Integrated Nutrient Management for Improved Coffee Production at West and Southwest Ethiopia. A Review

Bikila Takala
Ethiopian Institute of Agricultural Research, Jimma Agricultural Research Center, P. O. Box 192, Jimma Ethiopia

Abstract
Soil degradation is one of Ethiopia's most severe problems, contributing for the country's low coffee production. Many researches have been conducted by Jimma agricultural research and its sub centers to ameliorate the challenges and improve coffee productions across major coffee growing areas of the west and south western Ethiopia. The goal of this review was to summarize and document major research achievements recorded so far in integrated nutrient management on coffee and recommend future research directions. Integrated application of inorganic and organic fertilizers is the main sources for replenishing plant nutrients in agricultural soils. However, selecting the optimum combination of these resources based on soil type and crop species is necessary. In this context, field experiment was conducted at Haru and Agaro research sub center to assess the effect of decomposed coffee husk and NP Fertilizer on soil physicochemical properties and yield of coffee. Research results indicated yield of Limmu coffee increased by application of 50% recommended rate of N and P mineral fertilizer (RMF) (172 and 77 kg ha^{-1} NP, respectively) + 50% recommended rate of decomposed coffee husk (DCH) (10 ton ha^{-1}) at Agaro. Similar trial conducted at Haru also showed that application of 50% NP + 75%DCH improved yield of Wollega coffee variety. Besides, application of Desmodium cover crop + 50% NP (172 and 63 kg ha^{-1} N and P, respectively) and NP mineral fertilizer ensure high coffee yield at Jimma. In conclusion, integrated use of organic and inorganic fertilizers was recommended for coffee production at Agaro, Haru and Jimma and their surrounding areas. Future research should concentrate on evaluating other organic inputs and combined reclamation of lime-mineral fertilizer-compost, frequency of application, economic benefits, and long-term effects on soil physicochemical properties, coffee yield and bean quality, and establish cost effective soil fertility management in coffee-growing areas of the country.
Keywords: Coffee, decomposed coffee husk, desmodium and soil fertility
DOI: 10.7176/JEES/13-2-01
Publication date: March 31st 2023

Introduction

Soil degradation is one of the most challenging problems in coffee growing areas of the country (Anteneh and Bikila, 2021). The soils are exposed to nutrient leaching over a long period of time resulting in low organic matter content and require careful management to support good crop yields. However, 95% of Ethiopian coffee farmers don't use inorganic fertilizers while the rest add it at levels significantly below the recommended rate (Paulos, 1994). As a result, productivity of coffee in the country remains very low demanding much more vigorous technological intervention in the sector (Solomon *et al*., 2008).

Coffee is a crop that demands huge nutrients which need to be supplied either by the soil or organic and/or mineral fertilizers (Solomon *et al*., 2008; Anteneh and Bikila, 2021; Gemechu and Tesfaye, 2021). More nutrients are removed annually by the harvested products coffee trees in comparison to other tree crops (Vander Vossen, 2004). Nitrogen and potassium are the two dominant nutrients that are taken up in relatively higher proportion, nitrogen being for vegetative growth and potassium is more important in fruit development (Vander Vossen, 2004; Wintgens, 2004). Nutrient management is, therefore, among the key factors that affect productivity of the coffee tree (Anteneh and Bikila, 2021; Gemechu and Tesfaye, 2021).

It is believed that the use of organic and/or inorganic fertilizer is required for increased crop yield and quality. Several research efforts have been made over the last five decades to recommend the best soil nutrient and soil health management technologies for improved coffee production in the country. The integration of organic fertilizers like vermicomposting and conventional compost with inorganic sources improve and sustain soil fertility/productivity and coffee yield in the country (Taye and Tesfaye, 2001; Anteneh and Bikila, 2021). Besides, today, where coffee buyers are enthusiastic to organic coffee, coffee grown using combined use of organic and inorganic source of nutrients undauntedly fetch premium price in the world market. Therefore, the objective of this paper was to summarize and document major research achievements recorded so far in integrated nutrient management for Arabica coffee production and recommend future research directions at west and southwestern coffee producing areas of Ethiopia.

