academicresearchJournals

Vol. 5(4), pp. 313-319, July 2017
DOI: 10.14662/ARJASR2017.030

ISSN: 2360-7874
http://www.academicresearchjournals.org/ARJASR/Index.htm

Academic Research Journal of Agricultural Science and Research

Full Length Research

Effects of planting density and number vertical on yield and yield component of south Ethiopia coffee selections at Awada, Sidama zone, Southern Ethiopia

[1*]Ashenafi Nigussie, [2] Adane Adugna, [3]Leta Ajema, [3] Tesfaye Shimber and [4]Endale Taye

[1, 2, 3,] Ethiopia Institute of Agricultural Research, Wondo Genet Agriculture Research Center P.O.Box 198 Shashemene Ethiopia

Corresponding Author's email: nigussie.ashenafi@yahoo.com

Accepted 15 May 2017

A field experiment was conducted at Awada Agriculture Research Sub-center experimental site in two sets between 2005 and 2015 having two promising improved south Ethiopian coffee selections with distinct canopy class: open type (13/77) and compact type (85/238) to determine appropriate plant density and number of verticals for enhanced yield and yield component. Three levels of spacing (2.50 m x 2.50 m, 2.00 m x 2.00 m and 1.50 m x 1.50 m) and three vertical or bearing head number (one, two and free growth as farmers practice) were used as treatments and laid out in a randomized complete block design (RCBD) with three replications. Analysis of variance revealed that; clean coffee yield significantly influenced by different spacing level; highest and lowest clean coffee yield were obtained at 4444 trees/ha (Sp3) and 1600 coffee trees/ha (SP1) planting density, respectively. Regardless of number of vertical, except pooled mean analysis in most harvesting seasons clean coffee yield significantly influenced by different number of verticals. The combined analysis of variance also revealed highly significant yield variations among crop seasons and showed interactions effect with spacing and number of verticals. Moreover, open type coffee variety was showed interaction effect among spacing by number of verticals but compact type coffee variety not yet influenced by interaction effect. Generally, these finding suggest that close spacing with their required number of verticals significantly promoted the yield responses of Arabica coffee cultivars under two contrasting coffee varieties. Therefore, 1.5m X 1.5m (SP3) spacing with single stem (V1), and 1.5m X 1.5m (SP3) spacing with multiple stems (V2) treatments combinations were recommended for open and compact type coffee varieties to enhance yield and yield components, respectively.

Key words: - Bearing heads, Coffee selections, Number vertical and planting density

Cite this article as: Nigussie A, Adugna A, Ajema L, Shimber T, Taye E (2017). Effects of planting density and number vertical on yield and yield component of south Ethiopia coffee selections at Awada, Sidama zone, Southern Ethiopia. Acad. Res. J. Agri. Sci. Res. 5(4): 313-319

INTRODUCTION

After petroleum, coffee is the most valuable traded commodity worldwide, with global retail sales estimated to be US$ 90 billion. Brazil is the largest world's coffee producer, followed by Vietnam and Colombia. About 70% of the world crop is grown on smallholdings smaller than 10 ha, and hence it is often a family business that provides maintenance for over 25 million people worldwide. Among some 100 species of the Coffea genus (Davies et al., 2006), only C. arabica L. (arabica coffee) and C. canephora Pierre ex A. Froehner (robusta coffee) are economically important worldwide, with these species being responsible for about 99% of world bean production. Presently, Arabica coffee accounts for about 80 % of the world's coffee production (Coffee Research Institute, 2006a).

The primary center of origin and genetic diversity of *Coffea arabica* is Ethiopia, which is recognized as its oldest exporter in the world (Waller *et al*., 2007). It is cultivated within the elevation range of 1,000 to 2,100 meters above sea level (m.a.s.l.) where the average yearly precipitation is 1,500 to 2,000 mm. These offer the characteristic features for its sustainable cultivation as semi-wild or spontaneous and naturalized coffee plantation (Workafes and Kassu, 2000).

Coffee production is important to the Ethiopian economy with about 15 million people directly or indirectly deriving their livelihoods from coffee by generating about 25% of total export earnings. Thus, the majority of coffee farmers in the country practice the old traditional cropping patterns, where the limited available farmlands remain less efficiently utilized. In addition to this, several production constraints were faced, among which the most important could be the heavy dependence on unimproved coffee cultivars produced under poor management practices, including the low-density coffee planting patterns and limited number of bearing heads.

