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Effects of Coffee (*Coffea arabica* L.) Strip intercropping with Pineapple (*Ananas comosus* L.) on Yield and Yield Advantages of the component Crops

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Abstract
*Intercropping has a number of advantages over mono-cropping production style which has significant problems and that there are a sufficient justification for studying intercropping approaches. Consequently, researchers have proposed a systematic intercropping approach to benefits from intercropping yield advantage, productivity of the component crops, economic return, yield stability, pest control, nutrient use efficiency etc. Because of these advantages, intercropping is practiced in many parts of the world, especially in the developing countries like Ethiopia. A field experiment was conducted at Awada Agriculture Research Sub-center experimental site between 2012 and 2018/19 to evaluate the effect of strip intercropping ratios of coffee with pineapple on yield and yield components of both crops and to determine economically optimum coffee to Pineapple strip intercropping ratio for the study area. The experiment was laid out in a randomized complete block design with three replications. Coffee variety (Fayate) and Smooth Cayenne Pineapple variety were used. The experiment was contained five treatments: sole coffee, sole Pineapple, 1C:1, 1:2, and 1:3ratio of coffee to pineapple. The over year mean result of coffee with pineapple strip intercropping indicates that, sole coffee (*1608kg/ha*) planted plots were statically higher than all other treatments. 1C:1P (1289kg/ha) was also significantly higher than 1C:2P (1128kg/ha) and 1C:3P (1148kg/ha) of coffee pineapple intercropping treatments. A LER of ranging from 1.23 up to 1.50 or relative yield advantage of 23% up to 50% was obtained from the coffee-Pineapple strip intercropping treatment. Therefore, this finding recommends that strip intercropping of coffee with Pineapple at 1:3 ratios is a viable option for sustainable productivity in yield and yield profit to farmers as revealed by the highest total LER.*

Key words: - *Coffee, Pineapple, LER, and Strip-intercropping*
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1. Introduction

Intercropping system allows better resource use efficiency and reducing the needs for external inputs (Dariush *et al*., 2006) is a practice of growing two or more crops in the same piece of land at the same time and plays an important role in subsistence food production in developing countries (Tsubo *et al*., 2005). Strip cropping is a prominent part of an intercropping practice that two or more crops in strips are wide enough to permit independent cultivation but narrow enough for the crop to interact impartially, synergistically or antagonistically. It has been well known that, intercropping provides many advantages like improved utilization of growth resources by the intercropped species (Banik *et al*., 2006); used as a method of controlling weeds, insect pests, diseases and control of soil erosion (Matusso *et al*., 2012). Interactions in the component crops under intercropping facilitate each other to achieve maximum yielding or productivity (Knudsen *et al*., 2004) and cloud reduces the yield of the less competitive crops in intercropping. Ethiopia is a leading Arabica coffee producer in Africa, that the production is concentrated in two major coffee producing regions (Oromia 64%) and Southern Nation Nationality and People's Regional State (SNNPRS) (35%) and others (1%) (Birhanu, 2017) and Sidama Zone is the largest coffee producer of SNNPRS with a share of 73,030.04ha (CSA, 2017). Coffee serves as the major cash source to the farm household, which expends the cash to its different uses. According to (Damenu *et al.,* 2008), the crop is commonly grown as a garden plantation being intercropped with different crops such as pineapple, banana, enset, and some other fruit crops. The coffee based intercropping system provides an improved farm earning for smallholder farmers without an adverse impact on the yield and quality of coffee (Van Asten *et al*., 2011).

Even though pineapple production was been intensified throughout the world, leaded by a countries like, Thailand, Philippines, Mexico, Nigeria, Kenya, Democratic Republic of Congo, Ivory Coast, and South Africa

are the leading pineapple producing countries (Hossain M, 2016), its production in Ethiopia is still at its infant stage that concentrated only at south and south west part of the country (Gezehagn *et al.,* 2019; Shamil *et al.,* 2019). The Author's also stated that, Farmers in the area cultivated pineapple as a cash crop in a mixed farming system for decades. According to CSA data 2016/17 in Ethiopia, pineapple was planted by 70,584 farmers on more than 645.2ha. Farmers in the South and South west Ethiopia are producing pineapple by intercropping with other perennial crop like coffee on a piece land. According to the survey conducted at south Ethiopia, Pineapple cultivation was been started since its introduction through the religious missioners are highly depend on traditional agro forestry system (Gezehagn *et al.,* 2019) because of the land scarcity and high population pressure at the study area. The farmers did not use any agronomic intercropping recommendation as there was no documented scientific research result specifically at the study area and generally through the country. Therefore, the present study was carried out to address how the major enterprises of coffee with Pineapple cropping system can be intensified to ensure sustainable productivity in the farming system by evaluating the effect of coffee-Pineapple strip intercropping ratios on growth, yield and yield components, and to determine economically sound coffee-Pineapple strip intercropping ratio for the study area.

