American Journal of Bioscience and Bioengineering
2024, Vol. 12, No. 4, pp. 62-67
https://doi.org/10.11648/j.bio.20241204.12

Research Article

A Study of the Effect of Sorghum Varieties and Cowpea Intercropping on Land Productivity and Competition Index in Fedis District, Eastern Ethiopia

Wubshet Tesfaye*

Animal Feed Resource and Rangeland Improvement, Oromia Agricultural Research Institute, Sinana Agricultural Research center, Bale Robe, Ethiopia

Abstract

Now a day human population increasing rapidly and cause land shortage land degradation, and poor soil fertility. Intercropping provides an opportunity to harness available resources by the cultivation of two or more crops planted simultaneously in the same land to produced cereal-legume for food and feed. A field study was conducted in Fedis District in 2018 to determine the impact of intercropping early maturing sorghum varieties and cowpeas on the land productivity and competition index. With a total of 11 treatments; two cowpea cultivars (9333 and 9334) and three varieties of early maturing sorghum (Teshale, Birhan and Melkam), their intercropping and sole cropping were determined using a randomized complete block design with three replications. Intercropping of sorghum-cowpea varieties produced significantly higher total land productivity than sole cropping of both varieties. The value of land equivalent ratio ranges from 1.21 for Sorghum (Teshale) + Cowpea (9334) to 1.36 for sorghum (Birhan) + cowpea (9333) and the overall mean was obtained as 1.30. The Percentage of the land saved of grain yields obtained was ranges 17.37% to 26.47% from of sorghum Teshale + cowpea varieties (9334) to sorghum Birhan + cowpea varieties (9333) and for Biomass yield production recorded from 27.01% to 36.71% that obtained from sorghum Melkam + cowpea (9333) and sorghum Birhan + cowpea (9334). Intercropped of sorghum-cowpea over all mean 23.25% for grain yield and 31.515% for biomass land was saved than sowing alone. Based on the result sorghum-cowpea intercropped, had the strength of relationship interaction and compatible; preferably sorghum Melkam + cowpea (9333) appropriate to increase the productions in study area and with similar agro-ecology.

Keywords

Aggressivity Index, Competition Index, Intercropping, Land Equivalent Ratio

1. Introduction

A number of factors affect livestock production, including land degradation, land shortage, and poor soil fertility [17] and due to rapidly increasing human population pressure, cropping is expanding and grazing areas are shrinking [2]. Intercropping provides an opportunity to harness available resources by the cultivation of two or more crops planted simultaneously in the same land that provides the possibility of yield benefit and minimize crop failure [6]. A major bene-

*Corresponding author: Wubshettesfaye2010@gmail.com (Wubshet Tesfaye)

Received: 15 July 2024; **Accepted:** 6 August 2024; **Published:** 27 August 2024

fit of intercropping is an increase in production per unit area compared to sole cropping through the effective use of resources (water, nutrients, and solar energy), which reduces weed competitions and stabilizes the yield [13]. It also provides an opportunity for farmers to improve agriculture through increased production, enhanced soil conservation and significant labor savings [12] among other benefits Legumes contribute to maintaining the soil fertility via N fixation, which is increased in intercrops due to the more competitive character of the cereal for soil inorganic N. This leads to complementary and more efficient use of N sources by the crops in the intercrop system [15]. Thus, its design improved the system for a given agro-ecological situation based on their superiority over the existing system, which is adapted by the farmers of the area in terms of their biological productivity and stability of production with the least harm of the ecosystem. Farmer generally takes decisions on the technologies to adopt on the bases of cost, risk and return calculation. In small-scale farms, the farmers raise as a risk minimizing measures against a total crops failures [16]. Intercropping system has long been practiced by smallholder farmers in various tropical and sub-tropical regions worldwide [7].

