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The Effect of Integrated Weed Management Methods on Growth and Yields of Arabica Coffee at Awada, Southern Ethiopia

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Abstract: *Coffee production in Ethiopia is ancient practice; the plant is now grown in various parts of the world; in Ethiopia around 3% of the global coffee market. Coffee is important to the economy of Ethiopia. Therefore the objective of the present study was to determine the appropriate weed management method for optimum growth and yield of coffee. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. About 16 coffee trees per plot spacing between plot 2mx2m and spacing between blocks 4m. It includes two times slashing, three times slashing + mulching ,one time slashing followed by herbicide applications, herbicides +haricot bean intercropping + hand weeding, herbicides + soy bean intercropping + hand weeding, weed free all year round. The recently released variety Angefa (1377) and roundup herbicide were used. The total fresh cherry (gm/tree) and buni cherry were collected, both total fresh cherry and buni were converted into clean coffee in qt/ha as final green bean yields in each harvesting season. The experimental data were analyzed using SAS software. Difference between means was assessed at 5% probability level. There was significant difference between the tested treatments in green bean yields of coffee per hectare for the means of overall five years seasons. Coffee bean yields in the average means of overall five years was obtained sequentially, 1slashing followed by herbicide ,herbicide + haricot bean intercropping +hand weeding, herbicide + soybean intercropping + hand weeding, weed free all year round, 3 times slashing + mulching and 2 times slashing. Different weed species that were identified found in the experimental site.*

Keywords: *Coffee* Integrated * weed management* green bean Yield*

1. Introduction

Coffee production in Ethiopia is a ancient practice, Ethiopia is where *Coffea arabica* plant originates. The plant is now grown in various parts of the world; in Ethiopia around 3% of the global coffee market. Coffee is important to the economy of Ethiopia; around 60% of foreign income comes from coffee, with an estimated 15 million of the population relying on some aspect of coffee production for their income. (Thomas et al 2004). In Ethiopia is the only center of origin and diversity of Arabica coffee (Anthony et al.2001). Arabica coffee is cultivated in most parts of the tropics, accounting for 80% of the world coffee market, and about 70% of the production (Woldemariam et al. 2002). Coffee plays an important role in the world economy. It is the second most valuable exported commodity on earth after oil (Pendergrast, 2010). More than 80 countries in the developing world depend on coffee as a major source of their foreign currency earnings. For instance, coffee generated about US$13 billion in 1983 (Cannell ,1983), and until 2000, it contributed to 80% of Burundi's, 55% of Uganda's and 30% of Nicaragua's hard currency earnings from exported yields (Oxfarm, 2002).

The Ethiopian Economy is highly dependent on coffee it contributes around 25% of the country's foreign exchange income. Its cultivation, processing, trading, transportation and marketing provide employment for millions of people (EEA (Ethiopian Economic Association), 2001). It is also the defining feature of the national culture and identity, with 44% of the production consumed domestically (Mayne, et al. 2002).

Coffee related enterprises are a major economic driver in the regions where it is cultivated in Brazil and elsewhere as it generates jobs, provide income and stimulate development. However, for greater coffee agribusiness competitiveness, it is necessary to meet social-environmental requirements expected by international consumers (Araujo-Junior et al., 2008).

Coffee planting in rows used as weed management systems and it helps to minimizing soil degradation by erosion (Carvalho et al., 2007), reducing compaction and improving soil workability and machines trafficability (Araujo-Junior et al., 2008, 2011).

Coffee plantations intercropping system is commonly used by farmers. By inserting an economic crop in between coffee rows, soil erosion can be reduced and the economic return per area unit raised, through the production of two crops instead of coffee only and the reduced costs in coffee production, mainly through reductions in weed management operations (Melles et al., 1985).

Sustainability practices also apply in weed management in influencing environmental quality and crop yield. Weeds of coffee plantations controlled efficiency and reasonableness without cause negative interference in the development, growth and yield of crops (Ronchi & Silva 2006),

Amongst all agronomic practices involved in coffee production, the weed management strategy/system is one of the most intensive in coffee bean production and critical to eco-friendly management ranging from two to five operations per year. The adopted weed management system in coffee plantations can have major effects on the soil environment, affecting physical, chemical and biological conditions, resulting in changes soil compressive behavior and load bearing capacity affecting yield potential in coffee plantations (AraujoJunior et al., 2008; 2011).