2. Material and Method

2.1. Description of the Study Area

The study was conducted at Awada Agricultural Research Sub-Center (AARSC). It is 315 km far away from Addis Abeba close to Yirgalem town situated in the moderate to cool semi-arid mid highland agro-ecology of south Ethiopia (Mesfin and Bayetta, 2008). It is located at 6º3'N Latitude and 38ºE Longitude at an altitude at an elevation of about 1740 meter above sea level. The area has a semi-bimodal rainfall distribution characterized by double wet and dry seasons (Fig. 1) with an average precipitation of 1342 mm per annum, while the annual average minimum and maximum air temperatures are 11^0C and 28.4^0C, respectively. The major soil types of the center are *Nitisol* and chromatic-cambisols that are highly suitable for coffee production (Mesfin and Bayetta, 2008).

Table 1: Mean monthly maximum and minimum air temperature of the study area

Months	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct
Minimum	5	4	6	7	10	10	7	7	9	12	11	7
Maximum	14.	11	17	16	23	20	20	18	26	29	25	20
Mean	9.5	7.5	11	11	16	15	13.5	12.5	17.5	20.5	18	13

Source: Awada Agro-meteorology station data, (2020)

2.2. Experimental Design and Treatment Arrangements

The experiment was conducted at Awada Agricultural Research sub-center in Sidama Zone, Southern Ethiopia. It was arranged in a randomized complete block design (RCBD) with three replications. The treatments consist of sole coffee sole Pineapple, 1: 1, 1: 2, and 1: 3 the ratio of coffee with Pineapple, respectively. Fayate coffee variety released from the sub-center was used as the experimental material with smooth cayenne pineapple variety planted in the field following the rainy season when rainfall starts. All desirable managements were carried out accordingly for both the companion crop.

Table 2: Treatment combination and spacing arrangement of the companion crops

S/N	Coffee to Pineapple row ratio	Within raw spacing (m)	
	Treatments	Coffee	Pineapple
1	Sole coffee	2.25*2.1	-
2	1 : 1	2.25*1.3	1
3	1 : 2	3*1.3	2
4	1 : 3	3.1.3	3
5	Sole Pineapple	-	Sole

N.B: The spacing between coffee and Pineapple crop were three meters.

2.3. Data Collection

Representative sample from the central rows of each plot were identified by excluding the borders to collect yield and yield contributing characters such as plant height (cm), Height up to a primary branch, number of primary branches, number of nodes, internode length and clean coffee yield. The number of primary branches was recorded by counting the number of primary branches on the main stem and the number of nodes on the primary branch was recorded by counting the number of nodes per primary branch. The number of nodes on the main stem was measured as a total number of nodes count per tree and all necessary growth parameter was been recorded. The fresh cherry weight that had already been recorded per tree bases was used and converted to clean coffee in 100kg ha^{-1}. Pineapple growth and Yield parameter were also recorded by selecting the sample plant from each central plot of the experimental unit. Plant height (cm), leaf width, fruit length, fruit diameter, fruit weight and yield data were collected from the central part of each experimental unit. Land Equivalent Ratios (LER) for Coffee and Pineapple yield were calculated according to Willey, R., (1985), procedures follows.

$$TLER = PLER\ coffee + PLER\ Pineapple$$

Where TLER, total land equivalent ratio; PLER coffee, Partial land equivalent ratio of coffee; PLER Pineapple, Partial land equivalent ratio of Pineapple. The collected data were statistically analyzed using SAS computer soft ware version 9.3 English and the significance difference between any two treatments means were tested by least significant difference (LSD) at 5% probability level.