Major Achievements

Integrated organic and inorganic fertilizers rate and application technique

Nitrogen and phosphorus mineral fertilizer treatments (with and without), organic fertilizer sources *viz*, *Sesbania sesban* and coffee by-product and organic fertilizer application techniques such as soil surface and soil incorporation at the ratio of 0:100, 50:50 and 100:0 were evaluated at JARC for three cropping season (1999 – 2003) for their effect in promoting coffee yield. The organic sources were evaluated at rates of 0, 5, 10, 15 and 20 ton ha^{-1} on a dry weight basis (Table 1).

The finding indicated relatively higher mean clean coffee yield for plots not received NP fertilizer than the NP applied ones. The result also indicated greater advantage of decomposed coffee compost than *Sesbania sesban* to boost the yield potential of Arabica coffee (Table 1). Application of organic sources at the rate of 10 ton ha^{-1} gave the highest average clean coffee yield (Table 1 and Figure 1). Furthermore, soil surface and soil incorporate application of organic source at ratio of 0:100 and 50:50%, respectively, promote higher coffee yields at the initial and subsequent crop years. An equal proportion of surface application and soil incorporation of the organic resources (50:50%) was found to be superior over the other techniques of application (Table 1).

Table 1. Mean clean coffee yield (kg ha^{-1}) as affected by fertilizer sources at Jimma

Treatment	Cropping year			Mean
	1999/2000	2001/02	2003/04	
NP mineral fertilizer	NS	NS	NS	NS
With (172 and 63 kg ha^{-1} NP, respectively)	1886	4044	2043	2658
Without	1837	4118	2938	2964
Organic fertilizer	NS	NS	NS	NS
Sesbania sesban	1872	3853	2124	2616
Coffee husk compost	1850	4310	2857	3006
Organic fertilizer (OF) rate (ton ha^{-1})	NS	NS	**	NS
0	1873	4277	2516^{a}	2889
5	2210	4130	1939^{b}	2760
10	1796	4040	2700^{a}	2845
15	1667	3833	2400^{ab}	2633
20	1761	4126	2898^{a}	2928
Application techniques of O F (SA:SI%)	NS	NS	NS	NS
0:100	2040	4028	2361	2810
50:50	1846	4203	2606	2885
100:0	1699	4013	2504	2739
Mean	1861	4081	2490	2811
CV (%)	60.07	28.30	39.74	

NS = Not significant; *, ** significant at P ≤ 0.05 and P ≤ 0.01, respectively. Means with the same superscript letter within a column are not significantly different at P = 0.05 probability level. SA = Surface application and SI = Soil incorporation. **Source:** Taye *et al.* (2007).

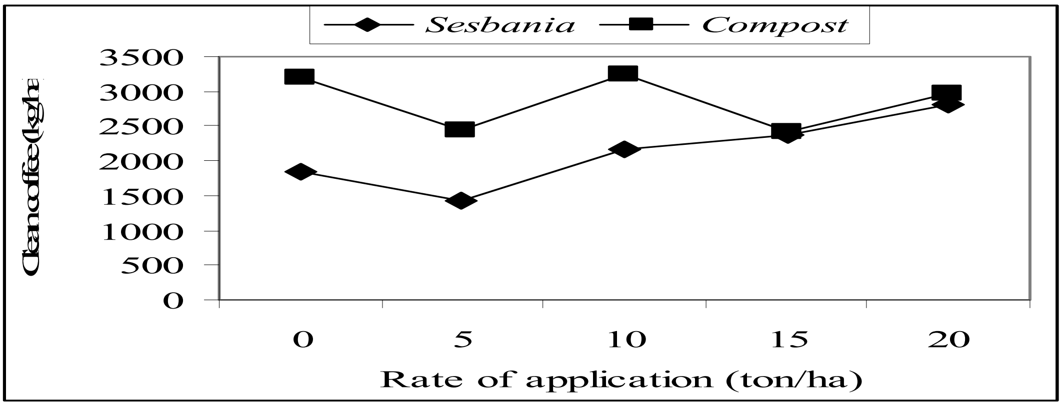

Figure 1. Clean coffee yield (kg ha^{-1}) as influenced by the application rate of organic fertilizer sources. **Source:** Taye *et al*. (2007).

