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Yield and Yield Advantage of the Component Crops as Affected by Strip Intercropping of Coffee (*Coffea arabica* L.) with Pineapple (*Ananas comosus* L.)

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Abstract: Intercropping has a number of advantages over mono-cropping production system, which has significant problems and that there are sufficient justification for studying intercropping approaches. Consequently, researchers have proposed a systematic intercropping approach to evaluate the benefits of strip intercropping in terms of yield advantage, economic return, yield stability, pest control, nutrient use efficiency, etc. However, because of these advantages, intercropping is practiced in many parts of the world, especially in developing countries like Ethiopia. A field experiment was conducted at Awada Agriculture Research Sub-center during 2012 and 2019 to evaluate the effect of strip intercropping ratios of coffee with pineapple on the 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 comprised five treatments: sole coffee, sole Pineapple, 1C:1, 1:2, and 1:3 ratio of coffee with pineapple. The pooled mean analysis revealed that the sole planted coffee and pineapple were produced statically highest yields in contrast with other intercropped treatments. Regarding strip intercropping treatments, the highest and lowest clean coffee yield were recorded at 1C:1P (1289 kg ha^{-1}) and 1C:2P (1128 kg ha^{-1}) treatments. The highest total land equivalent ratio was recorded at 1C:3P (1.50), closely followed by 4C:1P (1.36), 1C:1P (1.32), and 1C:2P (1.23) or a relative yield advantage of 23 to 50% was obtained from the coffee-Pineapple strip intercropping treatments. Therefore, this finding recommend that strip intercropping of coffee with pineapple at 1C:3P ratio is a viable option for sustainable productivity in yield and yield profit to farmers as revealed by the highest total LER.

Keywords: Arabica Coffee, Pineapple, LER, Strip-Intercropping

1. Introduction

Coffee is one of the main commodity in an international trade, representing a significant source of income to several coffee-producing countries including Ethiopia [1]. Ethiopia is considered the origin of Arabica coffee, which accounts for 66% of the world coffee market [2, 3]. In Ethiopia, coffee has a significant role in the economy sector, which contributes 5% of the gross domestic product (GDP), 10% of the total national income, 42% for government taxes from foreign trade and more than 26% for total export earnings [4]. Furthermore, it provides an employment opportunity for about 25% of the population [4]. It is also the major source of rural household income and food security mainly in the coffee-producing areas of the country [5]. Ethiopia is leading in Africa, the fifth-largest Arabica coffee-producing country, and the seventh largest coffee exporter in the world [6]. Coffee exports from Ethiopia accounted for approximately 3.31% in value of world coffee green exports between the years 2001 and 2010 [7].

Intercropping system permits improved resource use efficiency and reduces the need for external inputs [8]. It 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 [9]. 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 intercropped species [10], used as a method of controlling weeds, insect pests, diseases and control of soil erosion [11]. Interactions in the component crops under intercropping facilitate each other to achieve maximum yielding or productivity [12] and cloud reduces the yield of the less competitive crops in intercropping.

Ethiopia is a leading Arabica coffee producer in Africa, so 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%) [13]. Sidama Zone is the largest coffee producer of SNNPRS with a share of 73,030.04 ha [14]. Coffee serves as the major cash source to the farm household, which expends the cash on its different uses. According to [15] the crop is commonly grown as a garden plantation being intercropped with different crops such as pineapple, banana, Enset (*Enset ventricosum Welw. Cheesman),* 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 [16].

Even though pineapple production has been intensified throughout the world, leaded by countries like Thailand, Philippines, Mexico, Nigeria, Kenya, Democratic Republic of Congo, Ivory Coast, and South Africa are the leading pineapple producing countries [17] its production in Ethiopia is still at its infant stage that concentrated only at south and south west part of the country [18, 19]. 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 [14] in Ethiopia, 70,584 farmers on more than 645.2 ha planted pineapple. In Ethiopia, pineapple is successfully grown in southern and southwestern parts of the country as small-scale farming system and the average yield of the crop is low about 1.38 tons/ha [20] compared to global average fruit yield of 67.5 t/ha [21]. This low yield is partly due to different production constraints including different intercropping practiced in the region with coffee (*Coffea arabica* L.), low fertility status of the soil [22], lack of improved pineapple technologies for diverse environmental conditions, longer maturity, and lack of improved post-harvest handling technologies are a few to mention [23]. Besides, the lack of sufficient information on the nutritional requirement of pineapple leads low productivity [24], which also includes managements for pineapple at seedling stage in the nursery before transplanting to the permanent fields, and non-availability of planting material [16].

