Int.J.Curr.Res.Aca.Rev.2021; 9(10): 31-44

International Journal of Current Research and Academic Review

ISSN: 2347-3215 (Online) Volume 9 Number 10 (October-2021)

Journal homepage: http://www.ijcrar.com

doi: https://doi.org/10.20546/ijcrar.2021.910.006

Progress of Intercropping Research of Arabica Coffee with Fruits, Spices, Tuber, Root, Grain Legumes and Enset Crops in Ethiopia

Anteneh Netsere*

Ethiopian Institute of Agricultural Research, Jimma Research Centre, Natural Resource Management Research Process, Jimma, Ethiopia

**Corresponding author*

Abstract

Ethiopian coffee farmers have intercropped coffee with fruits, spices, enset, root and tuber crops, and grain legumes around their homesteads which is characterized by low plant population density. Crop diversifications of this type have been proposed as a viable option for mitigating the negative effects of conventional low-yield cropping systems, crop failure, and price volatility by making better use of growth resources and inputs. The purpose of this review was to summarize and document major achievements that have been recorded so far in coffee intercropping with food and cash crops in the country. Field trials revealed that, when planted in the proper combinations, intercropping has no effect on the growth and yield of coffee trees. Compact coffee cultivars were better suited for intercropping than intermediate and open coffee cultivars for long-term crop yield sustainability. When compared to pure stands, intercropped plots had a higher yield advantage. This was most noticeable in the early season for annual crops with a lower population of coffee trees. Similarly, the gross monetary benefits of intercropping coffee with banana, avocado, orange, potato, korarima, turmeric, ginger, yam, and grain legumes (soybean and haricot bean) outweighed the benefits of sole coffee plots. Coffee intercropping with locally adapted and compatible cash and food crops is generally agronomically beneficial and economically viable for small-scale coffee farmers in coffee growing areas of the country. Intercropping coffee with fruits, spices, enset, root and tubers, and grain legumes can thus be used as an important remedy to cure and boost productivity and economic return in the country's garden coffee production, depending on the suitability of the land and the priorities of the farmers.

Article Info

Accepted: 18 September 2021
Available Online: 20 October 2021

Keywords

Arabica coffee, Intercropping, Land equivalent ratio, Monetary advantage.

Introduction

Smallholder coffee growers in Ethiopia have a very small amount of farm land, rarely more than half a hectare. As a result, productivity of the crop can be increased by either increasing horizontal acreage or intensifying cultivation. The former is becoming more difficult due to rising population pressure in emerging countries such as Ethiopia. Intercropping, a type of multiple cropping system, has long been used in the country's garden coffee production system by subsistence coffee farmers to increase crop yield per unit time and per unit area (Endale *et al.*, 2014).

Intercropping is defined as the simultaneous growing of two or more crops on the same field at the same time, resulting in crop intensification in both time and space dimensions (Hailu, 2015). Growing two or more crops on the same plot of land at the same time can increase crop yield per unit area, reduce risks of crop failure and volatile market risks. Farmers benefit from the practice with a more balanced diet and additional cash. Intercropping has been shown to aid in the efficient use of agricultural inputs such as family labor, natural resources, *viz*. carbon dioxide, light, soil moisture, and plant nutrients, and it is a viable alternative to weed management or control (Dhima *et al.*, 2007; Gebru *et al.*, 2015). Family labor and natural resources should be used more efficiently as farm inputs. It also assists farmers in earning additional income from a variety of crops grown on their limited land area while reducing soil erosion and preserving soil fertility. It also provides animal feed for improved animal products and assists farmers in earning additional income from a variety of crops grown on their limited land area (Sullivan, 2003).

Intercropping advantages can be measured in terms of relative crop output, monetary returns, and calories gained (Hailu, 2015). Intercropping advantages and disadvantages, on the other hand, are determined by climatic conditions, soil fertility, plant form and growth duration, disease and insect pests, and people's socioeconomic status. The benefits of the approach can be quantified in terms of land equivalent ratio and relative crop yields (Francis, 1986).

Endale *et al.*, (2014) demonstrate the multipurpose value of intercropping coffee plants with grain legumes, spices, root crops during the establishment stage and the cycle conversion. In Ethiopia, coffee is primarily grown in a multi-story cropping system, with shade trees, papaya, citrus, and enset on the upper story, coffee and cereals (maize, sorghum, and teff) on the lower story, vegetables (cabbage, pepper, and kale), spices (turmeric, ginger, and korerima), and root crops (sweet potato and Irish potato) on the ground floor (Awoke, 1997; Endale *et al.*, 2014). Crop combinations and planting layouts, on the other hand, are infinitely flexible, ranging from mixed copping, which involves randomly planting a variety of species in a field, to more rigorous row or strip intercropping.

Because of the practical importance of intercropping to small-scale coffee farmers in Ethiopia, the Jimma Agricultural Research Center (JARC) and universities have conducted research to improve the productivity of conventional low-yield cropping systems in the country's major coffee growing regions. Hence, the aim of this paper is to summarize and document major achievements' recorded so far in intercropping research of Arabica coffee with fruits, spice, tuber, root, grain legumes and enset crops for improved production of coffee and component cops in Ethiopia.

Materials and Methods

Academic publications were gathered from various institutions such as the Ethiopian Institute of Agricultural Research and universities in the form of soft copy and hard copy literature sources such as progress reports, proceedings, journals, and universities thesis work. For review, information dealing with Ethiopia's progress in research on intercropping Arabica coffee with fruits, spice, root, tuber, cereals and enset crops were chosen and grouped together. The research was carried out at the JARC, as well as the Tepi, Gera, Metu, and Awada Research Sub-centers, and Wonago trial site, which represented the country's major coffee growing agroecologies. The geographical descriptions of the study sites are shown in Table 1.

Results and Discussion

Intercropping of Coffee with Fruit Crops

Ethiopian coffee farmers have traditionally grown coffee in the shade and intercropped it with fruit trees, most commonly bananas, oranges (*Citrus sinensis*), and avocados (*Persea americana*), near their homesteads to provide shade, food, and income. JARC conducted research on coffee intercropping with the aforementioned fruit trees to determine the component crop intercropping ratio that maximizes yield, and the results are discussed below.

Coffee with banana (*Musa* spp.)

