
Intercropping Coffee (*Coffea arabica*) and Korarima (*Aframomum corrorima* (Braun) P.C.M. Jansen) at Tepi, Southwest Ethiopia

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Abstract: A field experiment was conducted at Tepi, southwest Ethiopia, from 2013 – 2017, to determine optimum plant population yield of component crops and land productivity in the coffee/korarima intercropping system. Test crops were Catimore-J21 variety for coffee and a local variety of korarima. The experiment consisted of five treatments arranged in a Randomized Complete Block Design with three replications. Data collected were statistically analyzed using SAS computer software. The productivity of the system was evaluated using a land equivalent ratio. Results showed that the coffee yield was significantly ($p < 0.05$) influenced by intercropping, while the growth of the coffee tree did not significantly affect by intercropping. Whereas, the growth and yield of korarima plants were significantly ($p < 0.05$) influenced by intercropping except for plant height, length, and girth of fruit capsule. Accordingly, the higher coffee yield advantages were found from sole plots when compared with intercropped coffee plots and followed by 2 to 1 coffee and korarima intercropping ratio. Similarly, the advanced yield of korarima was recorded from sole stands followed by 1 to 2 coffee and korarima intercropping ratio. The maximum land equivalent ratio was recorded at a planting pattern of 2 to 1 coffee and korarima intercropping ratio as compared to other treatments. Therefore, it could be concluded that intercropping of coffee with korarima is biologically and agronomically feasible, and the aforementioned treatment could be recommended for the study area. However, it is important to advise farmers in the area and similar agro-ecology to supplement irrigation water to the field especially during the dry spell period.

Keywords: Coffee Yield, Intercropping, Land Equivalent Ratio, Korarima Yield

1. Introduction

In most developing countries of the tropics, the bulk of food consumed is derived from small scale agriculture. The cropping systems of these countries are characterized by the

landholding of few hectares, limited mechanization, low levels of purchased inputs, intensive labor, and multiple cropping that include intercropping as its mainstay [13, 14]. Although risk minimization is the major objective of intercropping in developing countries, small farmers also

view intercropping as a potential system for diversification and intensification of production on their smallholdings. Though intercropping is defined by different authors differently, the basic idea is more or less alike. It is defined as the growth of two or more crops simultaneously on the same field with crop intensification in both time and space dimensions [30, 13].

Growing two or more crops on the same land at the same time can increase crop yield per unit area, reduce risks associated with crop failure and price fall. Also, it helps farmers to get balanced nutrition and an additional income. Several authors indicated that intercropping helps for efficient use of farm inputs including family labor, growth resources [3]; and weed control [7]. Farm inputs including family labor and natural resources may also be more efficiently utilized. However, the merits and demerits of intercropping depend upon climatic conditions, soil fertility, plant morphology and growth duration, disease and insect pests, and socio-economic aspects of the people. The benefits of the approach can be evaluated in terms of the land equivalent ratio (LER) [30] and relative crop yields obtained [10].

In the southwestern part of Ethiopia, the farming system is commonly characterized by the growth of one or more of these complementary crop species. In previous studies, it has been reported that successful intercropping of cardamom and other lowland spices with coffee (*Coffea arabica*) [16] could be attributed to the optimal shade level that the coffee plant gave to the cardamom during the growing periods. Besides, [27] reported that intercropping of coffee with sweet orange gave the highest yield as compared to the sole planting. On the contrary, [4] showed that there is no significant difference between intercropping of coffee with ginger and turmeric, even through time yield from intercropping decline compared to sole cropping system of both crops. Conversely, a review report by [5] intercropping of coffee with avocado gives the lowest yield as compared to sole planting and again, coffee intercropped with potato gives lower yield compared with the sole planting system. Korarima is used traditional medicine and as a food preservative, to flavor coffee and bread, as a source of income from local and export markets, for soil conservation and as a substitute of Indian cardamom [12]. It is a shade loving plant and, grows in high rain forests areas of the country like wild Arabica coffee [19]. Despite, its

importance, there is a dearth of information on its compatibility with coffee in Tepi farming system. Therefore, the objective of this research was to determine the optimum intercropping mixture, yield of component crops, and land productivity in the coffee korarima intercropping system.

2. Material and Methods

2.1. Description of the Experimental Site

The experiment was conducted at Teppi Agricultural Research Center (formerly known as Teppi National Spices Research Center) from 2013 - 2017. The center is located at 7°10' N latitude and 35°25' E longitude and situated at an altitude of 1200 m.a.s.l, representing a lowland altitude according to Ethiopian traditional agro-ecological division, the elevation is the basis for this classification [11]. It is characterized by hot humid with an average annual rainfall of 1559 mm, and a mean maximum and minimum temperature of 30.23°C and 16.09°C, respectively [16]. The soil type of the experimental site is classified as Nitisols, which is dominated by a loam texture with a pH range of 5.60 to 6.0 [1]. The soil depth is very deep (>150 cm) and has a color of dark brown (7.5 YR3/2) when moist. The organic matter content is medium to very high (2.47 to 7.02%) according to [21] classification. The total nitrogen content is low to very high (0.09 to 0.73%) according to [29] classification, while the available phosphorus is low to medium (0.97 to 7.36 ppm) based on the rating of [23]. The meteorological data for the years 2012/13 to 2016/17 were obtained from Teppi Agricultural Research Center and presented in Table 1 and Figure 1.