Similarly, separate experiments were conducted to evaluate the integrated application of inorganic NP mineral fertilize + decomposed coffee husk and Desmodium cover crop + NP mineral fertilizer in promoting yield of coffee at Haru, Agaro and Jimma, respectively. The result showed that combined application of 50% of the recommended NP mineral fertilizer (RMF) (172 and 77 kg ha^{-1} NP, respectively) + 75% the recommended decomposed coffee husk (DCH) (10 ton ha^{-1} or 4 kg $tree^{-1}$ on dry weight base), 50% RMF + 50% DCH and *Desmodium* + RMF significantly ($P \leq 0.05$) resulted the highest mean clean coffee yield at Haru, Agaro and Jimma, respectively (Figure 2, Table 2 and 3). Generally, the result confirmed that integrated application of organic and inorganic fertilizer ensure optimum coffee yield, acceptable bean quality (Figure 3) and high economic return (Table 4) to intensify Arabica coffee production in in the study locations.

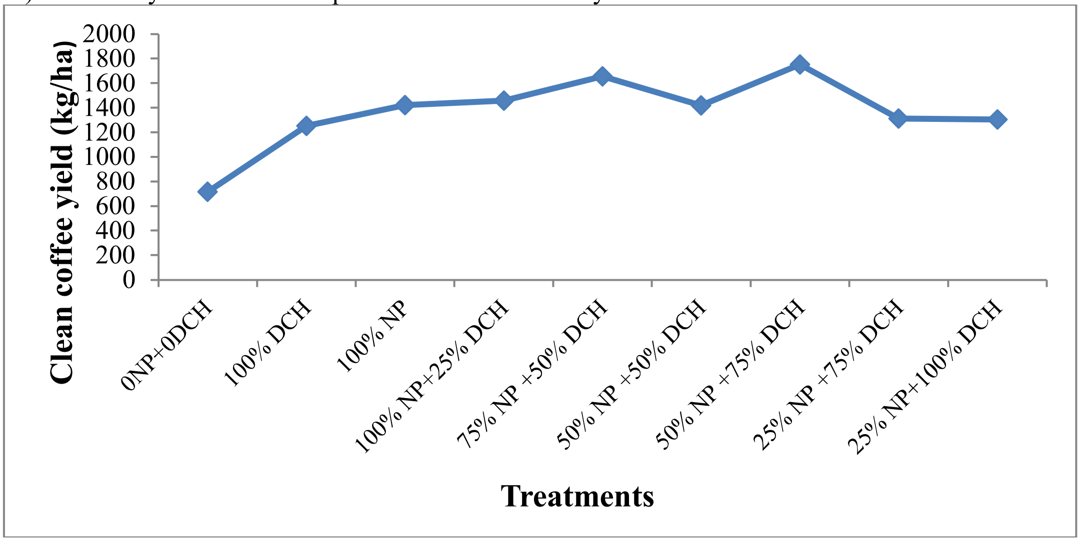

Figure 2. Effects of integrated nutrient management on clean coffee yield at Haru, west Wollega **Source**: Gemechu *et al*. (2021).

Table 2. Effect of integrated organic and inorganic fertilizers application on clean coffee yield at Agaro, southwest, Ethiopia

Treatment	Clean coffee yield (kg ha^{-1})					Over year mean
	2015/16	2016/17	2017/18	2018/19	2019/20	
100% DCH	1008.7b	1663.5cd	1665.4e	2433.3ab	2536.7ab	1861.5b
100% NP	1143.2ab	1725.7bcd	2049.7abcd	2176.7bc	2216.7b	1862.4b
100% NP + 25% DCH	1228.1a	2104.5a	2049.7de	2293.3bc	2303.3b	1943.5b
75% NP + 50%DCH	1118.4ab	1861.0abc	1788.0bcde	2376.7b	2380.0b	1924.4b
50% NP +50% DCH	1021.1b	1563.3d	1911.1a	2733.3a	2800.0a	2083.5a
50% NP + 75%DCH	800.7c	1232.1e	2299.8cde	2066.7cd	2150.0bc	1624.4cd
25% NP + 75%DCH	1235.7a	1956.4ab	1872.5bcde	2233.3bc	2133.3bc	1898.8b
25% NP + 100%DCH	1125.6ab	1774.4bcd	1935.4abc	1766.7de	1753.3cd	1711.4c
Control (without fertilizer)	757.4a	1693.5bcd	2136.9ab	1583.3e	1656.7d	1570..5d
LSD (0.05)	**199.9**	**266.7**	**275.1**	**307.4**	**410.1**	**126.9**
CV (%)	**11.01**	**8.91**	**8.03**	**8.13**	**10.71**	**9.55**