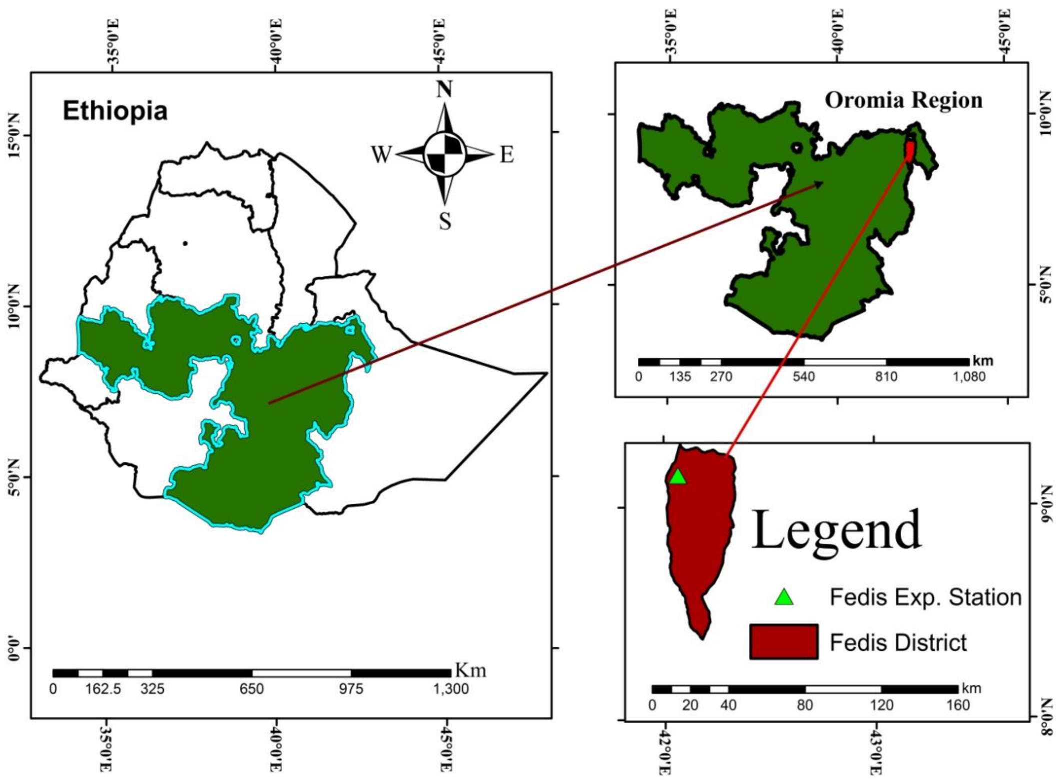
Intercropping system is the practice of cultivating two or more crops simultaneously on the same piece of land during the same time span [9] and it is a potentially beneficial system of crop production [4]. When compared to a sole cropping system, cereal-legume intercrops have shown to improve soil fertility and yields, control weeds, diseases, and insects, conserve soil moisture [3]. Mixtures of sorghum-legume showed advantages in land use efficiency expressed as LER than monoculture sorghum [11]. Areas where intercropping is practiced, crop yield is enhanced simply by growing two or more compatible crops without using costly agricultural inputs.

To evaluate the effect of intercropping on land productivity and competition index of sorghum and cowpea.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted under rain-fed conditions in Fedis Agricultural Research Center, in Fedis District on Boko station, which is 550 km to the East of Addis Ababa and 24 km southeast of Harari city. The Fedis district situated at an altitude of 1200 to 1600 m and 1500 m of boko station above sea level. The amount of rainfall varies between 650 and 750 mm, while the average temperature of the district ranges between 25 and 30 ℃. In the vicinity of the site; Vertisols and Afilsols soil type are common to the area. Soil is loam.



Source of the map: Ethio-GIS shape file, 20120

Figure 1. *Map of the study area.*

2.2. Description of the *Experimental Materials*

Two-cowpea Lines (9334 and 9333) were used with three varieties of early maturing sorghum (Teshale, Birhan and Melkam) and all the materials were obtained from Fedis Agricultural Research Center. The experimental materials were selected on the basis of their current and potential importance and mainly on their productivity and heights of the plants.