At the Metu trial site in southwest Ethiopia, between the 2018/19 and 2020/21 cropping years, CBD resistant coffee cultivars (variety 74110) were row intercropped with banana (variety *Butezua*) at a ratio of 4:1, 3:1 2:1, and 1:1. A pure stand of each test crop was also included in the study for comparison purposes.

According to the results of a multi-year analysis of variance, intercropping of coffee and banana significantly ($P \leq 0.01$) affected the yield performance of both crops. Coffee and banana intercropping ratio of 4:1 yielded the highest clean coffee and green banana yields of 1357.3 and 20,482 kg ha^{-1} followed by 3:1

intercropped ratio yielding 1346.5 and 21,321 kg ha^{-1} clean coffee and green banana yields, respectively (Table 1).

All intercropping ratios in the trial registered land equivalent ratios (LER) >1 demonstrated the yield advantage of growing coffee and banana together, implying their complementarities in maximizing available resources and mutually beneficial effects on one another. Accordingly, the coffee banana intercropping ratios of 4:1 and 3:1 produced higher mean LER of 1.78 and 1.61, respectively (Figure 2a). Similarly, higher monetary benefits of 161.06 and 134.23% were obtained from coffee/banana intercropping ratios of 4:1 and 3:1, respectively (Figure 2b). In general, the study found that the critical coffee to banana intercropping ratios of 4:1 and 3:1 for Metu areas and locations with similar agro-ecologies (Fanthahun, 2021).

Coffee with orange (*Citrus sinensis*)

CBD resistant coffee variety were row interplanted with sweet orange trees in 1:1, 3:1, 1:3, 3:2, and 2:3 ratios at JARC. For comparison sole plots of both crops were included in the study. The result revealed that in four of the nine crop years studied, significant and inconsistent differences in coffee output between the treatments were registered. Accordingly, lowest mean clean coffee yields of 700 and 530 kg ha^{-1} were registered in the 1st and 8th crop years, while the highest 2950 and 3250 kg ha^{-1} clean coffee recorded in the 5th and 6th crop years, respectively (Table 5). The coffee plant's biennial bearing habit can be attributed to a significant portion of this variation.

In general, sole panted coffee yielded the lowest when compared to intercropped stands in most crop years, demonstrating the importance of intercropping in maximizing yield. It could also be explained in terms of mutual shading and efficient use of available light as a result of the intercropping of two perennial fruit trees. This is especially true for the vast majority of crop years and overall years mean, when the highest coffee output was recorded at a coffee-to-orange intercropping ratio of 1:3. Due to disease attack, orange fruits from all plots were not healthy and normal, and thus were deemed unmarketable biological yield, making calculating economic benefits impossible. Coffee intercropped with orange produced a higher yield advantage than single plots. Generally, the LER >1 for all intercropped plots (Figure 2), indicating that intercropping the two perennial crops out yielded more than sole plot of each crop. Similarly, Taye *et al.*, (2004) emphasized the importance of intercropping coffee with sweet orange.

Coffee with avocado (*Persea americana*)

At JARC, the CBD resistant variety (7440) was intercropped between rows of already established avocado trees in 0:28, 91:0, 67:24, 63:28, 71:20, 75:16, and 79:12 ratios with a total plant density of 91 trees per plot. In addition, for comparison a pure stand of each crop was included in the trial. Results of this trial showed that the intercropped plot outperformed the pure coffee stand, indicating that the avocado trees cast intense shadows on the coffee plants beneath. Average yields and yield advantages of coffee and avocado trees have increased over time as coffee and avocado populations have increased and decreased, respectively. Furthermore, intercropping ratios of 71:20 and 75:16 coffee and avocado have been shown to provide the best yield benefits of both crops (Table 3 and 4).

Similarly, the estimated LER reflected the yield benefits of coffee and avocado intercropping, with lower values at higher avocado tree population densities. Furthermore, during the early crop year, higher LER values were recorded (Figure 3). These demonstrate the detrimental effects of extensive shadowing from closely spaced avocado trees, especially as they age.

As a result, the best coffee-to-avocado intercropping ratio appears to be 75:16 in Jimma-like conditions. Furthermore, it was suggested that portions of avocado plant branches be trimmed or coffee trees beneath canopies be thinned out for optimal light interception and crop output.

Intercropping of Coffee with Spices

Coffee with korarima (*Aframomum korarima*)

Catimore-J21 and 74165 coffee varieties were row intercropped with local korarima in 1:1, 2:1, and 1:2 ratios at Jimma, and in 1:1, 2:1, and 1:2 ratios and+ staggered planting at Tepi. At each study site, a single plot of each crop was included in the trial for comparison. According to the study's findings, intercropping had a significant ($P \leq 0.05$) effect on the yield of coffee trees and korarima plants at both study sites. Sole plots produced the highest coffee yield benefits in both study locations, followed by 2:1 and 1:1 at Tepi and staggered planting and 1:2 at Gera (Table 6 and 7).

The LER >1 for all intercropping ratios of coffee and korarima demonstrated the yield advantage of growing coffee and korarima concurrently. As a result, at Tepi and Gera, planting with a 2:1 coffee/korerima intercropping ratio and staggered planting yielded the highest LER (Figure 4). The study's findings suggest that coffee intercropping with korerima is both agronomically and physiologically viable in southwest Ethiopia. As a result, depending on the location's suitability and the farmers' priorities, intercropping coffee with korarima can be used as an important remedy to increase crop productivity and provide economic benefits to farmers in farm diversification of the coffee production system. However, the researchers advised farmers in the area and those with similar agro-ecology to supplement irrigation water to the field, especially during dry spells.

Coffee with turmeric (*Curcuma longa*) *and* ginger (*Zingiber officinale* Rose)

Intermediate (7440) and compact (7410 and 74112) CBD resistant coffee cultivars planted at population densities of 1600, 2500, 3265, 4444, and 6398 trees ha^{-1} were intercropped with turmeric and ginger at Tepi Agricultural Research Center in southwest Ethiopia. Turmeric was intercropped with 7410 coffee cultivar and ginger cultivars Gin.37/79 and Gin.40/79 intercropped with 74112 and 7440 coffee cultivars, respectively.