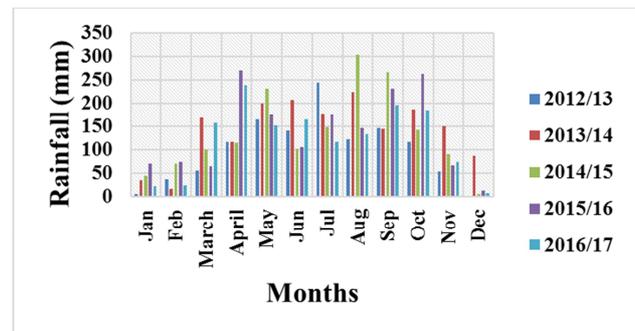


Figure 1. Monthly rainfall (mm) of the study area (2012/13-2016/17).

Table 1. Monthly minimum and maximum temperature (°C) of the study area (2012/13-2016/17).

Month	2012/13		2013/14		2014/15		2015/16		2016/17	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Jan	11.7	31.8	12.3	33.6	13.5	29.3	12.6	31.4	13.65	31.65
Feb	13.7	34.7	13.7	34.2	12.9	30.6	13	32.2	13.8	32.7
March	15	33.4	14.8	32.6	14.6	32.7	13.6	32.1	15.8	31.9
April	15.7	31.7	15.3	30.6	16.5	30.7	15	29.6	16.1	30.1
May	15.3	29	14.8	29	16.2	29.1	14.5	29.3	15.2	29.8
Jun	15.4	28.4	14.4	28.6	15.6	27.5	14	28.3	14.9	28.9
Jul	15	27.2	14.9	27.4	15.6	27.1	13.7	26.1	13.8	26.5
Aug	14.8	28.2	14.4	27.4	15.3	26.9	13.9	27	12	26.9
Sep	15	28.3	14.4	27.2	15.1	27.8	13.7	28	14.9	27.8
Oct	13.9	29.2	14.4	29.3	14.25	28.85	14.1	28.4	14.9	28.85
Nov	12.3	30.4	14.4	28.4	13.1	30.1	-	-	-	-
Dec	9.4	33.1	14.4	28.6	11.3	31.2	-	-	-	-

2.2. Experimental Materials, Experimental Design and Management

The treatments included sole stands of coffee and korarima, four intercropping ratios of coffee and korarima viz., coffee and korarima in alternate rows (1:1), 2 rows of coffee to a row of korarima (2:1), 1 row of coffee to two rows of korarima (3:1), and a staggered planting of coffee with korarima (i.e. four coffee trees were planted alternatively around the korarima tree) and a detail description of the treatment was depicted in Table 2. The experiment was laid out in a randomized complete block design with three replications. Coffee seedlings for each experimental plot were planted in the 2012/13 cropping calendar based on their

respective planting spaces. In 2013/14, one-year-old seedlings of local korarima variety were planted at the beginning of the rainy season using an appropriate planting space for each treatment as stated in Table 2. Catimore-J21 and local varieties of coffee and korarima were used for the study. In the course of the study, coffee trees were trained in a single stem and capped at 2 m height. Undesirable lateral growths of long drooping primaries, secondary branches growing within 15cm were controlled and removed throughout the experiment. Except for experimental variables other field management practices viz., weeding, fertilization, disease, and insect pest controls were applied for both crops as of the recommendation [5].

Table 2. Detail information about the treatments.

Treatments	Planting space (m)	Plot area (m ²)	Plant population of the component crops	
			Coffee	Korarima
Sole Coffee	2*2	22*14 = 308	77	-
Sole Korarima	3*3	24*15 = 360	-	40
1C:1K	3*3	24*15 = 360	28	20
2C:1K	2*2 (b/n C)	21.5*15 = 322.5	35	21
	3*3 (b/n C & K)			
1C:2K	3*3 (b/n K & C)	24*15 = 360	21	25
	3*3 (b/n K)			
Staggared (4C:1K)	3*3 (b/n K & C), 4 coffees were planted around a korarima plant	30*18 = 540	77	60

N.B: C stands for coffee and K stands for Korarima

2.3. Data Collection

Both coffee and korarima started bearing fruits about 3 years after planting, the vegetative phase was completed in the first two consecutive years. Before the commencement of data collection, about ten coffee trees and five korarima plants were randomly selected from each plot as a sample plant. Accordingly, the growth, yield, and yield-related parameters of coffee viz. stem height, number of primary branches, number of nodes of a primary branch, internode length of the primary branch, and clean coffee yield were taken both in 2015/16 and 2016/17. Whereas, the yield and yield-related parameters of korarima, such as plant height, tiller and leaf numbers, capsule length, and girth, fresh capsule yield were recorded in the 2016/17 cropping calendar.