Weed competition, coffee growth, yield, and quality are seriously decreased and weed control is one of the largest tasks, which entails high cost (Ronchi & Silva, 2006; Silva & Ronchi, 2008). Crop yield losses due to weed competition varied from 24% to 92% (Lemes et al., 2010). In Ethiopia, the warm wet and humid conditions prevailing in the coffee growing areas of southern Ethiopia not only result diverse weed flora ranging from soft annuals to extremely difficult to control perennials but also encourage the continuous growth of weeds all year round. According to (Tadesse, 1998) yield loss as a result of weed competition can reach as high as 65 % to complete crop failure depending on the type of weeds, coffee growth stage and the prevailing growth conditions. Any weed control practice should aim at marinating or improving soil structure, should be adaptable to local conditions and should not encourage the colonization of a particular weed(s). Therefore, the objective of the present study was to determine the appropriate weed management method for optimum growth and yield of coffee.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted at Awada Research Sub-center experimental field during the period 2012-2016 Southern Ethiopia. It is located 6^{o} 3’N Latitude and 38^{o} E Longitude with an altitude of 1750 meters above sea level with the respective annual mean minimum and maximum rainfall of 858.1 mm and 1676.3 mm respectively. The annual average minimum and maximum air temperatures are 11.00 C and 28.4 0 C, respectively. The soil is Eutric Nitosol and Chromotic Cambisols that are highly suitable for coffee production (IAR, 1996).

2.2. Application of Treatments

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. About 16 coffee trees per plot spacing between plot 2mx2m and spacing between blocks 4m. It includes two times slashing, three times slashing + mulching ,one time slashing followed by herbicide applications, herbicides +haricot bean intercropping + hand weeding, herbicides + soy bean intercropping + hand weeding, weed free all year round. The recently released variety Angefa(1377) and roundup herbicide were used .

The types of weed species were recorded as broad leaf weeds and grass weeds in the experimental field and the identification of species was done by visual observation and by the aid of weed identification guides. The weed density was determined by counting the number of weeds in the 50cm*50cm quadrate before treatment applications.

The canopy diameter (cm) of the coffee tree was determined by measuring the canopy length in two opposite directions (N.S&W.E) and the mean average value of the two directions was recorded as a canopy diameter of the each treatment. The size of stem girth was determined by measuring the thickness of the stem at the ground level using caliper. The number of primary branches was determined by counting the number of primary branches starting from the ground surface up to the tip of the coffee plant. The length of the longest primary branch was determined by measuring the longest primary branch by selecting the longest primary branch from the others in cm. The height of coffee plant was determined by measuring the height of main stem (trunk) starting from the ground surface to the tip of the plant. The number of nodes was determined by counting the number of nodes on the main stem and longest primary branch starting from the ground level to the tip of the plant and from the first node of primary branch to the tip of the primary branch, respectively. The total fresh cherry (gm/tree) and buni cherry were collected, both total fresh cherry and buni were converted into clean coffee in qt/ha as final green bean yields in each harvesting season.

2.3. Data Analysis

The experimental data were analyzed using by Gomez and Gomez (1984) using SAS version 9.0 computer software program (SAS, 2002). Difference between means was assessed at 5 % probability level.

3. Result and Discussion

3.1. Coffee Bean Yield

The result of ANOVA for average green bean yields per hectare for five years (2012-2016) is presented in Table 1. The significant differences were not observed ($P<0.05$) between the tested treatments for the average green bean yields of coffee per hectare in each five years harvesting seasons. But, there was significant difference between the tested treatments in green bean yields of coffee per hectare for the means of overall five years seasons. In the present study it is clearly observed that all single weed management treatments gave low yield compared with those treatments with two or more weed managements in combination.