2.3. Treatments and Experimental Design

Cowpea and sorghum under sole and intercropping systems were laid out in a randomized complete block design (RCBD) with three replications in a plot area of (3×3) m^2, 1m between plot and 1.5m between block. Sorghum was planted at a spacing of 75 cm between rows x 20 cm between plants for sole and intercropping. Cowpea in intercropping was planted after twenty days of sorghum planting. Cowpea was planted in central rows of sorghum, which was 37.5 cm far away from sorghum row under intercropping and between sole rows of cowpea. In other words, intercropped cowpea was planted at a spacing of 75cm between rows. Sorghum-Cowpea intercropping were planted 1:1 (one row of cowpea with one row sorghum) row arrangement and seed proportion for intercropping 100:100 sorghum + cowpea respectively. The sole and intercropping cowpea planted in 37.5 cm between rows and 10 cm between plants.

2.4. Experimental Procedure and Field Management

Land preparation was done at the middle of April with a tractor, harrowed and leveled before planting. The seed rate of 12 kg ha^{-1} for sole and intercropping sorghum respectively was planted at row spacing of 75 cm through drip sowing with 5cm deeps when the soil has enough moisture for seed germination. After twenty days, cowpea varieties were planted with the seed rate of 30 kg ha^{-1} sole and intercropping, respectively. Application of NPS (19% N, 38% P_2O_5 and 7% S) and Urea (46% N) at 100 kg ha^{-1} rate was uniformly applied the time of sorghum planting while urea at the rate of 100 kg ha^{-1} was uniformly applied after plants emerged 2-3 leaves. Before urea applied, thinning done to reduce the population of sorghum to normal plant population and weeds were cleared.

2.5. Data Collection and Measurement

Competition Index and Land Productivity

The competitive behavior of component crops in different sorghum/cowpea planting patterns were determined in the data in terms of land equivalent ratio (LER), relative yield total (RYT), land equivalent coefficient (LEC) and percentage of land saved (LS%), of sorghum and cowpea by using the following formula.

Land equivalent ratio (LER): it was measured the effectiveness of intercropping in using the environmental resources compared to sole cropping was used to evaluate the productivity of intercrops compares with mono-crops and indicated the requirement of the relative land area growing in sole crops to produce the yields obtained when growing intercrops. It was calculated according to [8] LER = (LER sorghum + LER cowpea), where LER sorghum = (Ysi/Yss), and LER cowpea = (Yci/Ycs), where Yss and Ycs were the yields of sorghum and cowpea as sole crops respectively, and Ysi and Yci were the grain yields of sorghum and cowpea as intercrops, respectively.

If LER was >1, the intercrop is more efficient in terms of land use and if it is < 1 the intercropping was not efficient.

Land equivalent coefficient (LEC): it was measures of interaction concerned with the strength of the relationship thus calculated as LEC = La x Lb

Where, La = LER of main crops (sorghum) and Lb = LER of intercrop (cowpea) [1]. For a two-crop mixture, the minimum expected productivity coefficient (PC) was 25%, i.e. a yield advantage was obtained if LEC value exceeds 0.25.

Competition index (CI): it was used to evaluate the profitability and suitability of intercropping and calculated as:

$$\mathrm{CI} = \frac{(N'ss - Nsi)(N'cs - Nci)}{\mathrm{NsiBci}}$$

Where N'_{ss} = yield crop sorghum in monoculture, N_{si} = yield crop Sorghum in intercropping, N'_{cs} = yield crop cowpea in monoculture Nci = yield crop cowpea in intercropping. If CI < 1, intercropping had been an issue and if CI > 1, the profitability of intercropping had been less than monoculture.

The relative crowding coefficient (RCC): it was the second a measure of the relative dominance of one species over the other in a mixture [18, 5]. Was calculated as: RCC = (RCC sorghum x RCC cowpea), where RCC sorghum = Ysi x Zcp/[(Yss –Ysi) x Zsp], and RCC cowpea = Yci x Zsp/[(Ycs –Yci) x Zcp], where Zsp and Zcp were the proportions of sorghum and cowpea in the mixture (100:100), respectively. The crop component that had a higher coefficient to be dominant, and if the coefficient of a particular crop species was less than, equal to or greater than 1, then that species had produced less yield, the same yield, or more than "expected", respectively [18, 8].