2.4. Land Equivalent Ratio (LER)

The productivity of the intercropping system in terms of the land equivalent ratio (LER) was used [30, 18, 6, 20, 8] to measure the yield advantage of coffee-korarima based cropping over the sole crops. Thus, LER was calculated by using the following formula;

$$\text{Land Equivalent Ratio (LER)} = \left(\frac{Y_{ij}}{Y_{ii}}\right) + \left(\frac{Y_{ji}}{Y_{jj}}\right)$$

Where, Y is the yields of component crops per unit area, Y_{ii} and Y_{jj} sole crop yield of coffee and korarima and Y_{ij} and Y_{ji} are intercropped yields of coffee and korarima, respectively. When the value of LER shows >1 , the

intercropping system favors the growth and yield of the component crops. In contrast, if the value of LER demonstrates <1 , the intercropping system negatively affects the growth and yield of the component crops grown in mixtures [9]. Besides, the interspecific competition becomes stronger compared with the interspecific interaction within the intercropping system when the value of LER < 1 [32].

2.5. Data Analysis

The collected data were subjected to statistical analysis. Analyses of variance were carried out using SAS version 9.2 English [24]. Significant differences between and or among treatments were delineated by Least Significant Differences (LSD) at a 5% probability [17].

3. Result and Discussions

3.1. Growth and Yield of Coffee and Korarima

Coffee growth parameters, viz., number of primary branches, number of nodes of the primary branch and internode length of primary branch did not significantly ($p < 0.05$) influenced by intercropping ratios with korarima (Tables 3 and 4). However, mean clean coffee yield variation among treatments was significant for consecutive two cropping seasons (Table 4). The maximum yield was obtained from sole coffee 1826 and 1747 kg ha⁻¹ in 2015/2016 and 2016/2017, respectively. Whereas, the minimum coffee yield (464.8 and 866 kg ha⁻¹) was found in

2015/2016 and 2016/2017, respectively, from the same plot in which coffee and korarima were intercropped in 1:2 ratio (Table 4). On the other hand, the growth of korarima plant height, length, and girth of fruit capsule did not significantly ($p < 0.05$) influenced by intercropping with coffee. However, korarima yield, tiller number per plant, and leaf number per tiller were significantly ($p < 0.05$) influenced by intercropping with coffee (Table 5). The highest number of tillers and leaves were recorded from sole korarima stands followed by 1:1 coffee with korarima intercropping ratio. Likewise, the yield of sole korarima was significant over other intercropped treatments except for a 1:2 intercropped ratio of coffee with korarima (Table 5). This mainly associated competition for resources, in most cases when crops growing in a sole it receives all the resources without any competition with the component crops and increases yield, to the opposite, if it is intercropped with any crops resulted in yield reduction due to competition for resources. Also, the gradual increasing shade level by the upper strata of coffee canopies and reduced light interception by korarima underneath during the latter year of production.

The present result in agreement with the findings of [28]

and [2] mean yields of both coffee and korarima and other spices significantly higher for sole stands than for the intercropped plots. Furthermore, the report by [22] on coffee intercropping with fruit trees showed that in most cases both yield and quality of coffee, as well as the component fruit trees, increases when both crops growing in the sole stand than intercropping regardless of the fruit type. Moreover, [5] reported that a higher yield of coffee was obtained in the sole crop than intercropping of coffee with avocado and potato. In contrast to the above finding, a review report by [27] showed that when coffee intercropping with sweet orange sole planted coffee gave the lowest yield as compared to the intercropped stands. Conversely, [26] reported that intercropping of cardamom with grevillea and pepper gave the highest growth, yield, and quality than a sole crop. Further, a report by [12] found growth and yield of coffee do not affect by the intercropping system. Likewise, [4] concluded that when coffee intercropped with ginger and turmeric there were no significant differences between sole and intercropped systems. By the same token, a report by [5] showed that growth and yield performance of coffee did not affect by when intercropped with Enset.

Table 3. Growth of coffee tree as influenced by intercropping with korarima.