This suggests that single weed management approach would not be adequate except weed free all year condition where various weed species with different growth habit and physiological characteristics predominate. Similarly in Kenya clean weeding nearly doubled the yields as compared to unwedded coffee (Mburu et al, 1990). Control of weed not only quality of coffee it also used for protecting soil erosion. Similarly Cunha & Alvarenga (2003) found that soil green cover with forage peanut in the inter rows in the coffee crops formed a dense undergrowth vegetation, reducing weed infestation, with weeding savings and increased protection against the soil erosion.

Table1. *ANOVA of effect of integrated weed management method yield data*

Coffee green bean yield per years	Mean Squares for different sources of variation and their significance			
	Replication (df=2)	Treatment(df=5)	Error(df=10)	CV
Yld12	1.11ns	0.27ns	0.39	42.05
Yld13	4.62ns	34.26ns	17.22	62.1
Yld14	8.68ns	12.67ns	4.82	31.21
Yld15	38.41ns	56.91ns	27.92	25.34
Yld16	30.95ns	17.28ns	23.47	38.22
Yld mean	0.57ns	10.87*	2.27	15.45

*ns = not significant, * and ** significant at 0.05 and 0.01 level of probability, respectively. d.f = degree of freedom, CV = coefficient of variation, Yld12, Yld13, Yld14, Yld15, Yld16 and Yld mean are average green bean yield quintal per hectares for 2012,2013,2014,2015,2016 and mean yield over the five years, respectively.*

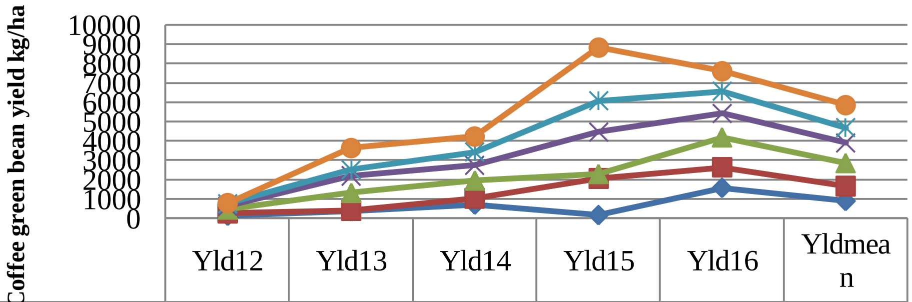
In all five cropping years coffee yields were not found significantly ($p>0.05$) vary on the tested treatments. On the other side, the average mean of overall years consistently confirm that there were significant variations of coffee green bean yields (Table2 and figure 1). Hence, the coffee bean yields in the average means of overall five years in sequential (high to low) order was obtained at treatment weed free all year round , 1slashing followed by herbicide ,herbicide + haricot bean intercropping

+hand weeding, herbicide + soybean intercropping + hand weeding, 3 times slashing + mulching and 2 times slashing (Table 2 and figure 1).

Table2. *Effect of integrated weed management method on mean coffee bean yield for five consecutive years at Awada*

Treatments	Mean yield of clean coffee over years (qt/ha)					
	Yld12	Yld13	Yld14	Yld15	Yld16	Yld mean
2 times slashing	1.36	3.65	7.13	16.90	15.72	8.95bcd
3 times slashing +mulching	1.26	4.20	3.21	18.79	10.49	7.59d
1slashing followed herbicide	1.97	9.09	9.17	24.10	15.53	11.97a
Herbicide + haricot bean intercropping +hand weeding	1.74	8.79	8.02	21.68	12.37	10.52abc
Herbicide + Soy bean intercropping +hand weeding	1.26	3.24	6.72	16.27	11.55	7.81cd
Weed free all year	1.30	11.12	7.96	27.39	10.39	11.63ab
LSD(0.05)	ns	ns	ns	ns	ns	2.74