Key: - DCH = Decomposed coffee husk (10 ton ha^{-1} or 4 kg $tree^{-1}$ on dry weight base); Mean values followed by the same letter(s) with in a column are not statistically significant at P = 0.05 probability level. **Source**: Obsa et al., (2021)

Table 3. Effects of Desmodium and mineral fertilizer on clean coffee yield (kg ha^{-1}) at Jimma

Treatment	Cropping season				Over years mean clean coffee yield (kg ha^{-1})	% yield increase over the control
	2016/17	2017/18	2018/19	2019/20		
Control	520.3c	929.4b	590.4	354.3d	598.6b	-
D	673.0bc	960.2b	892.7	780.7c	826.6bb	38.01
RMF	1339.7a	1614.2a	918.5	1231.9ab	1276.1a	113.18
D + 25% MF	896.7bac	1028.5b	1079.2	1122.7bc	1031.8a	72.34
D + 50% RMF	1134.3ba	1495.3a	1204.5	913.4bc	1186.9a	98.28
D + 75% RMF	749.0bc	1269.4ba	770.4	1574.0a	1090.7a	82.21
F-test	*	*	**NS**	**	**	
SE(±)	**54.09**	**45.42**	**72.48**	**78.02**	**32.47**	
CV (%)	**33.7**	**20.6**	**44.1**	**20.20**	**16.87**	

NS, * and ** = Non significant and significant at 0.05 and 0.01 probability level, respectively. Means within a column followed by same letter(s) are not significantly different at 0.05 probability level. RMF[‡] = Recommended mineral fertilizer (172 and 63 kg ha^{-1} N and P, respectively) and D = *Desmodium*. **Source:** Anteneh *et al,* (2021)

Table 4. Partial budget and dominance analysis of Arabica coffee yield response as influenced by *Desmodium* and mineral fertilizer Jimma

Treatment	Unadjusted yield (kg ha^{-1})	Adjusted yield (kg ha^{-1})	Gross benefit (Birr ha^{-1})	Total variable cost	Net benefit (Birr ha^{-1})	MRR (%)
Control	598.6	538.7	35015.5	0	35015.5	0
Desmodium	826.6	743.9	48353.5	0	48353.5	0
RMF	1276.1	1148.5	74652.5	12708.6	61943.9	241.9
Desmodium + 25% of the RMF	1031.8	928.6	60359.0	3177.2	57181.8	277.9
Desmodium + 50% of the RMF	1186.9	1068.2	69422.0	6354.4	63067.6	185.3
Desmodium + 75% of the RMF	1090.7	981.6	63804.0	9531.6	54272.4	

32.00 Ethiopian Birr (ETB) = 1.00 US Dollar. Field prices of clean coffee bean, TSP and UREA valued with respective prices of 65.00, 13.50 and 12.68 ETB kg^{-1}. RMF = Recommended mineral fertilizer (172 and 63 kg ha^{-1} N and P, respectively). ND = Non dominated and D = Dominated. **Source:** Anteneh *et al,* (2021)