Treatments	№. of Primary Branches			№. of Nodes of Primary Branch		
	2015/16	2016/17	Mean	2015/16	2016/17	Mean
Sole Coffee	66.60	56.20	61.40	18.80	38.60	28.70
Sole Korarima	-	-	-	-	-	-
1:1 C to K	66.80	61.00	63.90	18.73	39.27	29.00
2:1 C to K	60.60	55.27	57.93	20.07	41.07	30.57
1:2 C to K	65.93	57.33	61.63	21.20	41.13	31.17
C.V (%)	14.13	9.26	11.15	9.26	14.46	8.14
LSD _(0.05)	NS	NS	NS	NS	NS	NS

NS=Not significant ($P > 0.05$), Coffee (C) and Korarima (K)

Table 4. Internode length of the primary branch and clean coffee yield as affected by intercropping with korarima.

Treatments	Internode Length of Primary Branch			Clean Coffee Yield (kg ha ⁻¹)		
	2015/16	2016/17	Mean	2015/16	2016/17	Mean
Sole Coffee	3.67	3.89	3.78	1826.00 ^a	1747.00 ^a	1786.50 ^a
Sole Korarima	-	-	-	-	-	-
1:1 C to K	3.64	3.86	3.75	677.80 ^{bc}	1180.00 ^{ab}	928.90 ^b
2:1 C to K	3.42	3.75	3.58	1228.40 ^{ab}	1553.00 ^a	1390.70 ^a
1:2 C to K	3.46	3.74	3.60	464.80 ^c	866.00 ^b	665.40 ^b
C.V (%)	6.42	5.98	5.14	30.14	24.67	18.70
LSD _(0.05)	NS	NS	NS	*	*	*

NS = Not significant ($P > 0.05$), * = $P < 0.05$, Means with the same letter are not significantly different according to LSD test at $P = 0.05$, Coffee (C) and Korarima (K)

Table 5. Growth and yield of korarima as influenced by intercropping with coffee.

Treatments	Plant Height (cm)	№. of Tillers (Plant ⁻¹)	№. of Leaf (Tiller ⁻¹)	Capsule Length (cm)	Capsule Girth (cm)	Dry Yield (kg ha ⁻¹)
Sole Coffee	-	-	-	-	-	-
Sole Korarima	161.67	2.4 ^a	22.00 ^a	42.87	29.40	615.33 ^a
1:1 C to K	164.00	2.27 ^{ab}	18.73 ^{ab}	42.33	30.00	521.73 ^b
2:1 C to K	171.67	2.07 ^{ab}	17.73 ^{ab}	43.33	30.80	506.13 ^b
1:2 C to K	158.33	1.60 ^b	17.60 ^b	44.20	29.13	561.60 ^{ab}
C.V (%)	9.37	17.60	11.43	4.35	3.02	5.08
LSD _(0.05)	NS	*	*	NS	NS	*

NS = Not significant ($P > 0.05$), * = $P < 0.05$, Means with the same letter are not significantly different according to LSD test at $P = 0.05$, Coffee (C) and Korarima (K)

3.2. Land Equivalent Ratio (LER)

Based on the data, land productivity was better with two rows of coffee and one row of korarima ratio has higher productivity of land or land use efficiency as compared to other treatments (Table 6). This is due to their corresponding to utilizing efficiently the available resources and their beneficial effects on each other. A similar result also reported by [28], land equivalent ratio depicted the yield advantage of growing coffee and spice together than sole planting. By the same token, a report by [26] showed that cardamom intercropped with grevillea produced 2.3 times more than in monoculture. Moreover, [22] found irrespective of the fruit trees used intercropping of coffee with fruit trees improved yield and quality of the coffee. Furthermore, [4] reported when coffee intercropped with ginger and/or turmeric resulted in better LER than sole cropping. Also, [27] depicted that higher LER obtained better yield advantages of intercropping of the two crops as compared with sole plots of each crop. Conversely, regardless of the season and method of intercropping [5] reported that intercropping of coffee with avocado and gives better LER than sole cropping especially in early crop year and again, they reported that when potato interplanted with the compact coffee cultivar it resulted in better LER than the sole planting.

Table 6. Coffee with korarima intercropping effect on the productivity of land (LER).

Treatments	Land Equivalent Ratio (LER)
Sole Coffee	-
Sole Korarima	-
1:1 Coffee to Korarima	1.22
2:1 Coffee to Korarima	1.50
1:2 Coffee to Korarima	1.17

4. Conclusion

The study indicated that intercropping of coffee with korarima can be advisable for farmers to produce both crops without significant yield reduction and enhance the productivity of their land. Korarima must be planted after two or three coffee harvests, to avoid inter-competition at the early growth stage and to balance the compatibility of the component crops. Usually, the growth of the korarima plant is very fast and it covers all spaces within a short period. Hence, the shade level for korarima will increase obtained from both coffee and shade tree. Accordingly, two rows of coffee and one row of korarima intercropping ratio showed better productivity of land, so it could be recommended for the study area. However, it is important to advise farmers in this area to supplement irrigation water to the field especially during the dry spell period (October-April).

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