Aggressivity Index (AI): it was a measure of competitive relationships between two crops in mixed cropping. This was expressed according to [8] as follows: Sorghum = (Ysi/Yss x Zsp) – (Yci/Ycs x Zcp) and Cowpea = (Yci/Ycs x Zcp) – (Ysi/Yss x Zsp). Where Zsp and Zcp are the proportions of sorghum and cowpea in the mixture, respectively. Thus if AI Sorghum = 0, both crops are equally competitive, if AI sorghum is positive, then it was dominant and if AI Sorghum was negative, then sorghum was weak.

Relative Yield Total (RYT): it was used for intercropping using the equation of RYG= DMYGL/ DMYGG and RYL = DMYLG / DMYLL, Where: DMYGG was dry matter yield of sorghum (G) as a sole crop, DMYLL was dry matter yield of legume (L) as a sole crop, DMYGL the dry matter yields of sorghum/cowpea intercropping.

Percentage of the land saved (LS%) were determined as described by [19] using the formula below; Land saved (%) =100− (1/$_{LER}$ ×100)

3. Results and Discussion

Land equivalent coefficient (LEC) and Competition index (CI): the result that obtained in (Table 1) showed that ranges from 0.30 to 0.43. According to [1], in all treatments, intercropping under sorghum-cowpea had a yield advantage. For a two-crop mixture, the minimum expected productivity coefficient (PC) was 25%, i.e. a yield advantage was obtained if LEC value exceeds 0.25. So that sorghum-cowpea intercropped, had the strength of relationship interaction. Thus may be due to sorghum and cowpea varieties were compatible crops and there was not a nutrient competition among crops.

The competition index was used to evaluate the profitability and suitability of intercropping. In (Table 1) results show that maximum to minimum 0.28, 0.22, 0.201, 0.15, 0.09 and 0.03 that obtained from cowpea (9334) + sorghum Teshale (T1), cowpea (9334) + sorghum Birhan (T2), cowpea (9334) + sorghum Melkam (T3), cowpea (9333) + sorghum Birhan (T5), cowpea (9333) + sorghum Melkam (T6), and cowpea (9334) + sorghum Teshale (T4) respectively and the mean was 0.163. Those results were indicated that in all treatments intercropping was profitable and suitable, as classification; (CI < 1) were lined with CI < 1, intercropping had been an issue and if CI > 1, the profitability of intercropping had been less than monoculture. The CI sorghum-cowpea intercropping was only 16.3% in average total and cowpea (9334) genotype more affected by intercropping than cowpea (9333) genotype. The profitability and suitability of intercropping affected by plant height, plant density and varieties of the crops so that sorghum and cowpea were compatible crops and could be attributed to less competition of growth resources between the intercrops. Similarly, with [10], cereal-legumes intercropping systems had greater economic returns and other competitive indices.

Relative Yield Total (RYT): it was the second importance indication of land productivity for intercropping forage production strategies that were calculated based on dry biomass yields of sorghum/cowpea intercropping. The result that obtained in (Table 1) ranges from 1.36 to 1.58, and overall means 1.46, but among treatments, there were no significant differences. According to [14], the results were indicated that from 36% to 58% and overall mean 46% more area was required for a sole cropping system in order to produced equal dry biomass yield from an intercropping system. Thus, result lined with the work that reported of [10] the intercropping of sorghum-cowpea the greatest green forage yield was obtained with sorghum and cowpea sown in 3-row stripes. The numerical variation may be due to the competitive performance of component crops in intercropping systems vary depending upon variety, type of intercropping, soil fertility and agro-climatic conditions.

Table 1. Competition, Land productivity and percentage of land save of sorghum/cowpea intercropping.

