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Advantage of Intercropping Roselle with Common Bean over Sole Cropping in Ethiopia

Dejene Tadesse Banjaw
Ethiopian Institute of Agricultural Research, Wondo Genet Agricultural Research Center,
P.O. box 198 Shashamane, Ethiopia

Abstract
This experiment was conducted in Ethiopia, during 2017/2018 dry season to determine the roselle-common bean advantage over sole cropping through competition indices. The experiment was carried out in a RCBD with a 2x4 factorial arrangement of two roselle varieties with four planting densities of common bean plus three sole cropping. It was replicated three times having 11 treatments (sole cropping of two roselle varieties (Hibiscus-Sudan and Hibiscus-Jamaica) and a common bean variety (Ibbado) and intercropping of the two roselle varieties with four common bean planting densities combinations (25%, 50%, 75%, and 100%)). Data analysis was done using SAS software version 9.3 and the differences between means were assessed using Duncan`s Multiple Range Test at 5% probability level. Partial land equivalent ratio (LER) analysis showed that there was no significant difference between two roselle varieties while partial LER of common was significantly higher when intercropped with Hibiscus-Sudan (0.51) than with Hibiscus-Jamaica (0.38). Both roselle varieties and common bean planting density did not influence total LER and monetary advantage index (MAI). However, intercropping Hibiscus-Sudan variety resulted higher yield advantage (35%) and monetary advantage (17,946 ETB) and combination of common bean with roselle at 100% planting density resulted 39% yield advantage and 21,410 ETB. Therefore, we recommend combination of Hibiscus-Sudan and 100% planting density of common bean for growers in the same agroecology with the study area for better yield and economic advantage.
Keywords: Competition indices, intercropping mixture, LER
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Introduction

Intercropping which is growing two or more crops on the same land unit in a particular growing season (Sullivan, 2003) seen as advantageous in the world, particularly in developing world for enhancing yield per unit area to answer food and feed requests of growing population. Despite of some limitations, intercropping has various advantages over sole cropping, such as, it increases yield per unit area (Ali *et al*., 2015), avoids a risk of total yield loss as when one crop fails the producer may harvest the other crop (Heydari *et al*., 2016), and improves household income of the producers (Zhang *et al*., 2015). Another important aspect of intercropping is the reduction of the negative impact of weed, insect, and disease incidences compared to sole cropping (Lithourgidis *et al*., 2011). The yield and economic advantage of intercropping might be due to efficient use of limited resources like arable land. In Ethiopia, a country where population has been increasing and where the size of arable land was being reduced to due to environmental and urbanization, intercropping is assumed important practice to increase yield per unit area bean (Hirpa, 2014; Adafre, 2016). Studies reported the advantage of intercropping through combinations of different crop species, including medicinal plants in the country (Lulie and Bogale, 2014). Roselle (*Hibiscus sabdariffa* L.), belonging to the family Malvaceae, is one of the important medicinal plants grown in tropical and subtropical regions mainly for its calyx (Plotto *et al.,* 2004). In addition to its health benefit, roselle has industrial and nutritional values (Mahadevan and Kamboj*,* 2009). Compatibility and higher intercrop productivity of roselle with legume crops were reported (Heydari *et al.,* 2016; Gendy *et al.,* 2017). However, the performance of roselle in intercropping system has not been well known in Ethiopia, except some inter and intra row spacing determination (Gebremedin, 2015) and cost-benefit studies during direct sowing and transplanting roselle varieties (Girma *et al*., 2014). Cultivation of roselle is restricted to few growers though it is an important medicinal plant in the country. Lack of appropriate cropping system and weak research-extension linkage are among the main production constraints of roselle in Sidama zone of the Southern Nations, Nationalities, and Peoples Region (SNNPR) of Ethiopia. Hence, in order to expand the production of this crop and provide a quality product to the domestic and foreign markets, identification of a certain cropping system, like intercropping with legume crops such as common bean, can be one of the best options. Therefore, identification and utilization of a suitable cropping system for different roselle varieties can play a key role to increase productivity of the crop and land use efficiency in potential growing areas. Hence, this study was initiated to evaluate productivity of two different roselle varieties intercropped with different planting densities of common bean using competition indices.

MATERIALS AND METHODS

The experiment was conducted during 2017/2018 cropping season at Hawassa, in Southern Ethiopia. This study site is located at $7^{0}05'$ North latitude, $39^{0}29'$ East longitude and at an altitude of 1652 m a.s.l. It receives a bimodal rainfall with short and long rainy seasons from March to April and June to August, respectively and the average annual precipitation ranges from 1000 to 1800 mm. The minimum and maximum mean temperatures of the area are 13 and 27 °C, respectively. The soil textural class of the area is sandy loam with a pH of 7.2 (Dessie & Kleman, 2007). Two roselle varieties (WG-Hibiscus-Sudan and WG-Hibiscus-Jamaica) and a common bean variety (Ibbado) were used for the study.