Sole plot of each crop was included in the investigation for comparison. The result depicted that there were no significant differences in yield performance between sole and intercropped coffee plots throughout the study period, though the intercropped had a lower yield than the sole plot. Similarly, no significant difference in mean yield was found between coffee varieties. In both sole and intercropped plots, coffee cultivar 7440 outperformed 74112 and 74110 (Table 7). This demonstrates the Tepi region's highly suitable for intermediate coffee varieties.

Population density had a significant ($P \leq 0.01$) effect on coffee production, and average clean coffee yields decreased dramatically with reduced tree population over crop years as shown in the graph for the last harvest year (Fig. 4b). When intermediate coffee cultivars were compared to compact coffee cultivars, intermediate coffee cultivars had the greatest yield drop, indicating that the latter coffee cultivars are better suited to intercropping. This result is consistent with of Taye *et al.*, (2001) findings. The mean yield of turmeric and ginger in sole stands was significantly ($P \leq 0.01$) higher than in intercropped plots throughout the study period. Turmeric yield was higher for intercropped plots than sole plots in the early year, and mean yield of turmeric and ginger intercropped with coffee decreased significantly with increasing coffee population density (Figure 2b) and age of coffee trees. This is most likely due to the upper strata of coffee canopies gradually increasing shade levels and, as a result, decreasing light interception by turmeric and ginger beneath during the final year of production. The biannual bearing pattern of coffee trees resulted in uneven yield throughout the growing season. Unlike turmeric and ginger, however, the yields of the three coffee cultivars increased as coffee plant density increased (Figure 3a and b). Furthermore, the LER demonstrated the yield advantage of growing coffee, turmeric, and ginger together, implying their complementarily in maximizing available resources and mutually beneficial effects on one another. However, ginger and coffee cultivar 74112 at the start of the crop year, and ginger and coffee cultivar 7440 at the end of the crop year had LER < 1 (Figure 3c). Furthermore, sole plots produced higher gross field benefit or income than intercropped plots of all crop types (Table 8). A side from that, when ginger and turmeric were intercropped with compact coffee type rather than intermediate cultivar, the former coffee cultivar produced a higher relative yield, demonstrating its intercropping potential (Taye *et al.*, 2008). In general, the results confirm that coffee intercropping with turmeric and ginger was agronomically and economically beneficial in southwest Ethiopia.

Intercropping of Coffee with Root, Tuber, Grain Legumes, Spices and Enset Crops

Coffee with potato *(Solanum tuberosum)*

CBD resistant coffee varieties with compact (74110 and 74148) and open (741) canopy natures were intercropped with Irish potato at JARC. A single plot of each test crop was included for comparison. According to the trial results, the intercropped plot of coffee cultivar 74110 produced the highest average coffee yield, followed by coffee line 74148 grown alone. Cultivar 74110 yielded the least amount of coffee among the intercropped plots, whereas cultivar 74110 planted alone yielded a yield comparable to cultivar 741 intercropped with potato (Table 11). As a result, the largest and smallest coffee yield advantages, as well as the LER, were calculated for cultivars 74110 and 741148. Similarly, pure stands outperformed intercropped coffee stands in terms of average potato tuber yields (Table 9).

Table.1 Geographical description of the study sites

Location	Altitude (m.a.s.l.)	Rainfall (mm)	Temperature (^{0}C)		Agro ecology
			Maximum	Minimum	
Jimma	1753	1521.1	26.2	12.1	SH2-Sub humid tepid to cool mid highlands
Tepi	>1200	1685.9	29.9	15.4	H1-Hot to warm humid low to high altitude
Gera	1900	1877.8	26.3	10.9	H2- Humid tepid to cool high altitude
Metu	>1550	1810.6	28.0	12.2	SH2-Sub humid tepid to cool mid highlands
Awada	1740	-	-	-	M2-moist tepid to cool mid
Wonago	1855	1446	28.1	18.6	SH2-Sub humid tepid to cool mid highlands

- = Data not available.

Table.2 Mean clean coffee and fresh banana fruit yield (kg ha^{-1}) as affected by coffee to banana intercropping ratios at Metu

Coffee /Banana intercropping ratio	Clean coffee yield (kg ha^{-1})				Banana fruit yield (kg ha^{-1})			
	2018/19	2019/20	2020/21	Mean	2018/19	2019/20	2020/21	Mean
1:1	800^{c}	1036.0^{c}	487.5^{c}	**1036.0^{c}**	18710^{a}	10519^{b}	34543^{d}	21257^{b}
2:1	839^{c}	1249.6^{bc}	999.8^{b}	**1249.6b^{c}**	17003^{ab}	12648^{a}	27187^{e}	18946^{b}
3:1	1079^{b}	1346.5^{b}	1065.0^{b}	**1346.5^{b}**	16163^{b}	9574^{c}	38227^{b}	21321^{b}
4:1	1870^{a}	1357.3^{b}	1477.2^{a}	**1357.3^{b}**	17287^{ab}	7806^{c}	36353^{c}	20482^{b}
Sole coffee	1138^{b}	1902.5^{a}	1209.0^{b}	**1902.5^{a}**	-	-	-	-
Sole banana	-	-	-	**-**	31297^{bc}	8926^{c}	44510^{a}	28244^{a}

- Figures followed by the same superscript letter(s) within a column are not significantly different at 0.05 probability level.

Source: Fantahun (2021).

Table.3 Mean clean coffee yield (kg ha^{-1}) as affected by coffee to orange tree intercropping ratios in Jimma

Coffee/orange intercropping ratio	Plant population (trees ha^{-1})		Clean coffee yield (kg ha^{-1})									Mean
	Coffee	Orange	1991/92	1993/94	1994/95	1995/96	1996/97	1997/98	1998/9	1999/00	2000/01	
			NS	NS	NS	*	*	**	NS	*	NS	**
1:1	1250	1250	850	2070	1230	3450^{a}	3860^{ab}	730^{a}	1440	3410^{b}	840	**1930 ab**
3:1	625	1875	530	2150	1460	1710^{b}	2430^{b}	560^{c}	1790	3170^{bc}	1510	**1700 bc**
3:2	1875	625	670	1690	1370	1860^{b}	2650^{b}	440^{c}	1540	3280^{bc}	1010	**1610 bc**
1:3	1500	1000	980	1890	2160	1760^{b}	4680^{b}	390^{c}	2380	4370^{a}	1570	**2240 a**
2:3	1000	1500	610	1970	1320	1430^{b}	2770^{bc}	600^{b}	1950	2930^{bc}	1050	**1630 c**
Sole coffee	2500	2500	58	1540	780	2010^{b}	1830^{c}	460^{c}	220	2360^{c}	890	**1420 c**
Mean			**700de**	**1890b**	**1390c**	**2040b**	**2950a**	**530e**	**1960**	**3250a**	**1150d**	**_**
CV (%)			**35.7**	**34.7**	**38.5**	**31.5**	**30.4c**	**16.5**	**66.7**	**15.6**	**39.3**	**38.3**

Mean followed by the same superscript letter(s) within a column or row are not significantly different from each other at P = 0.05 probability level. **Source:** Taye *et al.*, (2004).

