International Journal of Advanced Research and Review

www.ijarr.in

DIVERSIFICATION OF ARABICA COFFEE (*COFFEA ARABICA* L.) WITH ENSET FOR SUSTAINABLE PRODUCTION

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ABSTRACT

Crop diversification refers to the practice of cultivating various crops on a single farm or within a particular area. In general, crop diversification is utmost importance as it contributes significantly to the maintenance of food security, environmental sustainability, and economic stability within the agricultural industry. The study was conducted at Gera Agricultural Research Sub-Center from 2014 to 2020 cropping seasons to draw biologically and economically sound recommendations for the coffee to enset intercropping ratio in highland agro-ecologies like Gera, located in southwestern Ethiopia. The experimental treatments included sole coffee, sole enset, one row of coffee to one row of enset (1C:1E), two rows of coffee to one row of enset (2C:1E), three rows of coffee to one row of enset (3C:1E), and a staggered planting pattern where enset was planted at the center of four coffee trees with a 4m distance. The treatments were arranged in a randomized complete block design with three replications. There were significant differences ($P \leq 0.05$) observed among the treatments in terms of the mean clean coffee and kocho yield, and overall quality over the years. The highest overall years mean clean coffee yield (1573.75kg/ha) was obtained from sole coffee, followed by staggered planting and the 2C:1E treatment, which yielded 1173.45kg/ha and 1087.17kg/ha, respectively. For kocho, the highest overall years mean (6276kg/ha) was obtained from the equal ratio (1C:1E) treatment, followed by staggered planting pattern with a yield of 5167kg/ha. The staggered treatment showed the highest Land Equivalent Ratio (LER) and yield advantage, with values of 2.06 and 0.766, respectively, for the overall mean. The results also indicated that the overall quality of the crops fell within highly acceptable ranges. In conclusion, the staggered intercropping coffee with enset proved to be the most effective planting system.

Keywords: Coffee Quality, Crop Diversification, Land Equivalent Ratio, Yield Advantage

1. INTRODUCTION

Crop diversification is the foremost strategy in the advancement of sustainable agriculture. This approach enables the utilization of biological cycles to minimize inputs, preserve the resource base, optimize yields, and additionally mitigate risks associated with ecological and environmental factors. Crop diversification increases land use efficiency and crop yields by improving soil physical and chemical properties. The implementation of crop intensification systems has led to an enhancement in the farm's net yield and overall system productivity [1]. Intercropping, a farming technique that involves cultivating multiple crops together on a single field, presents a viable approach to enhance crop productivity in terms of both time and space. By adopting this method, farmers can not only boost the yield per unit area but also minimize the potential risks linked to crop failure and price volatility. Furthermore, intercropping promotes balanced nutrition and serves as a means to generate supplementary income [2]. The challenge lies in the current population growth and the limited availability of land. It is interesting to note that smallholder farmers, who own less than one hectare of cultivated land on average, contribute to more than 95% of the country's agricultural output. To improve resource utilization and increase the productivity of crops, it is essential to diversify coffee cultivation with various crops [3].

Several studies conducted by different researchers have highlighted the practice of intercropping coffee plants with various crops such as banana, enset, citrus, and avocado and [4-6] have all reported on this phenomenon. Intercropping coffee with enset, in particular, has been found to have numerous benefits. It significantly contributes to improving soil fertility through mulching, soil conservation, moisture retention, and nutrient recycling. Furthermore, it optimizes light interception, helps control coffee diseases and pests, and ultimately enhances sustainable coffee productivity [7]. The advantages of intercropping extend beyond agricultural aspects. Smallholder farmers, who practice intercropping experience improved farm earnings, increased resilience to drought and extreme weather events, reduced vulnerability to coffee price fluctuations, and enhanced food security for their families. These findings have been supported by studies conducted by [6, 8, 9]. In addition to these benefits, intercropping also facilitates the efficient utilization of farm inputs. This includes the utilization of family labor, growth resources, and weed control. [10] have emphasized the importance of intercropping in this regard.

Small-scale farmers in Ethiopia commonly cultivate Enset alongside Arabica coffee for various purposes. In the Southern Nations, Nationalities, and Peoples' Region (SNNPR), the coffee farming system is characterized by the coexistence of coffee and enset on the majority of farms. Enset is primarily grown to provide shade for coffee trees and serves as a staple food crop in the region. Despite existing recommendations on intercropping coffee with enset for different agricultural environments, such as those mentioned by [7, 11], highland agro-ecologies like Gera have not been adequately addressed. Therefore, the aim of this research was to develop biologically and economically viable recommendations for the optimal Coffee to Enset intercropping ratio in highland agro-ecologies like Gera, situated in southwestern Ethiopia.