The treatments were arranged in factorial Randomized Complete Block Design (RCBD) with three replications. The experiment consisted of a total of 11 treatments (2 roselle varieties × 4 planting densities of common bean plus 3 sole plots). The size of each plot was 8.64 m^2 (3.6 m x 2.4m), and pathways between plots and blocks were 1 and 2 m, respectively. Row and plant spacing for roselle were 60cm and 30cm respectively while that of common bean were 40cm and 10cm for sole cropping and for 100% mixture with roselle. Plant spacing used for 75%, 50%, and 25% common bean planting densities were 13cm, 20cm and 40cm respectively. Roselle and common bean seeds were sown on separate rows with roselle sown first and followed by common bean after 30 days of roselle. All necessary management practices were applied as required uniformly.

Roselle calyx was harvested from each net plot area, sun dried and converted to per hectare to record dry calyx yield per hectare. Common bean seed yield was recorded after weighing seeds of the whole central plants (by excluding the border rows and plants) using digital balance (model YP 20002) and after the seeds were adjusted to 10% moisture content using a digital moisture tester (model M-3G) according to the following formula (Hellevang, 1995).

Adjusted yield = [(100-AM)/(100-SM)] X Obtained yield, Where, A M = actual moisture and SM =standard moisture. Intercropping productivity was evaluated using the following competition indices.

Land equivalent ratio (LER): The yield advantage of roselle and common bean intercropping was determined by calculating LER, which is the amount of land required under sole cropping to obtain the same yield as produced in the intercrop (Mead and Willey, 1980) as cited by Bantie *et al*. (2014). When LER measures 1.0 or greater than 1.0, it means that an intercropping is more advantageous than sole cropping in utilizing resources. Hence, the effectiveness of roselle and common bean intercropping for using available resources was evaluated using the following formula.

LER = (YRI/YRP) + (YCBI/YCBP), Where, YRI = Calyx yield of roselle under intercropping, YCBI = Seed yield of common bean under intercropping, YRP = Calyx yield of roselle in sole cropping, and YCBP = Seed yield of common bean in sole cropping.

Monetary advantage index (MAI): The yields of both roselle and common bean crops in intercropping and sole cropping systems and their economic returns in terms of monetary value were evaluated by calculating MAI to check whether intercropping or sole cropping of roselle and common bean is profitable or not.

MAI= [(PR*YRI) + (PCB*YCBI)]*((LER-1)/LER), where, PR = Price of roselle calyx yield and PCB = Price of common bean seed yield.

Local market prices of a kg of dry calyx of roselle and a kg of common bean seed were used for monetary advantage determination. The average prices for a kg of a dry calyx of roselle (70 ETB) and common bean (11 ETB) were taken from local markets in Hawassa and Shashamane towns.

Data Analysis

All data collected were subjected to analysis of variance (ANOVA) using SAS software version 9.3. Whenever the ANOVA indicated the presence of significant variations between treatments, mean separation was done using Duncan`s Multiple Range Test at 5% probability level [CR (0.05)] to indicate the minimum difference between mean values under comparison for the variation to be significant or not.

Result and Discussion

Partial land equivalent ratio

ANOVA revealed that the interaction of main factors was not significant for both roselle and common bean partial land equivalent ratio ($P > 0.05$) (Table 1). However, partial land equivalent ratio of the two roselle varieties were significantly ($P \leq 0.05$) affected by common bean planting density. The higher partial land equivalent ratio of roselle (0.97) was obtained from intercropping with common bean at 25% planting density and the lowest (0.82) from intercropping with common bean at 100% planting density (Table 2). This might be due to the reduction in yield contribution of roselle as common bean planting density increased which favored yield of the common bean. This might have resulted from efficient utilization of resource as a result of increased competition of common bean at higher planting density. Furthermore, partial land equivalent ratio of common bean was significantly affected by roselle variety and common bean planting density ($p \leq 0.01$) (Table 1). The higher common bean partial land equivalent ratio (0.51) was obtained when intercropped with Hibiscus-Sudan and the lower (0.38) when intercropped with Hibiscus-Jamaica (Table 2). The lower partial land equivalent ratio, which was less than 0.5, showed the disadvantageous of intercropping, and thus, according to the present finding, common bean intercropping with variety Hibiscus-Jamaica was found to be inappropriate. This could be due to the competitive ability of the roselle variety for light, water and nutrients. On the other hand, the higher partial land equivalent ratio (0.51) of common bean from intercropping with Hibiscus-Sudan variety indicated as yield of common bean was more favored than the case of intercropping with Hibiscus-Jamaica. Furthermore, as common bean planting density increased from 25% to 100%, partial land equivalent ratio of common bean increased from 0.32 to 0.56, which, might be due to better resource utilization (Table 2). A similar increase in partial LER of common bean with increases in planting density has been reported for intercropping common bean with maize (Lulie *et al*., 2016).