Farmers in the South and Southwest Ethiopia are producing pineapple by intercropping with other perennial crops 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 depending on the traditional agro forestry system [18] because of the, land scarcity and high population pressure in 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. It is situated in the moderate to cool semi-arid mid-highland agro-ecology of south Ethiopia [25]. The study site is geographically located at 06° 3′ 0.43" N Latitude and 38° 0.2′ 20" E Longitude with an altitude of 1740 m above sea level (asl). The area has a semi-bimodal rainfall distribution, which is characterized by double wet, dry seasons with an average precipitation of 1342 mm per annum, while the annual average minimum and maximum air temperatures are 11 and 28.4°C, respectively (Table 1). The major soil types of the center are *Nitisol* and chromatic cambisols that are highly suitable for coffee production [25].

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 Agricultural Research sub-center 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 to 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 crops except shade tree *(susbania susben)* adjustments for only coffee sole plots as pineapple did not shade lover plant rather used as mutual shading or cover to the soil. Pineapple spacing between raw and plant were adjusted based on the previous different research recommendation (60 cm X 30 cm) spacing as it gave the highest number of fruits, fruit weight, fruit length, and fruit girth [26].

Table 2. *Treatment combination and spacing arrangement of the companion crops.*

S/N	Treatments Adjustment (Coffee: Pineapple)	Coffee spacing (m) Between raw and plant (m)	Pineapple spacing (cm) Between raw and plant (cm)	Space between Coffee and pineapple raw (m)
1	Sole coffee	2.25*2.10	---	-------
2	1: 1	2.25*1.30	60*30	1.12
3	1: 2	3.00*1.30	60*30	1.20
4	1: 3	3.00*1.30	60*30	0.90
5	Sole Pineapple	-----	60*30	---------

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. The fresh cherry weight was recorded per tree base converted to clean coffee in 100 kg ha^{-1}. Pineapple yield 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 [27] the procedure 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 and the significance differences between any two treatment means were tested by least significant difference (LSD) at 5% probability level.

3. Results and Discussion

3.1. Mean Results of Coffee Yield (kg ha^{-1})

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. The highest clean coffee yield was attained in sole planted coffee in all harvesting seasons. Concerning harvesting season, the maximum clean coffee yield was achieved during 2017 harvest season, while the yield recorded during 2018 cropping season from all plots were highly affected by the trips occurred during 2017 cropping season around the study area. Even though trips was occurred during 2017 cropping season, sole planted coffee is not yet aggressively affected compared to the strip intercropping treatments. In our study, we observed that the effect of trips to coffee was reduced while the number of strips was increasing, this possibly due to the mutual shading effect.

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

Treatments	2015	2016	2017	2018	Over year mean
1C:1P	6.752	16.33^{b}	22.28^{a}	6.20^{c}	12.89^{b}
1C:2P	7.733	12.57^{c}	18.66^{b}	6.18^{c}	11.28^{c}
1C:3P	6.304	16.24^{b}	13.35^{c}	10.02^{b}	11.48^{c}
Sole Coffee	7.821	19.34^{a}	22.54^{a}	14.61^{a}	16.08^{a}
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 $P \leq 0.05$.

The pooled mean analysis indicates that, sole planted coffee was produced statically higher clean coffee yield in contrast with other intercropped treatments. Regarding strip intercropping treatments, the highest and lowest yield were recorded at 1C:1P (1289 kg ha^{-1}) and 1C:2P (1128 kg ha^{-1}) treatments (Table 3). 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. Nutrients, moisture, and light have been well documented [28]. Strip planting of coffee trees between two established shade tree species had enhanced coffee yield compared to intercropping under each canopy.

3.2. Mean Results of Pineapple Fruit Growth and Yield (kg ha^{-1})

Analysis of variance revealed that coffee pineapple strip intercropping was significantly ($p<0.05$) affected pineapple yield and fruit length (Table 4) of pineapple yield. The yield response of a plot treated with sole pineapple (52083 kg/ha) was significantly higher than other strip intercropping

treatments (Table 4). The one to three (40981 kg/ha) ratio of coffee pineapple strip inter cropping was also significantly higher than one to one (26795 kg/ha) and one to two (27597 kg/ha) intercropping ratio of coffee pineapple. The mean fruit length was ranged from 12.50 to 11.87 that related with the report of 10.7 cm for Queen and 14.57 cm for Smooth Cayenne [18]. Research done in India also indicated that, the fruit length of "Mauritius" variety ranged from 14.73 to 15.95 cm and the mean fruit diameter ranged from 10.05 cm for Queen to 11.68 cm for Smooth cayenne that was directly in line with the current result of our research that ranged from 9.97 cm to 10.76 cm. The mean average fruit weight ranged from 1.01 kg for Queen to 1.65 kg for sugar loaf. Fruit weight (crown) ranged from 0.99 kg to 2.16 kg [29, 30]. On the other hand, the intercropping treatment has no negative and or positive impact on pineapple fruit length (Table 4).