Table.4 Clean coffee yield (kg ha^{-1}) and yield advantage as affected by coffee/avocado intercropping ratios at Jimma

Coffee/avocado intercropping ratio	Coffee yield (kg ha^{-1})			Mean	Coffee yield advantage			Mean
	1993/94	1994/95	1995/96		1993/94	1994/95	1995/96	
91:0	41670	13900	13430	**23000**	-	-	-	**-**
0:28	-	-	-	**-**	0.29	0.47	0.47	**0.41**
63;28	10710	78810	55360	**24960**	0.23	0.57	0.41	**0.40**
67:24	12150	85660	63630	**53813**	0.29	0.47	0.47	**0.41**
71:20	10370	74580	12265	**32405**	0.25	0.54	0.90	**0.56**
75:16	23250	10730	13017	**15666**	0.56	0.78	0.97	**0.77**
79:12	30130	99480	98380	**75997**	0.72	0.72	0.73	**0.72**

Source: Taye *et al*., (2008).

Table.5 Aavocado yield (kg ha^{-1}) and yield advantage as affected by coffee/avocado intercropping ratios at Jimma

Coffee/avocado intercropping ratio	Avocado yield (kg ha^{-1})			Mean	Avocado yield advantage			Mean avocado yield advantage
	1993/94	1994/95	1995/96		1993/94	1994/95	1995/96	
91:0	-	-	-	**-**	-	-	-	-
0:28	5870	32400	25100	**20456**	1.04	0.60	1.20	**0.95**
63;28	6120	19690	30310	**18707**	0.81	0.73	1.23	**0.92**
67:24	4750	24060	31080	**19965**	1.04	0.60	1.20	**0.95**
71:20	21010	14330	35050	**16797**	3.58	0.44	1.39	**1.80**
75:16	22970	34860	35300	**24377**	3.91	1.06	1.40	**2.12**
79:12	22970	34860	35300	**31023**	2.50	0.38	1.51	**1.46**

Source: Taye *et al*., (2008)

Table.6 Mean clean coffee and dry korarima capsule yield (kg ha^{-1}) as affected by coffee to korerima intercropping ratios at Tepi in southwest Ethiopia (mean of two crop years)

Coffee to korarima intercropping ratio	Mean clean coffee yield (kg ha^{-1})	Mean clean coffee yield advantage (%)	Mean korarima dry capsule yield (kg ha^{-1})	Mean korarima yield advantage (%)
1: 1	958.90b		521.73b	
2:1	1390.70a		506.13b	
1:2	665.40b		561.60ab	
Sole coffee	1786.5a		-	
Sole korerima	-		615.33 a	
F test	*		*	
CV (%(	**1870**		**5.08**	

Source: Behaillu *et al*., (2020).

Table.7 Mean clean coffee and dry korarima capsule yield (kg ha^{-1}) as affected by coffee to korerima intercropping ratios at Gera in southwest Ethiopia (mean of five crop years)

Coffee to korarima intercropping ratio	Mean clean coffee yield coffee (kg ha^{-1})	Mean coffee yield advantage (%)	Mean korarima dry capsule yield (kg ha^{-1})	Mean korarima yield advantage (%)
1: 1	495.86c		473.16ab	
2:1	476.86c		642.74a	
1:2	661.91b		588.10ab	
Staggered planting	976.34sab-		360.35b	
Sole coffee	1291.90a		-	
Sole korerima	-		717.88a	
F test				
CV (%)				

Source: Addis *et al.*, (2016).

Table.8 Esimated gross field benefit (EtB ha^{-1})frm coffee and spices over three consecuative crop years (1995/96 – 1997/98)

Corp type	1995/96			1996/97			1997/98		
	Sole	Intercrop	Mean	Sole	Intercrop	Mean	Sole	Intercrop	Mean
Coffee	9747	8665	9205	9398	6892	7645	9982	8298	9140
Turmeric	6659	3509	5084	3185	1438	2312	9675	3647	6661
Giner	12394	1933	7164	6442	1474	3958	4392	1145	2768
Total	**28800**	**14107**	**21454**	**18025**	**9804**	**13914**	**24049**	**13090**	**18569**

The money field prices of dry coffee bean were 225, 475 aand 591 Birr q^{-1}.and dry processed turmeric and fresh ginger yield were 150, 100 and 200 and 100, 75 snd 50 Birr q^{-1}during the 1996, 1997 and 1998 cropping year, respectively. 20 EtB = 1 US Dollar.
Source: Anteneh (2015).

Table.9 Effect of intercropping of coffee and potato on component crops yield at Jimma

Coffee cultivar	Coffee fresh cherry yield (kg ha^{-1})		Potato tuber yield (kg ha^{-1})		Yield advantage		LER
	Sole	Intercrop	Sole	Intercrop	Coffee	Potato	
74110	636	810	11133	4714	1.27	0.42	1.69
74148	997	543	8612	8069	0.54	0.94	1.48
741	683	629	9215	6224	0.92	0.68	1.60

Source: Taye *et al*., (2008).

Table.10 Coffee and component crops mean yield (kg ha^{-1}) as infulenced by intercropping treatment at Awada in south Ethiopia (mean of four years)

Treatment	Yield (kg ha^{-1})	Percent yield advantage of coffee	Percent yield advantage of component crops	LER
Soybean + coffee	1038	31.02	32.67	1.88
Haricobean + coffee	855	85.90	40.04	1.10
Ginger + coffee	831	3.48	23.15	1.64
Yam + coffee	850	1.16	17.34	1.35
Sole coffee	861	-		
Sole soybean	1505			
Sole haricot bean	587.			
Sle ginger	3612.5			
Sole yam	2575			

Source: Endale *et al.*, (2014).