Total land equivalent ratio

The combined (total) land equivalent ratio of roselle and common bean intercropping was not significantly influenced (P > 0.05) by the interaction between main factors, by roselle variety and common bean planting density (Table 1). However, numerically, total LER was higher for intercropping common bean with variety Hibiscus-Sudan (1.35) compared to the result obtained for intercropping common bean with variety Hibiscus-Jamaica (1.30) (Table 2). This showed that intercropping Hibiscus-Sudan with common bean was more advantageous compared to Hibiscus-Jamaica. Furthermore, as common bean planting density increased from 25% to 100%, there was an increasing trend in total LER from 1.29 to 1.39 (Table 2). This was in agreement with the reports of Lulie *et al.* (2016) and Adafre (2016) who observed increment in total LER as common bean planting density increased from 25% to 100%. Based on the values of total LER, advantage of intercropping roselle with pigeon pea (Pushpa *et al*., 2017), maize with faba bean (Rezaei-Chianeh *et al*., 2011) and cotton with cow pea (Aesim *et al*., 2008) has been reported.

Table 1. Analysis of variance for productivity of roselle - common bean intercropping

Source	DF	LER			MAI
		Roselle	Common bean	Total	
Rep	2	0.084**	0.022^{NS}	0.141*	177953659.4^{NS}
Var	1	0.047^{NS}	0.010**	0.012^{NS}	2632934.8^{NS}
PD	3	0.029*	0.077**	0.015^{NS}	42919364.2^{NS}
Var*PD	3	0.007^{NS}	0.010^{NS}	0.011^{NS}	27327736.2^{NS}
Error	14	0.011	0.009	0.027	78096750
CV		11.93	21.99	12.32	50.17

NS=not significant; *, **, and *** significant at P≤0.05, P≤0.01 and P≤0.001 probability levels respectively; Rep= Replication; DF = degree of freedom; LER=Land equivalent ratio; MAI=Monetary advantage index.

Monetary advantage index (MAI)

Monetary advantage index of roselle-common bean intercropping was not affected by variety, planting density and their interaction (p > 0.05) (Table 1). However, numerically the highest monetary advantage (17, 946 ETB) was obtained from Hibiscus-Sudan than from Hibiscus-Jamaica (17, 283 ETB) (Table 2). Besides, as planting density increased from 25% to 100%, MAI increased from15, 525 ETB to 21, 410 ETB (Table 2). This could be due to difference in the amount of yield of common bean.

Table 2. Productivity of two roselle varieties and different common bean planting densities under an intercropping system

Treatment	LER			MAI
	Roselle	Common bean	Total	
Roselle Variety				
Hibiscus-Sudan	0.84	0.51^{a}	1.35	17946
Hibiscus-Jamaica	0.93	0.38^{b}	1.30	17283
CR(0.05)	NS	0.08	NS	NS
Common Bean Planting Density				
100%	0.82^{b}	0.56^{a}	1.39	21410
75%	0.83^{b}	0.51^{a}	1.33	17548
50%	0.9^{ab}	0.38^{b}	1.29	15976
25%	0.97^{a}	0.32^{b}	1.29	15525
CR(0.05)	0.13	0.12	NS	NS
CV	11.93	21.99	12.32	50.17

NS=not significant; CV=Coefficient of variance; CD = Critical difference; LER= Land equivalent ratio; MAI=Monetary advantage index. Means in a column followed by the same letters are not significantly different at P≤5%.

SUMMARY AND CONCLUSIONS

The productivity of the intercropping roselle with common bean was evaluated based on land equivalent ratio (LER) and monetary advantage index (MAI). Partial LER of common bean was significantly influenced due to roselle variety, where, Hibiscus-Jamaica resulted in lower value (0.38). However, as planting density increased from 25% to 100%, partial LER of roselle decreased from 0.97 to 0.82, while that of common bean increased from 0.32 to 0.56. Both total LER and MAI were not significantly affected by roselle varieties and common bean planting densities. But, both parameters were numerically higher for Hibiscus-Sudan and showed an increasing trend as planting density increased. Intercropping Hibiscus-Sudan with common bean resulted in 35% yield advantage and 17,946 ETB monetary advantage while Hibiscus-Jamaica intercropped with common bean resulted in 30% yield advantage and 17,283 ETB monetary value. In addition, common bean at 100% planting density intercropped with roselle resulted in 39% yield advantage as well as 21,410 ETB monetary value. Therefore, it was suggested that a combination of Hibiscus-Sudan and common bean at 100% planting density would be advantageous for growers in the study area and in similar agroecologies for yield and economic advantages. However, further studies should be carried out under rainfed condition, at different locations and in different years to come up with more comprehensive.

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