2. MATERIALS AND METHODS

The experiment was conducted at the Gera Agricultural Research Sub-Center during the cropping seasons from 2014 to 2020. The sub-center is situated at an elevation of 1900 meters above sea level and receives an annual rainfall of 1877.8 mm. The average minimum and maximum temperatures at the location are 10.8 ℃ and 25.1℃, respectively. The treatments for the experiment included sole coffee, sole enset, one row of coffee to one row of enset (1C:1E), two rows of coffee to one row of enset (2C:1E), three rows of coffee to one row of enset (3C:1E), and a staggered planting pattern where enset was planted at the center of four coffee trees with a distance of 4m. The treatments were arranged in a randomized complete block design with three replications. One-year-old seedlings of the local enset clone were planted in the field at a spacing of 3m*2m in the sole plots. In the intercropped plots, the intra-row spacing was 2.0m. Similarly, in the plot rows planted with coffee and enset, they were separated by a distance of 2.5m. In the staggered planting, one enset was placed at the center of four coffee trees, with a staggered fashion to the next row. The recommended and adaptable compact type (74165) of Arabica coffee cultivar was used and the coffee seedlings were raised in polyethylene bags following the recommended nursery practices [12].

Four months after planting enset, the coffee seedlings were transplanted to the field at a spacing of 2m*2m. Field management practices were applied as per the recommendation for both crops [13].The coffee trees were trained to grow in a single stem and were capped at a height of 2.0m. Throughout the experimental period, all undesirable suckers, lateral growths of long drooping primaries, and secondary branches growing within 15cm were controlled and removed. The yield of both coffee and enset (kocho and bulla) was recorded and the raw and cup qualities were evaluated according to the coffee processing and quality analysis laboratory procedure of [14] at Jimma Agricultural Research Center. Additionally, the land equivalent ratio (LER) according to [15] and yield advantages were analyzed. All relevant data were summarized and subjected to analysis of variance (ANOVA) using SAS 9.0 version. Treatment mean separation was done by least significant differences (LSD) at a 5% probability level.

3. RESULTS AND DISCUSSION

3.1.Coffee Yield

The result revealed that a highly significant difference ($P \leq 0.01$) in overall years mean clean coffee yield among treatments (Table 1). The highest overall years mean clean coffee yield (1573.75kg/ha) was obtained from sole coffee, followed by staggered and 2C:1E treatments, which yielded 1173.45kg/ha and 1087.17kg/ha, respectively. Conversely, the lowest yield (678.1kg/ha) was observed in the equal ratio (1C:1E) treatment. The sole coffee and staggered treatments exhibited 132.07% and 73.04% higher clean coffee yield compared to the 1C:1E treatment, respectively.

The superior performance of sole coffee and staggered treatments in terms of clean coffee yield can be attributed to differences in population density and efficient utilization of shared resources such as light, moisture, and nutrients. As population density increased, so did the clean coffee yield, which aligns with a previous study by [11]. Similarly, [16] reported a positive correlation between coffee yield and coffee tree density per unit area. Furthermore, [7] highlighted the significant impact of coffee-enset strip intercropping on clean coffee yield.

Table 1. Overall years mean clean coffee yield (kg/ha) as affected by intercropping of Arabica coffee with Enset from 2014 to 2020 cropping seasons

Treatments	Overall years mean clean coffee yield (kg/ha)
Sole Coffee	1573.75^{a}
Sole Enset	-
1C:1E	678.10^{d}
2C:1E	1087.17^{bc}
3C:1E	986.60^{c}
Staggered	1173.45^{b}
LSD (5%)	165.47
CV (%)	7.99

Figures followed by similar letters are non-significant at a 5% probability level.

The 2015, 2017 and 2019 cropping seasons showed fluctuations in coffee yield (Figure 1). This occurrence can be attributed to the exposure of coffee plants to sunlight after the enset plant was harvested, resulting in a reduction of shading effect on the coffee trees. Across all cropping years, the lowest clean coffee yield was obtained when the ratio of coffee to enset was equal (1C:1E). This decrease in yield was associated with a decrease in coffee population density and an increase in enset compared to other treatments. This finding aligns with the research conducted by [11], which showed that a decrease in coffee population density and an increase in enset per unit area led to a decrease in mean clean coffee yield per unit area at an equal ratio (1C:1E). Similar results were also reported by [5], where the lowest yield was obtained from an equal proportion (1C:1E) of the two crops compared to other treatments.