Table.11 Effect of intercropping coffee with enset on growth perform ace of coffee trees at Wonago

Coffee:enset intercropping ratio	Plant height (cm)	Numbaer of primeries	Plant vigour [visual scorw (1-4)*
	NS	NS	NS
1:0	218	75	3.8
1:1	218	54	2.1
2:1	248	67	3.3
3:1	237	74	4.0
4:1	218	73	3.8

1 and 4 stand for poor and very good plant vigor, respectively. **Source:** IAR (1983).

Table.12 Mean fresh coffee yield and elative coffee yield coffee intercropped with enset at Wonago

Coffee:enset intercropping ratio	Coffee yield (kg ha^{-1})				Coffee yield advantage			
	1985/86	1986/87	1987/88	Mean	1985/86	1986/87	1987/88	Mean
	*	NS	NS	**NS**				
1:0	10999	3179	7760	**6979**	-	-	-	**-**
1:1	1364	2105	2582	**2000**	0.12	0.97	0.33	**0.29**
2:1	6797	3454	4686	**4578**	0.62	1.58	0.60	**0.71**
3:1	8513	4409	5381	**6101**	0.77	2.02	0.69	**0.87**
4:1	7766	3146	6110	**5674**	0.71	1.44	0.79	**0.81**

NS and * = Non-significant and significant at 1% probability level, respectively**. Source***:* IAR (1983).

Table.13 Mean fresh coffee yield (kg ha^{-1}) and elative coffee yield coffee intercropped with enset at Jimma

Coffee:enset intercropping ratio	Coffee yield (kg ha^{-1})				Coffee yield advantage			
	1986/87	1987/88	1988/89	Mean	1986/87	1987/88	1988/89	Mean
1:0	1955	1089	1633	**1759**	-	-	-	**-**
1:1	994	1892	1328	**1405**	0.51	1.12	0.51	**0.80**
2:1	2075	1217	1509	**1600**	1.06	0.70	0.92	**0.61**

Source: IAR (1983).

Table.14 Mean clean coffee and enset yield (kg ha^{-1}) as affected by coffee and enset intercropping ratios at Tepi

Coffee:enset intercropping ratio	Coffee yield (kg ha^{-1})				Enset yield (kg ha^{-1})			
	2013	2014	2015	Mean	2013	2015	Mean	Mean
1:1	668.63c	792.83b	593.37d	**685.61d**	22049b	20321b	21185b	
2:1	706.00c	799.30b	670.67d	**725.32d**	18805bc	17104b	17954b	
3:1	835.37bc	822.07b	823.03c	**827.19c**	15314cd	14438b	14876c	
1:0	1142.70a	1072.33a	14290a	**1214.88a**	-	-	-	
0:1	-	-	-	_	43000a	453b33a	44162a	
Staggered	998.40ab	959.07b	1027.07b	**994.84b**	13646d	15342b	14593c	

Mean within a colon followed by the sane letter(s) are not significantly different at 0.05 probabiliy level. Sorce**:** Behailu *et al.,* (2020)

Fig.1 Mean LER (a) and monetary advantage (b) as affected by coffee/banana intercropping ratios at Metu (mean of three years). C = Coffee and B = Banana. Clean coffee and fresh banana bunch yield, banana suckers, and NPS, urea and K_2O_5 mineral fertilizers were valued at the open market price of 63.67, 9.33 7.00, 13.50, 13.15 14.20 EtB (Ethiopian Birr) kg^{-1} respectively. 40 ETB = 1 US Dollar. **Source:** Fantahun (2021).

a b

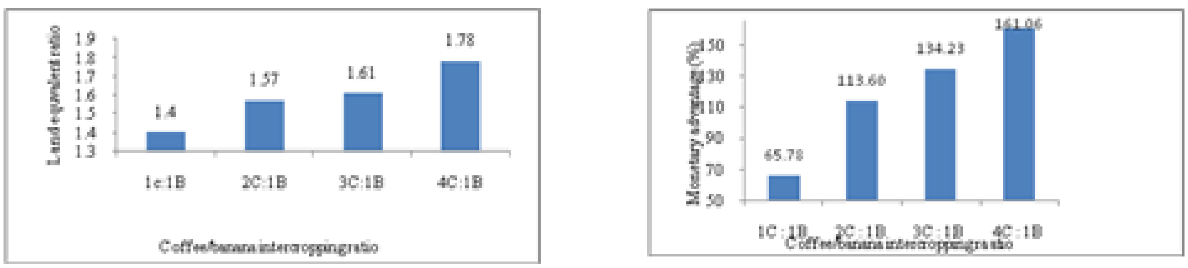


Fig.2 Mean LER as affected by coffee/orange intercropping ratios at Jimma. C = Coffee and Or = Orange. **Source:** Taye *et al.*, (2004).

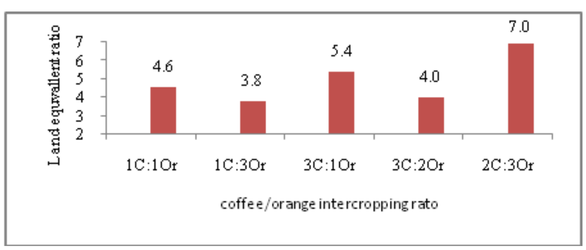


Fig.3 LER of intercroping coffee with avocado at various ratios and crop year in Jimmma. **Source:** Taye *et al.,* (2008).

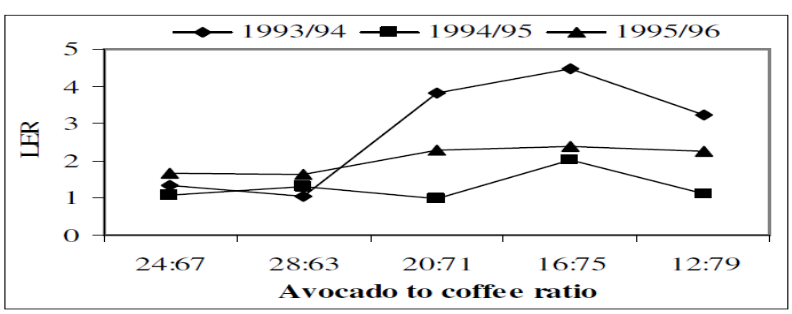


Fig.4 Mean LER of intercroping coffee and korarima at various ratios at Tepi and Gera. C = Coffee and K = Korarima. **Source:** Addis *et al*., (2016) and Behaillu *et al*., (2020).

