number of pods per plant decreased with the increase in planting density for all the varieties. This decrease in number of pods per plant at higher density could be attributed to increased competition among plants for growth factors. In line with this, in sorghum + mung bean and sorghum + pigeon pea intercropping, Subramanian and Rao (1988) reported that decrease in grain number per unit area was responsible for lower grain yields in intercrops than in sole crops.

Above ground dry biomass (kg ha^{-1}) was significantly (P<0.05) affected by the common bean varieties and highly significantly (P<0.05) by the planting density. The highest above ground dry biomass (4466 kg ha^{-1}) was recorded for variety Awash Melka while the lowest (3121 kg ha^{-1}) was recorded for variety Red Wolaita (Table 6). With regards to the planting density, the highest above ground dry biomass (5292 kg ha^{-1}) was recorded at common planting density of 75% and it was decreased significantly with the decrease in planting density of common bean to 25% (Table 6). This decrease might be decrease in population of common bean in the intercropping system. In agreement with this result, Sisay (2004) recorded the highest above ground dry biomass from 100% green gram broadcast with sorghum followed by 80% green gram broadcast with sorghum. Similarly, intercropping of full density of barley with five planting densities of faba bean (100:12.5%, 100:25%, 100:37.5%, 100:50% and 100:62.5%) showed significant increment on dry biomass yield of intercropped faba bean from 653 kg/ha to 2494 kg/ha as plant density of faba bean increased from 12.5% to 62.5% (Getachew *et al.,* 2006). Though the difference was not statistically significant sole crop bean gave higher above ground dry biomass than the intercrop.

Table 6: Main effects of varieties and planting density of common bean on growth parameters and yield components of common bean intercropped with rice and grown as sole crop

Treatment	Number of branches	Dry bio mass (kg/ha)	No. of seed per pod	100 seed wt (g)	Harvest index (%)
Common bean varieties					
Red Wolaita	2.93	3121^{b}	5.0^{a}	22.6^{c}	17.7^{bc}
Awash Melka	3.36	4416^{a}	3.5^{c}	22.3^{a}	27.7^{a}
Nasir	2.78	3166^{b}	4.8^{a}	20.3^{c}	18.7^{b}
LSD (0.05)	NS	839.2	0.35	8.3	3.1
Common bean Planting Density					
R + 25%	2.98	2323^{c}	4.7^{a}	31.7	18.7
R + 50%	2.92	3292^{b}	4.6^{a}	30.8	20.4
R + 75%	2.93	5292^{a}	3.9^{b}	30.6	20.2
LSD (0.05)	NS	726.8	0.3	NS	NS
CV (%)	25	23	7.7	25.6	16.9
Intercrop mean	2.9	3491	4.47	23.67	23.3
Sole crop mean	3.2	4147	4.47	32.84	23.7
LSD (0.05)	NS	NS	NS	8.1	NS
CV (%)	4.1	19	6.6	7.7	5.2

NS= Non-significantly different at 5% probability level; Means followed by the same letters are not significantly different at 5% level of significance according to LSD test.

The highest number of seeds per pod (5.0) was obtained from common bean variety Red Wolaita while the lowest number of seed per pod (3.5) was for variety Awash Melka (Table 6). This difference in number of seeds per pod might be due to the inherent behavior of the varieties where Awash melka with large seed size had the smallest number of seeds per pod.

The main effects of common bean varieties, planting density and the interaction had a highly significant ($P<0.01$) effect on grain yield of the intercropped common bean (Table 7). The highest grain yield (1842 kg ha^{-1}) was recorded for common bean variety Awash Melka at planting density of 75% while the lowest grain yield (180 kg ha^{-1}) was recorded for bean variety Red Wolaita at 25% planting density (Table 7). In general variety Awash Melka gave higher grain yield than the other varieties possibly due to its large seed size. Moreover, the grain yield of common bean was increased as the planting density increased which might be due to the increased population. In agreement with this result, Sisay (2004) reported the highest seed yield of green gram when it was intercropped with sorghum with full rate and the lowest seed yields of green gram from intercrop combinations containing 20% and 40% populations of green gram.

Table 7: The interaction effect of varieties and planting density of common bean on grain yield (kg ha^{-1}) of common bean intercropped with rice

Common bean Varieties (V)	Planting Density of Common bean (PD)			
	25%	50%	75%	
Red Wolaita	180^{g}	407^{e}	712^{c}	
Awash Melka	546^{d}	1142^{b}	1842^{a}	
Nasir	182^{g}	421^{d}	691^{g}	
Intercrop mean				708
Sole common bean mean				845
	V × PD		Sole vs Intercrop	
LSD$_{(0.05)}$	133		NS	
CV (%)	10.8		13.7	

NS= Non-significantly different at 5% probability level; Means followed by the same letters are not significantly different at 5% level of significance according to LSD test.