The clean weeding gave high yield for four consecutive years (figure 1) but there after yield tend to decline, this might be because in the clean weeding treatment although weed growth and competition is avoided as a result of clean weeding all round year, the ground was left open and exposed for serious erosion that at a certain period all available essential nutrients might have been lost through erosion leading to a gradual yield reduction. Hence the advantage of clean weeding will be only for few years followed by sharp decline of yield. A similar work was reported by Lumbanraja et al (2004) in Indonesia that after four years of investigation, Total C, Total N, available P and exchangeable Mg. were significantly reduced in coffee with no cover compared with coffee covered under Paspalum conjugatum. In Kenya clean weeding nearly doubled the yields as compared to unwedded coffee (Mburu et al, 1990). In this study it is clearly observed that in all five cropping seasons the coffee bean yields were not significantly different among the tested treatments, but there were significant differences among the tested treatments in overall average means for five years showed that in Awada, Sidama conditions there is a recommended improved weed management for coffee green bean yields. In this findings, the lowest yields was obtained in single weed managements like in treatment T2 (2 times slashing only) which was not recommended as the integrated weed managements for coffee green bean yields under Sidama Southern Ethiopia.



	Yld12	Yld13	Yld14	Yld15	Yld16	Yldmean
Weed free all year	13	1112	796	2739	1039	1163
Herbicide + haricot bean intercropping +hand weeding	126	324	672	1627	1155	781
Herbicide + haricot bean intercropping	174	879	802	2168	1237	1052
1slashing followed herbicide	197	909	917	241	1553	1197
3 times slashing	126	42	321	1879	1049	759
2 times slashing	136	365	713	169	1572	895

Figure1. *Effect of integrated weed management method on mean coffee bean yield for five consecutive years at Awada*

3.2. Weed Species and Density

The types of weed species that were found in the experimental site includes;- Digitaria spp, Cyprus spp. ,Biden's pilosa, Plantago lanceolata, Medicago spp, Galinsoga paruiflora, Aegopodium podagraria, convolvolus spp, Elosina indica Aquatic weeds, cynodon spp, commelina spp, Amaranthus spp, erograstics spp. Cyperus spp. According to Tadesse (1998) these weeds are highly competitive that at worst conditions coffee bushes can be completely smothered and yield reduction can reach as high as total crop failure. According to Muleta *et al.* (2007), whenever, there is dense population, the aggressive understory weeds are either totally absent or rarely encountered in coffee plantation. Hand weeding, mulching, intercropping with stable food and cash crops are among the most agronomic practices to overcome weed problems in organic coffee production (Mekuria *et al*., 2004). Goetz *et al*. (2004), reported fallow as one of the cultural weed control methods the efficiency against weed control depends on the duration of the fallow period. According to Aguilar *et al.* (2003), slashing also helps to suppress aggressive weeds and increases coffee vigor. Broad leaf and grass weeds were found in each treatment and the sample of weed populations were also taken from each treatment. The highest weed populations of broad leaf and grass weeds were found in treatment T2 and T1, respectively in 2015 and the lowest weed populations of broad leaf and grass weeds were found in treatment T6 and T3,T4 and T5 in 2012 and 2013 (table 3),respectively.

Table3. *Mean of Sampled of weed density of the effect of integrated weed management methods*

Treat ments	sample of weed density in each treatment applications (50cm*50cm)										types of weed species in the experimental site
	2012		2013		2014		2015		2016		Digitaria spp,Cyprus spp. Bidens pilosa, Plantago lanceolata, Medicago spp,Galinsoga paruiflora,Aegopodium podagraria, convolvulus spp, Elosina indicaAquatic weeds,cynodon spp, commelina spp,Amaranthus spp,erograstics spp. Cyperus spp.
	broad leaf	grass weeds	broad leaf	grass weeds	broad leaf	grass weeds	broad leaf	grass weeds	broad leaf	gras weeds	
1	12	58	38	22	33	69.0	118.0	163.0	23.0	25.0	
2	19	44	47	8	35	31.0	215.0	86.0	20.0	32.0	
3	5	28	64	5	72	14.0	146.0	97.0	19.0	39.0	
4	14	28	41	5	44	19.0	78.0	95.0	47.0	26.0	
5	16	22	41	5	45	20.0	144.0	74.0	32.0	22.0	
6	1	18	33	9	28	12.0	110.0	82.0	20.0	32.0	

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