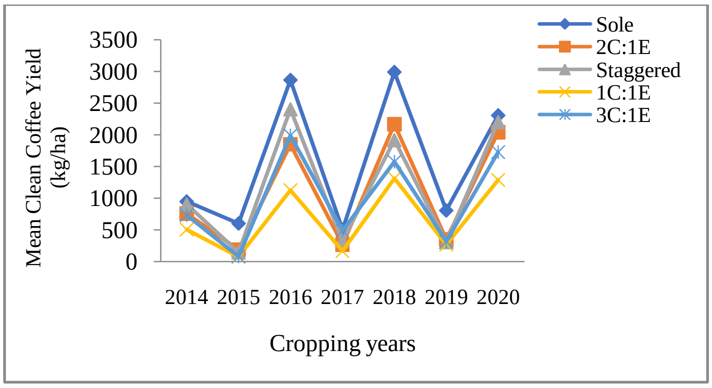

Figure 1. Mean clean coffee yield of cropping seasons (2014-2020)

3.2.Enset Yield

The results of the Enset (kocho) yield indicated a significant difference ($P \leq 0.05$) between the first two harvests of the 2013 and 2016 cropping years, as well as the overall years mean. The highest kocho yield in the overall years mean was obtained from 1C:1E (6276kg/ha), followed by a staggered planting pattern which yielded 5167kg/ha. In contrast, the lowest kocho yield (4399.5kg/ha) was obtained from 2C:1E (Table 2). The overall years mean bulla yield was not statistically significant (Table 2). However, only a significant bulla yield was obtained in 2016, with 1C:1E and staggered treatments yielding the highest at 126kg/ha and 95.53kg/ha, respectively (Table 2). Similar findings have been reported by [5, 11, 17].

Table 2. Mean yield of kocho and bulla (kg/ha) of cropping and overall years

Treatments	Kocho (kg/ha)				Bulla (kg/ha)			
	2013	2016	2020	Overall years mean	2013	2016	2020	Overall years mean
Sole Coffee	-	-	-	-	-	-	-	-
Sole Enset	4162[b]	5222.2[c]	4044.4	4476.2[b]	314.81	60.19[b]	111.11	162.04
1C:1E	6516[a]	7453.9[a]	4868.2	6279.3[a]	338.98	126.18[a]	141.24	202.13
2C:1E	3628.7[b]	5352.7[bc]	4216.9	4399.5[b]	120	94.53[ab]	141.09	118.75
3C:1E	3914.8[b]	6678.5[ab]	4022.2	4871.9[b]	176.3	81.48[b]	117.78	125.19
Staggered	4607[b]	6817.8[a]	4076.6	5167.1[ab]	254.06	95.53[ab]	123.3	157.63
LSD (5%)	1874	1428.7	NS	1235.5	NS	38.877	NS	NS
CV (%)	21.79	12.04	16.0	13.03	38.74	22.55	29.51	24.45

Figures followed by similar letters are non-significant at a 5% probability level.

3.3.Land Equivalent Ratio and Yield Advantage

The findings indicated that the highest and lowest Land Equivalent Ratio (LER) values, 2.06 and 1.78, respectively, were obtained from staggered and 2C:1E intercropping methods for the overall mean of the years (Table3). All intercropping treatments were found to be more beneficial compared to the sole treatment, as indicated by LER values greater than 1. This suggests that intercropping favored the growth and yield of the component crops, possibly due to the efficient utilization of shared resources [18]. These results are consistent with previous studies that have highlighted the advantages of intercropping coffee with enset, orange, potato, and spice crops [5, 17]. [4] and [17] also reported similar findings, showing that intercropping coffee with avocado and potato resulted in better LER values compared to the sole cultivation of each crop. Among the intercropping treatments, staggered treatment had the highest yield advantage (0.76), followed by 2C:1E treatment (0.69), while the equal ratio (1C:1E) treatment had the lowest yield advantage (0.43) (Table 3). Intercropping coffee with enset showed more advantages compared to growing coffee alone and this finding is consistent with a study conducted by [11], which showed that coffee and enset intercropping resulted in a higher yield advantage for coffee compared to growing it alone.