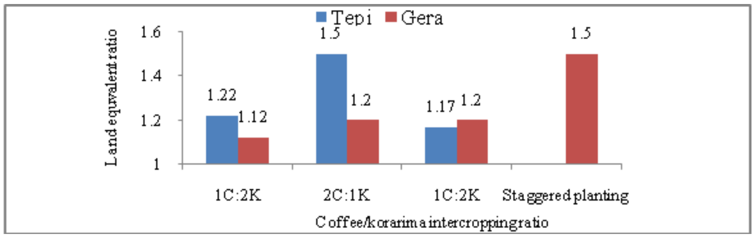
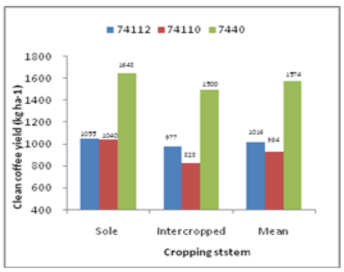
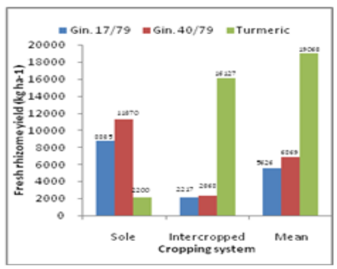


Fig.5 Mean clean coffee yield (kg ha^{-1}) (a), fresh rhizome yields of turmeric and ginger (kg ha^{-1}) (b) and LER (c) as influenced by the intercropping of coffee cultivar with turmeric and ginger at Tepi (mean of six crop years). **Source:** Anteneh (2015).

a



b



c

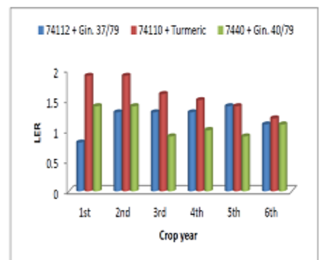
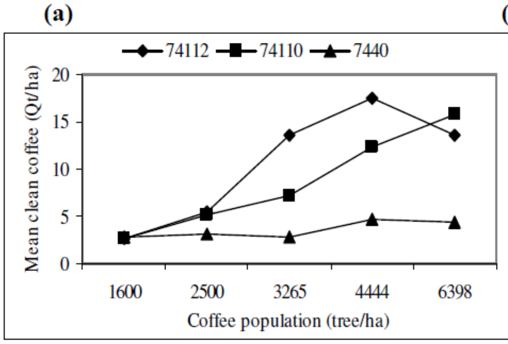


Fig.6 Mean clean coffee yield (a) and fresh rhizome yields of turmeric and ginger (b) as influenced by coffee population density at Tepi during the last crop year. 1Q = 100 kg. **Source:** Anteneh (2015).

(a)



(b)

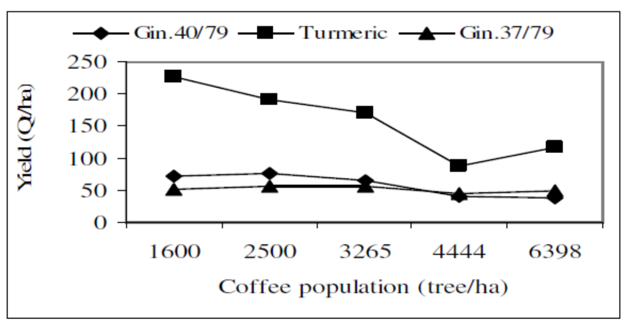
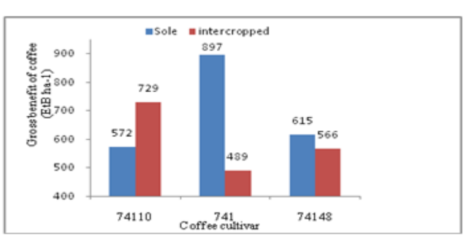


Fig.7 Effect of intercropping coffee and potato on goss benefit of coffee (a) and potato (b) at Jimma. The money field prices of fresh coffee cherry and potato were 0.90 cents and 1 EtB kg^{-1}, respectivly. Source: Taye *et al*., (2008).

(a)



(b)

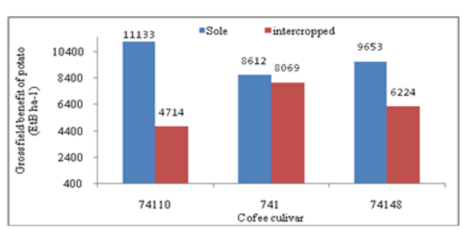
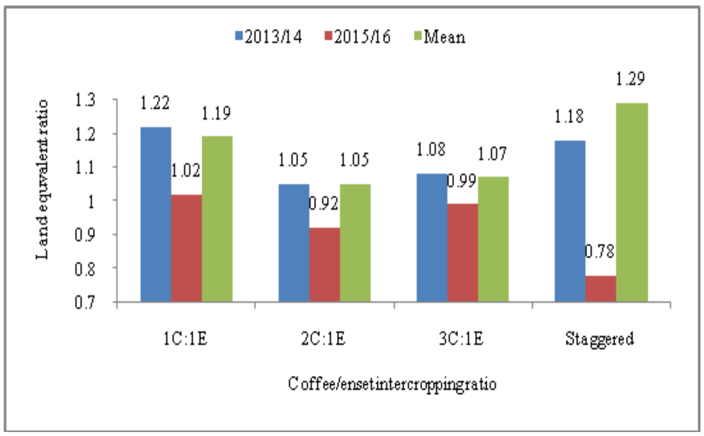


Fig.8 Land equvalent ratio (a) and values of coffee and ross economic returns (b) of intercropping of coffee and component crops at Awada. CF = Coffee, GG = Ginger, SYB = Soybean and HRB = Haricot bean.
Source: Endale *et al*., (2014).

a b

Fig.9 LER as infulenced by coffee and enset intercroppin ratio at Tepi. **Sorce:** Behailu *et al*., (2020)



When compared to other combinations, potato plants intercropped with cultivar 74148 produced the highest potato tubers. As a result, when interplanted with the compact coffee cultivar 74148, the greatest benefit in potato tuber production was observed (Table 9).