Figure 1: Pineapple data recording at a rainy season from sole Pineapple plot

3. Result and Discussion

3.1. Mean Results of Coffee yield (100kg/ha)

Analysis of variance revealed that coffee Pineapple strip intercropping was significantly ($p<0.05$) affected clean coffee yield (Table 3) except in the first harvesting season. In all harvesting time of year; superior coffee yield (1608kg/ha) was observed at sole planted coffee plots, which was significantly higher than other treatments except one to one (2228kg/ha) ratio of coffee with pineapple intercropping at the third (2017) harvesting season which was statically at a par with sole coffee planted plots and the non significant result at the first harvesting season (Table 3). The over year mean result of coffee with pineapple strip intercropping indicates that, sole coffee planted plots were statically higher than all other treatments. 1C:1P (1289kg/ha) was also significantly higher than 1C:2P (1128kg/ha) and 1C:3P (1148kg/ha) of coffee pineapple intercropping treatments. In line with this, unlike intercropping, the merits of strip cropping to minimize direct competition between shade tree and

coffee plant for the available resources, viz. nutrient, moisture and light have been well documented (Yacob *et al.,* 1996). Strip planting of coffee trees between two established shade tree species had enhanced coffee yield as compared to intercropping under each canopy.

Table 3 Mean result of Coffee yield affected by Coffee- Pineapple intercropping (100gk/ha)

Treatments	2015	2016	2017	2018	Over year mean
1C:1P	6.752	16.33b	22.28a	6.20c	12.89b
1C:2P	7.733	12.57c	18.66b	6.18c	11.28c
1C:3P	6.304	16.24b	13.35c	10.02b	11.48c
Sole Coffee	7.821	19.34a	22.54a	14.61a	16.08a
LSD (0.05)	NS	1.55	3.22	1.68	1.15
CV%	27.71	4.81	8.40	9.12	4.46

Means followed by the same letter(s) within a column are not significantly different at P≤0.05.

3.2. Mean Results of Pineapple fruit growth and yield (kg/ha)

Analysis of variance revealed that coffee Pineapple strip intercropping was significantly ($p<0.05$) affected pineapple yield and fruit length (Table 3) of pineapple yield. The plot treated with sole pineapple (52083kg/ha) was significantly higher than other strip intercropping treatments (Table 3). The one to three (40981kg/ha) ratio of coffee pineapple strip inter cropping was also significantly higher than one to one (26795kg/ha) and one to two (27597kg/ha) intercropping ration of coffee pineapple.

Table 4: Mean result of Pineapple yield as affected with coffee pineapple intercropping

Treatments	Fruit Diameter (cm)	Fruit Length (cm)	Yield (kg/ha)
1C:1P	10.18^{ab}	12.49	26795^{c}
1C:2P	9.97^{b}	11.87	27597^{c}
1C:3P	10.76^{a}	12.50	40981^{b}
Sole Pineapple	10.35^{ab}	12.08	52083^{a}
LSD (0.05)	0.6756	Ns	6675.30
CV%	3.27	4.78	9.06

3.3 Land Equivalent Ratio (LER)

Land Equivalent Ratio (LER) is the most commonly used method to indicate the yield advantage of intercropping per unit area of land and biological efficiency of intercropping as compared to the mono-cropping system. The results of the current study have proved that growing two or more crops in a piece of land at the same time, is significantly advantageous. It was observed that total LER value was significantly ($P<0.01$) influenced by the intercropping ratio of coffee with pineapple (Fig. 1). In this study, all intercropping patters had higher LER than sole planted crops, which indicated the superiority of intercropping over monoculture. The higher total land equivalent ratios were recorded at 1C:1P (1.32), 1C:2P (1.23) and 1C:3P (1.50) than that of 4C:1E (1.36). The LER ranging from 1.23 up to 1.50 in coffee strip intercropped with Pineapple ratio (Fig 2). This result indicated that mono cropping would require 23% up to 50% more units of lands required to have the same yield as compared to intercropped treatments. The association of coffee and pineapple at 1C:3P strip-intercropping ratio is vital for efficient growth resources utilization since they are complementary to each other. These results might be attributed to more efficient total resource exploitation and greater overall production as opposed to the other intercrop combinations (Haruna *et al,.* 2013; Zhang *et al,.* 2011; Thayamini *et al*., 2010). This result is also in line with the findings of other research studies of (Taye *et al*., 2008) and (Anteneh *et al.,* 2015) who demonstrated the advantage of coffee intercropping with enset, orange, potato and spice crops, as well as a higher value of LER (>1) was also recorded.