Table 3. Land equivalent ratio and yield advantage

Treatments	Land Equivalent Ratio			Yield Advantage							
	2016	2020	Mean	2014	2015	2016	2017	2018	2019	2020	Mean
Sole Coffee	-	-	-	-	-	-	-	-	-	-	-
Sole Enset	-	-	-	-	-	-	-	-	-	-	-
1C:1E	1.82	1.76	1.79	0.53	0.13	0.39	0.34	0.44	0.33	0.56	0.43
2C:1E	1.67	1.93	1.78	0.79	0.31	0.65	0.53	0.73	0.43	0.88	0.69
3C:1E	1.97	1.74	1.87	0.77	0.14	0.69	0.97	0.53	0.39	0.75	0.63
Staggered	2.15	1.96	2.06	0.95	0.24	0.84	0.65	0.64	0.38	0.96	0.76

3.4. Raw and Cup Quality

The result revealed that there were no significant differences among the treatments (*P> 0.05*) in terms of both raw and cup quality (Table 4 and 5). However, a significant difference (*P≤ 0.05*) was observed among the treatments regarding total quality. The highest total quality (81.83%) was achieved from both the sole coffee and 1C:1E treatments, while the lowest total quality (80.27%) was obtained from the staggered treatment (Table 5). It is worth noting that all cup quality results exceeded 80%, which falls within the highly acceptable range for cup test quality and similar findings were reported by [19].

Table 4. Effect of intercropping of coffee with enset on raw quality of coffee

Treatment	Screen Number 14 (%)	Shape and make (15%)	Color (15%)	Odor (10%)	Raw (40%)
Sole Coffee	94.00	12.78	13.28	10.00	36.06
1C:1E	94.67	13.17	13.06	10.00	36.22
2C:1E	95.33	13.00	13.33	10.00	36.33
3C:1E	94.67	12.83	13.11	10.00	35.94
Staggered	93.67	12.78	13.39	10.00	36.17
LSD (0.05)	NS	NS	NS	NS	NS
CV (%)	1.56	1.37	1.75	0.00	0.83

Figures followed by similar letters are non-significant at a 5% probability level.

Table 5. Effect of intercropping of coffee with enset on cup and total quality of coffee

Treatment	AI (5%)	AQ (5%)	AC (10%)	AS (5%)	BI (5%)	BO (10%)	FL (10%)	OAQ (10%)	Cup (60%)	Total (100%)
Sole Coffee	4.06	4.11	7.44	4.00	3.94	7.44	7.33	7.44	45.78	81.83[a]
1C:1E	3.94	4.06	7.44	4.00	4.00	7.44	7.22	7.39	45.50	81.83[a]
2C:1E	4.00	4.00	7.33	3.83	3.94	7.28	7.17	7.22	44.78	80.95[ab]
3C:1E	3.89	3.83	7.33	3.89	3.94	7.39	7.17	7.28	44.72	80.95[ab]
Staggered	4.00	3.94	7.22	3.667	3.89	7.33	7.11	7.17	44.34	80.27[b]
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	*
CV (%)	3.53	5.06	2.25	4.45	3.85	1.59	2.25	1.73	1.383	0.66

AI= aromatic intensity, AQ= aromatic quality, AC= Acidity, AS= Astringency, BI= Bitterness, BO= Body, FL= Flavor, OAQ= Organoleptic quality. Figures followed by similar letters are non-significant at 5% probability level.

4. SUMMARY AND CONCLUSION

Coffee-based intercropping system plays a crucial role in maximizing land and resource efficiency, ultimately leading to increased productivity. The findings indicated that the highest coffee yield was achieved through sole coffee, followed by staggered treatment and the 2C:1E ratio. In terms of kocho and bula yield, the highest results were obtained from the 1C:1E treatment, followed by staggered planting and sole enset, respectively. The overall quality of the coffee was significantly influenced by the cropping system as well. Staggered intercropping system showed the highest land equivalent ratio and yield advantages as compared to other treatments. Considering the limited farm size and the time required for coffee trees to bear fruit, intercropping with enset is the remedy to increase productivity per unit area of land. Therefore, a staggered intercropping system was recommended for efficient land utilization and increased productivity, particularly in highland agro-ecologies like Gera.

5. RECOMMENDATIONS

Farmers are advised to raise new enset seedlings a year prior to harvesting matured enset plants, ensuring immediate re-transplantation. It is crucial to minimize or avoid the influence of other shade trees in coffee and enset intercropping to ensure sustainable coffee production.

ACKNOWLEDGMENTS

The authors would like to thank Mr. Enadle Taye and Mr. Ewnetu Teshale for follow up of the activity on their presence in the department. Our acknowledgment also extended to the Coffee Agronomy and Physiology team members of Gera Agricultural Research Sub-Center for their unreserved management of the field activity.

ABBREVIATIONS

AC: Acidity
AI: Aromatic intensity
AQ: Aromatic quality
AS: Astringency
BI: Bitterness
BO: Body
FL: Flavor
LER: Land Equivalent Ratio
OAQ: Organoleptic quality

CONFLICTS OF INTEREST

All the authors do not have any possible conflicts of interest.

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