In this study, there was no significant difference in grain yield of the intercropped common bean sole cropped bean. However, this is in contrast to results by Huxley and Maigu (1978) who reported that in cereals and legumes intercropping system, the grain yield of the legume component declined, on average, by about 50% of the sole crop yield, where as the cereals yield was reduced by only 11 %. In agreement with this finding, Pal *et al.* (1993) reported that grain yield of sole cropped maize; sorghum and bean were significantly higher than the intercropped yield of these crop

d) Productivity and Economic Evaluation of Rice and Common Bean Intercropping

i. *Land Equivalent Ratio*

The agronomic productivity of this experiment was evaluated by calculating total land equivalent ratio (LER) by summing up the partial land equivalent ratio (PLER) of common bean and rice as described by Willey (1979). The main effect of variety and planting density of common bean and their interactions had a highly significant (P<0.01) effect on total Land Equivalent Ratio (Appendix Table 7).

The highest total LER of 2.38 was recorded when rice was intercropped with bean variety Awash Melka at planning density of 75% while the lowest total LER of 1.01 was obtained when bean variety Red Wolaita was intercropped at planting density of 25% (Table 17). In general, as the planting density of common bean increased, the total LER was increased indicating the importance of increased bean population in the intercropping system in improving the agronomic efficiency of the intercropping system. The value of LER above 1 indicates that the intercropping system utilizes the available growth resources more efficiently than sole cropped. In this study all of the total LER values of the intercropping system were greater than one, indicating that intercropping of rice and common bean was productive and had yield advantage over growing either rice or common bean in sole. This could be due to the efficient utilization of resources by the intercropped crops. In line with the results of this study, Ofori and Stern (1987) pointed out that the value of LER follow the density of legume component. Similarly, Eyob (2007) reported the highest LER of 1.94 from intercropping of faba bean with 75% plant density of sorghum. In contrast to this, Yesuf (2003) reported that the LER decreased with the increase planting density. Intercropping had higher mean LER (1.80) than sole crop (1.0) .

Table 8: Interaction effect of varieties and planting density of common bean on total land equivalent ratio of the intercropped rice and common bean

Common bean Varieties (V)	Planting Density of Common bean (PD) 25%	50%	75%	
Omo	1.01^{f}	1.23^{de}	1.47^{b}	
Ibbando	1.40^{bc}	1.92^{a}	2.38^{a}	
Hawassa Bume	1.10^{ef}	1.26^{cde}	1.49^{b}	
Intercrop mean				1.7
Sole mean				1.0
	V × PD		Sole vs Intercrop	
$LSD_{(0.05)}$	0.16		NS	
CV (%)	6.3		10.5	

NS= Non-significantly different at 5% probability level; Means followed by the same letters are not significantly different at 5% level of significance according to LSD test.

ii. *Gross Monetary Value*

The main effect of variety and planting density of common bean and their interactions had significant (P<0.05) effect on Gross Monetary Value (Appendix Table 7). The highest Gross Monetary Value of 30,883 ETB/ha was obtained from common bean variety Awash Melka intercropped with rice at planting density of 75% while the lowest Goss Monetary Value of 17,356 ETB/ha was obtained when bean variety Red wolaita was intercropped with rice at planting density of 25% (Table 18).

Table 9: Interaction effect of varieties and planting density of common bean on Gross Monetary Value of the inter cropped rice and common bean

Common bean Varieties (V)	Planting Density of Common bean (PD) 25%	50%	75%
Red Wolaita	17356	19584	21821
Awash Melka	21623^{b}	26787^{a}	30883^{a}
Nasir	18884de	20130^{bcd}	22454^{b}

Intercrop mean	28984
Sole rice mean	17169
Sole common bean	7493

NS= Non-significantly different at 5% probability level; Means followed by the same letters are not significantly different at 5% level of significance according to LSD test.

As it was in total LER, as the planting density of common bean increased, the Gross Monetary Value increased indicating the importance of increased bean population in the intercropping system in increasing the economic efficiency of the intercropping *system as rice had high price (18 Birr/kg) than bean (5.6 Birr/kg) in the local market. In this study* all the intercrops gave higher gross monetary value than either of sole rice or sole bean (Table 18). In agreement with the result of this study, Tesfay (2012) reported the highest GMV (46375.2 ETB/ha) from additive mixture of faba bean and wheat variety HAR 2501 at the seed rate of 75% while the lowest GMV (32222.1 ETB/ha) was obtained from intercropping of faba bean and variety HAR 2501 with seed rate of 50%.