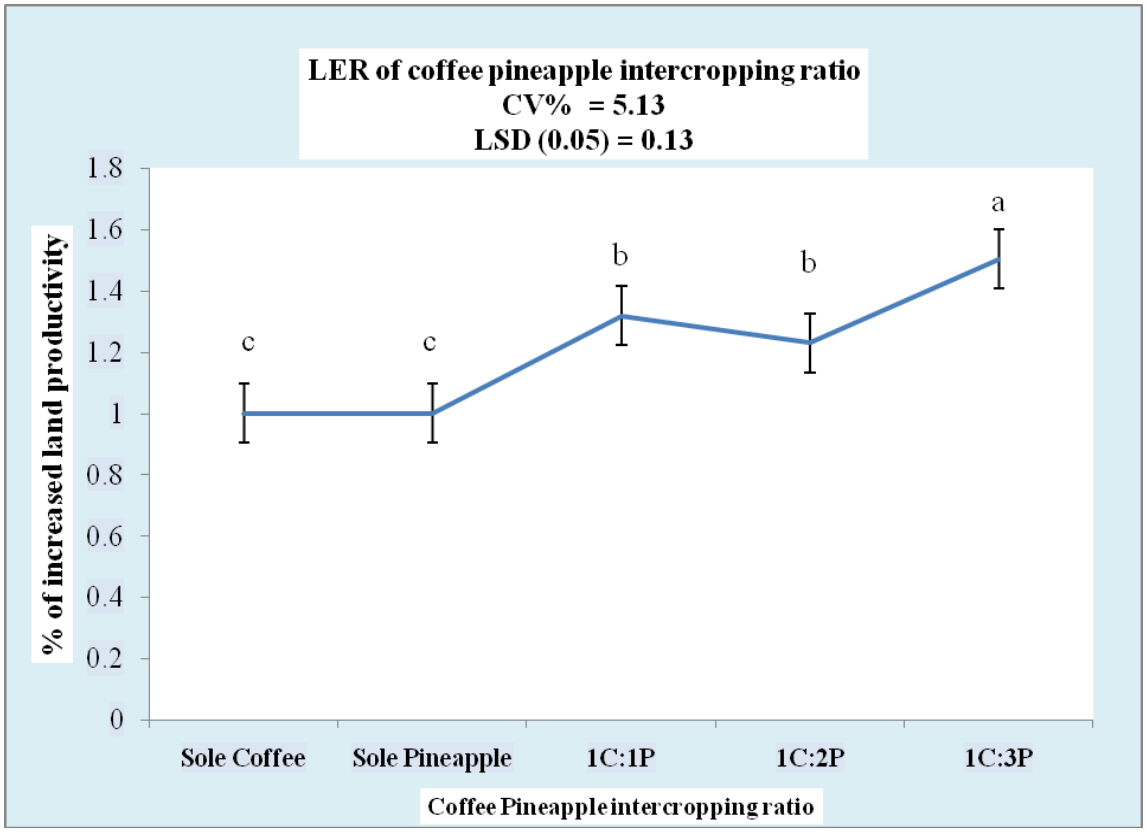

Figure 2: Total LER. Bars capped with the same letter/s are not significantly different at (P<0.05).

4. CONCLUSION

The generated results revealed that, coffee pineapple strip intercropping was significantly affected the yield and yield components coffee-pineapple strip intercropping. The pooled mean analysis result showed that there was a significant variation among different strip intercropping patters, highest (1608kg/ha) and lowest clean coffee yield (1128 kg/ha) was recorded from coffee strip inter-cropped with pineapple at 1:2 ratio. In the same way, economic yield of pineapple was significantly affected by different strip intercropping. The sole planting plots of pineapple produced significantly higher total yield than other intercropped plots. The total land equivalent ratio value was significantly (P<0.001) influenced by the intercropping ratio of coffee with pineapple; was 1.50 obtained in treatment where coffee strip intercropped with pineapple at 1:3 ratio, indicating strip intercropping at this level is more advantageous to produce higher yields per unit area of land through efficient utilization of growth resources. Therefore, this finding recommend that strip intercropping of coffee with pineapple at one to three ratio raised total productivity per unit area and time by improve land equivalent ratio and generate additional economic yield as revealed by the highest total LER.

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