In contrast, the combination of coffee and potato cultivars 74148 > 741 > 74110 was found to have a higher gross monetary return (Figure 5). Although the mean yields of solo potato stands were higher than those of intercropped plots of both crops, they were still significantly lower. The combination of coffee and potato cultivars 74148 > 741 > 74110, on the other hand, was found to have a higher gross monetary return (Figure 5).

Despite the fact that the mean yields of single potato stands were higher than those of intercropped plots of both crops, they were still significantly lower. The LER was >1 for all coffee cultivars, with the order 74110 > 741 > 74148 indicating their suitability for potato intercropping under Jimma conditions (Taye *et al.*, 2008).

Coffee with root, spices, grain legumes and enset crops

A compact coffee cultivar (85238) was intercropped with grain legumes [haricot bean (*Phaseolus vilgaris* L.) and soybean (*Glycine max*), spices [turmeric (*Curcuma longa*) and ginger (*Zingiber officinale* Rose), and root crop [yam (*Dioscores alata*)]. For comparison, the trial included a single plot of main crop and component crops.

The results of the tial's over-year analysis revealed that intercropping had no significant (P<0.05) effect on coffee yield performance. As a result, coffee intercropped with soybean produced the highest annual clean coffee yield of 1036 kg ha^{-1}. Intercropping significantly reduced yield of grain legume component crops after the second coffee harvest, with the exception of yam and ginger. This is demonstrated by yield differences of 14 08 to 51.85 and 24.24 to 49.08% across crop seasons between sole and intercropped soybean and haricot bean, respectively (Table 6).

All crops, on the other hand, had LER value greater than one. As a result, coffee intercropped with soybean, haricot bean, ginger, and yam had higher LER with average values of 1.88, 1.10, 1.64, and 1.35, respectively (Figure 6a). Furthermore, intercropped plots of coffee with ginger, yam, soybean, and haricot bean yielded significant gross economic returns, with respective mean values of 16495.45, 9375.00, 650.00, and 3231.5 EtB ha^{-1} (Figure 6b).

The findings showed that component crops such as spice (ginger), grain legumes (soybean and haricot bean), and root crop (yam) provided a significant gross economic return while having no effect on coffee yield. Similarly, Chaves and Gue rrerio (1989) reported that in a field trial in Brazil on young and mature coffee intercropped with various crops such as cotton, beans, rice, maize, and soybean, the intercrops removed large amounts of soil nutrients while having no effect on coffee tree growth.

A similar study on a newly established Arabica coffee hybrid Ruiru 11 intercropped with tomato (*Lycopersicon esculentum*), Irish potato (*Solanum tubersom*), and dry beans (*Phaseolus vulgaris*) found no negative effect on coffee productivity in the long run (Njoroge and Kimemia, 1995).

Coffee with enset *(Ensete ventricosum)*

At Wonago, Jimma, and Tepi, coffee and enset were intercropped in rows. On young and eight-year-old coffee plantations in the respective locations, coffee trees were intercropped with enset at ratios of 1:0, 1:1, 4:1, 2:1, and 3:1 at Wonago and 1:0, 1:1, 4:1, 2:1, and 3:1 at Jimma, and 1:1, 2:1, 3:1, and staggered planting at Tepi. According to the findings, At Jimma and Wonago, there were no significant ($P \leq 0.05$) differences in the growth and yield performance of coffee trees and enset plants (Table 7, 8 and 9). However, at Tepi, different intercropping ratios had a significant ($P<0.05$) effect on component crop yields (Table 110). Despite this, higher average coffee yield were obtained for 3:1 and 4:1 coffee to enset ratios, in the former two locations which were nearly identical to the value obtained for the sole coffee plot. Similarly, the maximum clean coffee yield of 1127.68 kg ha^{-1} followed by 1082.04 kg ha^{-1} was recorded from the sole coffee plot and staggered planting at Tepi. At all study locations, the lowest coffee yield was obtained from 1:1 coffee-to-enset intercropping ratio (Tables 8, 9 and 10). Coffee yield benefits varied across crop years at all study sites (Tables 8, 9 and 10). The study's findings revealed that using a high density of enset plants at a spacing of 2.5 m * 2.5 m appears to be detrimental to coffee tree growth and development due to the strong shade generated by densely spaced enset plants. Taye (2006) discovered that intense shade inhibits the growth and development of coffee plants. However, the critical coffees to enset ratios were discovered to be 3:1 and 1:1, respectively, for the Wonago and Jimma locations (IAR, 1983).

Furthermore, the LER value was greater than one in all intercropped ratios at all study locations. As a result, the maximum LER value was obtained from the 3:1, 2:1, and staggered planting plots at Wonago, Jimma, and Tepi, respectively (Figure 7). It can be concluded that a coffee and enset intercropping ratio of 3:1 and 2:1 at Wonago and Jimma, respectively, and staggered planting of coffee and enset at Tepi is a suitable cropping arrangement for increasing component crop yield productivity and ensuring food security for resource-poor farmers. As a result, the previously mentioned planting arrangement can be recommended for farmers and growers in the study locations.

In a properly designed cropping practice, coffee can be grown alongside fruit, spices, root and tuber crops, and grain legumes with no yield losses. Compact coffee cultivars are better suited for intercropping than open and intermediate coffee cultivars. Intercropping had the greatest impact on coffee yield performance in the first year of stand establishment. Intercropping coffee with a variety of food and cash crops has been shown to stabilize yield advantage and gross economic returns, particularly during the first year of stand establishment. As a result, small-scale farmers are better protected against crop failure and low market prices for a single crop. Intercropping is the only way to increase crop productivity per unit area of landed/or per year, given farmers' small farm sizes and the long time it takes for coffee trees to bear fruit. As a result, intercropping coffee with food and cash crops is an important approach to increasing yield and reducing risk associated with environmental and price fluctuations in the country's garden coffee production, depending on the farmers' preferences and priorities.

Acknowledgments

I would like to thank all of the researchers who provided research output for this review.