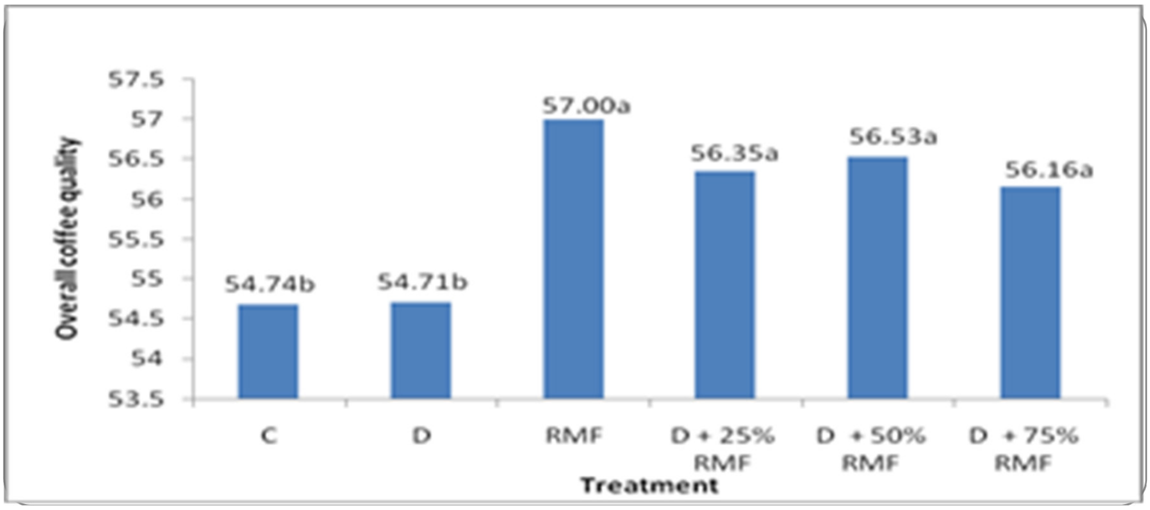

Figure 2. Effects of Desmodium and mineral fertilizer on overall bean quality. Bars capped with same letter are not significantly different at P = 0.01 probability level. C = Control, D = *Desmodium* and RMF = Recommended mineral fertilizer (172 and 63 kg ha^{-1} N and P, respectively). **Source:** Anteneh *et al*, (2021).

Conclusion

The present findings depict the potential use of locally available and cheap organic fertilizer sources as complements to mineral fertilizers for sustainable soil fertility amendment and promotion of organic coffee production in the country. Finally, investigation should continue in major coffee growing agro ecologies of the country to evaluate growth and yield response of coffee trees and row and cup quality of green coffee bean to varying levels of mineral fertilizers, compost and green manure cover crop and establish profitable levels of these agricultural inputs for sustainable production of the crop in the country.

References

Anteneh N. and Bikila T. 2021. Progress of Soil Fertility and Soil Health Management Research for Arabica Coffee Production in Ethiopia. *Plant.* 9(3): 70-80.

Anteneh N., Ewnetu T., Adugna B., Obsa A. and Alemseged Y.2022. Effect of Integrated Application of Mineral Fertilizer and Green Manure on Soil Chemical Properties, Coffee Yield and Bean Quality, and Weed Control in Jimma, Southwest Ethiopia. J . Biol. Chem. Research. 39(1), 62-77**.**

Gemechu C. and Tesfaye W. 2021. Effect of Integrated Use of Coffee Husk Compost and NPS Fertilizer on Soil Physicochemical Properties and Yield of Coffee (Coffea arabica L.) at Haru, Ethiopia. Agriculture, Forestry and Fisheries. 10(6), 233-244.

Gemechu Ch., Tolera A. and Tesfaye W.2021. Effect of Coffee Husk Compost and NPS Fertilizer Rates on Growth and Yield of Coffee (Coffea arabica L.) at Haru Research Sub-canter, Western Ethiopia. American Journal of Bioscience and Bioengineering. 9(3), 81-87.

Obsa A., Mohammed K., Ewnetu T. and Meseret N. 2021. Effect of Organic and Inorganic Fertilizers on Agronomic Growth and Soil Properties of Coffee (Coffea arabica L.) at Jimma, Southwestern Ethiopia. Int.J.Curr.Res.Aca.Rev. 9(01), 86-94.

Paulos Dubale. 1994. Ecology and soils of the major coffee growing regions of Ethiopia. In: Paulos Dubale (ed.), Mineral Fertilization of Coffee in Ethiopia, Institute of Agricultural Research, Addis Ababa, Ethiopia.

Solomon, E. Tesfu, K. And Tesfaye, Y. 2008. Inorganic fertilizer management and coffee production. In: Coffee Diversity and knowledge (Girma, A; Bayetta, B; Tesfaye, S; Endale, T. and Taye, K. Edds). Proceedings of a National work shop four decades of coffee research and development in Ethiopia. Pp. 217-225.

Taye Kufa, Endale Taye, Alemseged Yilma, Tesfaye Shimber and Anteneh Nestere. 2007. The use of *Sesbania sesban* and coffee compost as complements to mineral fertilizer for coffee production in southwest Ethiopia.

Taye K. and Tesfaye Sh. 2001. Organic coffee production: hope for small scale farmers in Ethiopia. Proceedings of the 19th International Scientific Colloquium on coffee, Trieste, 14-18 May 2001. ASIC, Paris. CD-ROM.

Van Der Vossen, H. A. M. 2004. Organic coffee production: Myth or reality-a review. Proceedings of the 20th International Scientific Colloquium on coffee, 11th-15th October, 2004. ASIC, Bangalore, India. CD-ROM.

Wintgens J. N. 2004. Coffee: Growing, Processing, Sustainable Production. A guide for growers, traders, and researchers. WILEY-VCH Verlag GmbH and Co.KGaA, Weinheim, Germany.