Trts	Partial (LER and RYT)				Total (LERandRYT)					
	Sorghum		Cowpea				LEC	LS%		CI
	GY	ADBY	GY	ADBY	GY	ADBY	GY	GY	ADBY	GY
T1	0.87	1.13	0.34	0.39	1.21	1.52	0.30	17.36	34.21	0.28
T2	0.82	1.04	0.49	0.54	1.31	1.58	0.40	23.66	36.71	0.22
T3	0.95	1.06	0.36	0.37	1.31	1.43	0.34	23.66	30.07	0.20
T4	0.98	1.03	0.36	0.42	1.34	1.45	0.35	25.37	31.03	0.03
T5	0.87	0.85	0.49	0.51	1.36	1.36	0.43	26.47	26.47	0.15
T6	0.96	0.99	0.32	0.38	1.28	1.37	0.31	21.88	27.01	0.09
Mean	0.91	1.02	0.39	0.44	1.30	1.46	0.35	23.25	31.51	0.16

LER = land equivalent ratio; RYT = relative yield total; LEC = land equivalent coefficient CI = competition index and LS = percentages of land saved

Percentage of the land saved (LS): in (Table 1) results indicated that the percentage of land saved ranges for grain yields from 17.37% to 26.47% that was obtained from treatments of sorghum Teshale + cowpea varieties (9334) to sorghum Birhan + cowpea varieties (9333) respectively and for Biomass yield production accounts from 27.01% to 36.71% that obtained from treatment sorghum Melkam + cowpea (9333) and sorghum Birhan + cowpea (9334) respectively. Sorghum-cowpea intercropping could be attributed to less competition of growth resources.

The relative crowding coefficient (RCC): it was the second a measure of the relative dominance of one species over the other in a mixture. The result that obtained reduction dominance ranges from 3.61 to 30.43 and the average was 12.33. Thus results indicate that in all treatments of sorghum-cowpea intercropping was more yield productive than sole and the highest RCC was obtained from cowpea (9333) + sorghum Teshale (T4) (30.43) and the lowest recorded of cowpea (9334) + sorghum Teshale (T1) (3.61). if the coefficient of a particular crop species was less than, equal to or greater than 1, then that species had produced less yield, the same yield, or more than “expected”, respectively [18].

Table 2. *Relative crowding coefficient and aggressivity index of sorghum/cowpea intercropping.*

Trts	Partial (RCC and AI)				Total (RCC and AI)		
	RCC	AI	RCC	AI	RCC	AI sorg	AI CP
T1	2.33	0.66	1.55	0.09	3.61	0.57	-0.57
T2	1.54	0.62	2.92	0.12	4.48	0.49	-0.49
T3	4.84	0.70	1.71	0.09	8.28	0.61	-0.61
T4	18.03	0.74	1.69	0.09	30.43	0.65	-0.65
T5	2.31	0.66	2.83	0.12	6.55	0.53	-0.53
T6	7.62	0.72	1.40	0.08	10.70	0.64	-0.64
Mean	6.11	0.68	2.02	0.09	12.33	0.58	-0.58

Aggressivity index (AI): it was a measure of competitive relationships between two crops in mixed cropping. The result was calculated according to [18] and [8] was expressed and showed in (Table 2), +0.58 for sorghum and -0.58 for cowpea so thus result indicated that Sorghum varieties were taken as dominant mainly due to seed proportion; according to [8] if AI sorghum = 0, both crops are equally competitive, if AI sorghum is positive, then it was dominant and if AI Sorghum was negative, then sorghum was weak.

4. Conclusions

The study was conducted with the objective to evaluate the productivity of sorghum and cowpea intercropping system. The field implemented with two cowpea varieties intercropping with three varieties sorghum and compared with sole cropping by randomized complete block design (RCBD) and three replications. Intercropping of early maturing sorghum with cowpea increased land productivity of Feed –food without affected the yields of both sorghum and cowpea those indicated that sorghum/cowpea intercropping were profitability and suitability.

Abbreviations

AI	Aggresivity Index
RCC	Relative Crowding Coefficient
LER	Land Equivalent Ratio
RYT	Relative Yield Total
LEC	Land Equivalent Coefficient
CI	Competition Index
LS	Percentages of Land Saved

Author Contributions

Wubshet Tesfaye is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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