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 the total LER value was significantly ($P<0.01$) influenced by the intercropping ratio of coffee to pineapple (Figure 1). In this study, all intercropping patterns had higher LER than sole planted crops, which indicated the superiority of intercropping over monoculture. The highest total land equivalent ratio was recorded at 1C:3P (1.50), closely followed by 4C:1P (1.36), 1C:1P (1.32), and 1C:2P (1.23). The LER ranging from 1.23 up to 1.50 in coffee strip intercropped with Pineapple ratio (Figure 1). This result indicated that mono cropping would require 23% up to 50% more units of land required to have the same yield compared to intercropped treatments. The association of coffee and pineapple at 1C:3P strip intercropping ratio is vital for efficient growth resource 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 [31, 32]. This result is also in line with the findings of other research studies of [33] and [34] who demonstrated the advantage of coffee intercropping with Enset (*Enset ventricosum Welw. Cheesman*) orange, potato and spice crops, as well as a higher value of LER (>1) was also recorded. It has been well known that intercropping provides many advantages like improved utilization of growth resources by intercropped species [6] and used as a method of controlling weeds, insect pests, diseases and control of soil erosion [11]. Interactions in the component crops under intercropping facilitate each other to achieve maximum yielding or productivity [35] and cloud also reduces the yield of the less competitive crops in intercropping.

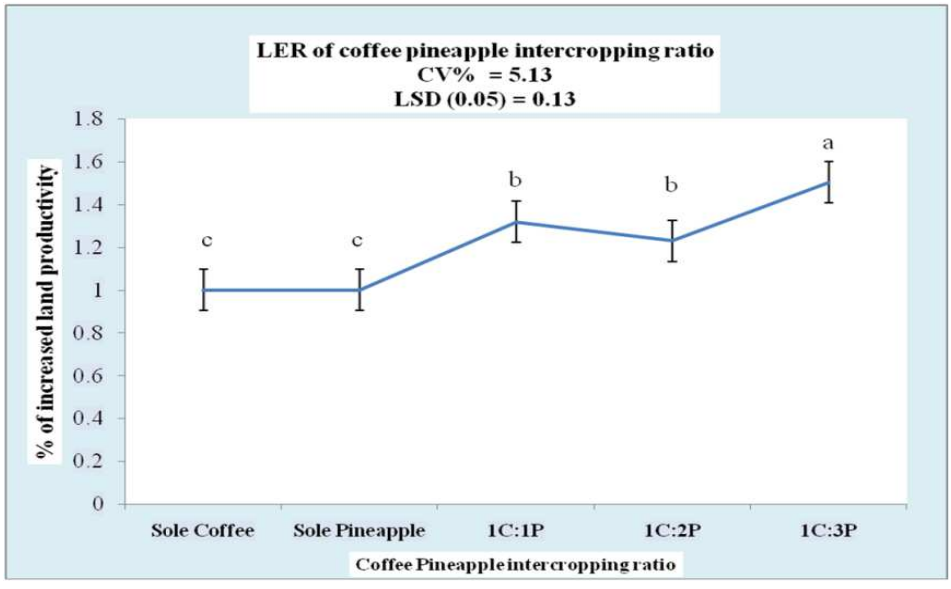

Figure 1. *Total LER. Bars capped with the same letter/s are not significantly different at ($P<0.05$).*

4. Conclusion

The generated results revealed that coffee pineapple strip intercropping was significantly affected the yield and yield advantage of the component crops. The pooled mean analysis result showed that there was a significant variation among different strip intercropping patterns, highest (1608 kg/ha) and lowest clean coffee yield (1128 kg/ha) was recorded from sole coffee and coffee strip inter-cropped with pineapple at 1:2 ratio, respectively. In the same way, the economic yield of pineapple was significantly affected by different strip intercropping. The sole planted pineapple produced the significantly highest total yield than other intercropped treatments.

The total land equivalent ratio value was significantly ($P < 0.001$) influenced by the intercropping ratio of coffee with pineapple. The highest total land equivalent ratio was recorded at 1C:3P (1.50), closely followed by 4C:1P (1.36), 1C:1P (1.32), and 1C:2P (1.23). The above result indicates that strip intercropping at 1C:3P 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 the total productivity per unit area and time to improve land equivalent ratio and generate additional economic yield as revealed by the highest total LER. Conduct further studies in relation to integrated organic and inorganic fertilizers is vital to improve and sustain crops productivity in the study area.

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