IV. Conclusion

Intercropping is an important option for efficient utilization of resource especially under gradually decreasing cultivated land. Even though there is practice of intercropping cereals and legumes in the study area, the practice of intercropping rice with different densities of common bean is not common. Therefore, this study was initiated with the objective of determining the effect of density and varieties of common bean intercropped with rice on performance of the associated crops at Kuja and Gojeb, sothwestern Ethiopia. The treatment consisted of three improved common bean varieties (Red Wolaita, Awash Melka and Nasir) and three planting densities (25%, 50% and 75%) of the recommended seed rate of sole common bean laid out in randomized complete block design (RCBD) in factorial arrangement and replicated three times.

The results of the study showed that days to 50% heading, days to 90% maturity, leaf area index, number of seeds per spike, 100 seed weight, grain yield, dry bio mass and harvest index were not significantly affected by the varieties of the associated common bean. However, days to 50% heading, days to 90% maturity and dry bio mass were significantly affected by common bean density. The shortest days to 50% heading (95.58 days) and the shortest days to 90% maturity (120.33 days) of the associated rice were recorded at 25% planting density of common bean and significantly increased with the increase in density of common bean to 75%. The highest dry biomass (12556 kg/ha) of the rice crops were recorded when intercropped with common bean at 25% planting density and both parameters decreased significantly with increase in planting density of common bean to 75%.

The interaction effect of varieties and planting density was highly significant (P<0.01) on plant height of the rice intercropped with common bean varieties. The highest plant height (78 cm) was recorded when rice was intercropped with common bean variety Nasir at planting density of 25%. In general as the planting density of common bean increased the height of the associated rice was increased.

The main effect of common bean varieties had significant (<0.05) effect on dry bio mass and highly significant (p<0.01) effect on days to 90% maturity, leaf area index, plant height, number of seed per pods, hundred seed weight and harvest index. The shortest days to 90% maturity (83.6 days) and the highest plant height (53 cm) were recorded for the Nasir variety. Common bean variety Awash Melka was found to have the highest days to maturity (117.3 days), dry bio mass (4466 kg/ha), hundred seed weight (52.3 g) and harvest index (27.7%).

The main effect of common bean density had significant effects on days to 90% maturity, leaf area index, plant height, dry bio mass and number of seeds per pod. The shortest days to 90% maturity (83.6 days) and the lowest leaf area index (1.4) were recorded at common bean planting density of 25% and significantly increased as the bean planting density increased to 75%. Conversely, the highest plant height (57.33cm) and the highest number seeds per pod (5.0) were recorded in responses to 25% planting density and significantly increased as the bean planting density increased to 75%.

Days to 50% emergence, stand count difference, leaf area and number of pods per plant of common bean were significantly affected by the interaction effect of rice intercropped with common bean. Grain yield of common bean was also significant affected by the interaction effect of rice intercropped with common bean. The shortest days to 50% emergence (10 days) of common bean was recorded at the Awash Melka and Nasir at planting density of 25% and Red Wolaita at 75% planting density intercropped with rice crop. The highest leaf area (2.9 cm^2) and the highest number of pods per plant (16.33) were recorded for varieties Awash Melka and Red Wolaita at 25% planting density intercropped with rice, respectively.

The main effect of variety and planting density of common bean and their interactions had a highly significant (P<0.01) effect on total Land Equivalent Ratio. The highest total LER of 2.38 was recorded when rice was intercropped with bean variety Awash Melka at planning density of 75% while the lowest total LER of 1.01 was obtained when bean variety Red Wolaita was intercropped at planting density of 25%. In general, as the planting density of common bean increased, the total LER was increased. As it was for LER, the main effect of variety and planting density of common bean and their interactions had significant (P<0.05) effect on Gross Monetary Value. The highest Gross Monetary Value of 30,883 ETB/ha was obtained from common bean variety Awash Melka intercropped with rice at planting density of 75% while the lowest Goss Monetary Value of 17,356 ETB/ha was obtained when bean variety Red Wolaita was intercropped with rice at planting density of 25%). In this study all the intercrops gave higher gross monetary value than either of sole rice or sole bean. Therefore, based on the above agronomic and economic evaluations, rice (100%) intercropped with common bean variety Awash Melka at planting density of 75% of the common bean can be recommended for intercropping of rice with common bean in the study area. However, as this is one field experiment, the experiment has to be repeated over seasons with consideration of farmers preference of the common bean varieties to reach at conclusive recommendation.

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