References

Addis Tadsesse, Endale Taye, Alemseged Yelma and Teshome Mesfine. 2015. Intercropping of

Arabica Coffee (*Coffea arabica* L.) with Korerima (*Aframomum korarima*) in South Western Ethiopia. *World Journal of Biology and Medical Sciences*. 3(1): 43-49.

Aggrawal, P., Garrity, D., Liboon, S. and Morris, R. 1992. Resource use and plant interaction in a rice and mung bean intercrop. Agronomy Journal, 84:71-78.

Antnehe Nestre and Taye kufa. 2015 Intercropping of Arabica Coffee (*Coffea arabica* L.) with turmeric and ginger in south western Ethiopia, journal of Biology, Agriculture and Healthcare, ISSN 2224-3208 (Paper) ISSN 2225-093X (Online), 5(7) :65-68.

Awoke, T. C. 1997. The culture of coffee in Ethiopia. *Agroforest Today*. 9(1): 19-21.

Baumann, T., Bastiaans, L. and Kropff, M. 2002. Intercropping system optimization for yield, quality, and weed suppression combining mechanistic and descriptive models. Agronomy Journal, 94:734-742.

Behailu Mekonnen, Essubalew Getachew, Shiferaw Temteme1 Anteneh Netsere, Girma Hailemichael, Lemi Yadessa. 2020. Intercropping of Coffee with Korarima (*Aframomum corrorima* (Braun) P. C. M. Jansen) at Tepi, Southwest Ethiopia *International Journal of Research in Agriculture and Forestry*. 7(6): 42-47

Behailu Mekonnen, Essubalew Getachew, Shiferaw Temteme, Tesfaye Shimber and Anteneh Netsere. 2020. Intercropping of Coffee with enset (*Enset ventricosum* Welw. Cheesman) at Teppi, Southwestern Ethiopia. *International Journal of Researchstudies in Agriculture*. 6(8): 15-22.

Chavesc J. C. O. and E. Guerreiro. 1989. Intercropping in coffee plantations. *Pesqui Agropecu Bras*. 24: 177-190.

Coste R. 1992. Coffee: The plant and the product. Macmillan, London.

Dhima, K. V., A. S. Lithourgidis, I. B. Vasilakoglou and C. A. Dordas, 2007. Competition indices of common vetch and cereal intercrops in two seeding ratio. *Field Crops Research*, 100: 249-256.

Edossa Etissa. 1998. Spices research achievements and experiences. Research Report NO 33, Institute of Agricultural Research, Addis Ababa, Ethiopia.

Endale taye, Anteneh Netsere and Getu Mitiku. 2014. Effect of intercropping of coffee with grain legumes, root and spice crops on productivity of coffee Arabica in south Ethiopia. Coffee Production, Variety and Trading: Ways to Maximize Ethiopian's Benefits. Proceedings of the National Conference, March 14-15. The Biological Society of Ethiopi, Addis Ababa Ethiopia 147pp.

Fentahun Asfaw Tessema. 2021. Effect of Intercropping of Arabica coffee (*Coffea arabica* L.) with banana on yield and yield components of the component crops and quality of coffee at Metu, southwestern Ethiopia. M. Sc. Thesis. Jimma University, College of Agriculture and Veterinary Medicine, Jimma, Ethiopia. 99 pp.

Gebru, H., K. W/Tsadik and T. Tana, 2015. Evaluation of Tomato (*Lycopersicon esculentum* Mill) and Maize (*Zea mays* L.) Intercropping System for Profitability of the Crops in Wolaita Zone, Southern Ethiopia. *Journal of Biology, Agriculture and Healthcare*, 5(1):132-140.

Hailu Gebru 2015. A review on the comparative advantages of intercropping to mono-cropping system. Journal of Biology, Agriculture and Healthcare, 5(9): 1-14.

IAR (Institute of Agricultural Research). 1983. Coffee department progress report for the period 1982/83. Jimma research Center, IAR, Addis Ababa, Ethiopia.

Kufa Taye, Shimber Tesfaye and Yilma Alemseged. 2004. Intercropping coffee with sweet orange at Jimma Research Center, Jimma, Ethiopia. *Journal of Café and Cacao*. 5(1-2); 17-21.

Njoroge, J. M., K. aand J. K. Kimemia. 1995. Effect of intercropping young compact Arabica coffee hybrid with food crops at three ecological zones on yield and coffee growth on Kenya. *Exp. Agr.* 31: 49-55.

Onwueme I. C. and T. D. Sinha. 1991. Field crops production in tropical Africa. CTA the Netherlands, 111-117.

Reddy, A. G. S. and I. V. Ananda. 1999. Coffee as an intercrop to coconut in the plains of Karnataka. *Indian Coffee*. 113:3-6.

Sullivan, P., 2003. Intercropping principles and production practice. Agronomy Systems Guide. Appropriate Technology Transfer for Rural Areas (ATTRA). 1-12p. Available on: www.attra.necta.org.

Taye Kufa, Tesfaye Shimber, Alemseged Yilma, Anteneh Netsere and Endale Taye 2001. The impact of close spacing on yield of Arabica coffee under contrasting Agro-ecologies of

Ethiopia. African Crop Science Journal, 9(2): 401-409.

Taye Kufa and Aleemseged Yilma. 2005. Farmers' croppin pattern in Sidamo and Gedio zones, southern Ethiopia. Pp. 1073- 1076. In: proceedings of the 20th International Conference on Coffee Science.

Taye Kufa, Ateeh etsere, Tesfaye Shimber, Edale Taye ad Alemseged Yilma. 2008. Intercropping of coffee with other crops. *In:* Girma Adugna, Bayetta Belachew, Tesfaye Shimber, Endale Taye and Taye Kufa (eds.) Coffee Diverssity and Knowledge. Proceedings of the National Workshop Four Decades of Coffee Research and Developmet in Ethiopia. 14 -17 August 2007, Addis Ababa, Ethiopia.

Willey, R. S. 1979. Intercropping-its importance and research needs. Part 1. Competition and yield advantages. *Field crop Res*. 32: 1-10.

How to cite this article:

Anteneh Netsere. 2021. Progress of Intercropping Research of Arabica Coffee with Fruits, Spices, Tuber, Root, Grain Legumes and Enset Crops in Ethiopia. *Int.J.Curr.Res.Aca.Rev.* 9(10), 31-44.
doi: https://doi.org/10.20546/ijcrar.2021.910.006