Earlier Arabica coffee plantations were established at fewer than 2000 trees ha-1 (Carr, 2001), or even below 1000 trees ha-1 as for the multi-stemmed conilon coffee in Brazil. However, several reports have indicated that coffee may be more suited for high-density plantings; indeed the productivity of dense plantings is generally much greater than that of traditional plantings (DaMatta, 2004a). The compact plant stature and disease resistance of some modern coffee cultivars have allowed closer spacing, resulting in almost complete ground coverage and better uptake of available soil nutrients by denser rooting (van der Vossen, 2005).

Moreover, in dense plantings, coffee roots develop deeper so that they take up water and nutrients from lower soil horizons (Cassidy and Kumar, 1984). Although planting density systems may increase production per unit area increases along with population density up to a certain level. By contrast, the yield per tree usually decreases with closer planting, even though it may be quite variable among environmental sites (Kuguru et al., 1978). The reduction in the fruit-bearing capacity of the trees with close spacing does not appear to be caused by a decrease in fruit setting (Kumar, 1979a), nor by a reduction in the number or length of plagiotropic branches (DaMatta, 2007). It may be attributed to the effect of shading on the number of fruits per node and possibly the number of fruit-bearing nodes, as already pointed out.

Singh (2002) also explained that establishment of optimum population per unit area of the field is essential to get maximum yield. Under conditions of sufficient soil moisture and nutrients, higher population is necessary to utilize all the growth factors efficiently. The level of plant population should be such that maximum solar radiation is utilized. The full yield potential of an individual plant is fully exploited when sown at wider spacing. Yield per plant decreases gradually as plant population per unit area increases. However, the yield per unit area is increased due to efficient utilization of growth factors.

The physiological aspects and yield benefits of high tree population have been documented in Ethiopia (Yilma, 1985) and elsewhere in the major coffee growing countries (Browning and Fisher, 1976; Kumar, 1978; Wringley, 1988). With this concern many research attempts have been made to generate technologies which help to attain high productivity per unit area by taking into account different crop intensification practices under distinct coffee growing environments (Yacob *et al*., 1996). The results, revealed consistently increased yield level with increasing population densities from 4,000 to 6,000 tree ha^{-1} and number of bearing heads (IAR, 1996; Yacob *et al*., 1996). Similar findings showed better vegetative growth performances of two distinct coffee cultivars planted using a high density planting system at Jima (Taye, 1996). Maximum coffee yield due to increasing number of bearing heads has been documented by Yacob *et al*. (1993).Though there is enormous potential of genetic and environmental components in most coffee growing areas in Ethiopia, but the benefits of plant population density and bearing heads not fully exploited.

However, optimal planting density for Arabica coffee through spacing and number of bearing heads depends on several factors including cultivars, availability of water and nutrients, pruning systems, cropping patterns and air evaporative demand and temperature. Having this justification the present study was initiated with following objective; to determine appropriate plant density and number of verticals for enhanced yield and yield component of south Ethiopia coffee selections.

MATERIAL AND METHOD

An experiment consisting of two promising improved south Ethiopian coffee selections with distinct canopy class: open type (13/77) and compact type (85/238) was conducted in two sets (Set I open type and Set II compact type) (between 2005 and 2015) at Awada Agriculture Research Sub-center experimental site, south Ethiopia. Awada Agricultural Research Sub-center is situated in the Tepid to cool semi arid mid highland agro-ecology. It is located at about 315 km south of Addis Ababa at $6^{0}3'$ N of latitude and 38^{0} E of longitude at an altitude of about 1740m a.s.l nearby Yirgalem town. The area has a semi-bimodal rainfall distribution characterized by double wet and dry seasons with an average precipitation of 1342 mm per annum.

Factorial combinations of three levels of spacing (1.50 m x 1.50 m, 2.00 m x 2.00 m and 2.50 m x 2.50 m) and three vertical or bearing head number (one, two and free growth as farmers practice) were laid out in a randomized complete block design (RCBD) with three replications. Seedlings of two coffee canopy classes were field transplanted in July 2005 GC at the respective spacing and, except those in free growth treatment; the plants were trained either as one head (single stem) or in a multiple stem system. All routine field management activities were uniformly and timely applied as per the recommendations.

In both set I and Set II, sixteen representative trees 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 primary branch, number of primary branch, number of nodes, inter node length and clean coffee yield.

The collected data were statistically analyzed using SAS computer soft ware version 9.0 English and the significance difference between any two treatments means were tested by least significant difference (LSD) at 5% probability level. It must be noted that data for yield measured for the seven years were pooled and analyzed to determine the year effect.

RESULT AND DISCUSSION

Growth indicating parameters

In this particular study plant height, height up to first primary branch, number of primary branch per plans, number of nods per plant and inter node length were not significantly influenced by different level of spacing and their interaction. However, plant height, number of nods per plant and inter node length were significantly ($p<0.05$) influenced by number of vertical or bearing heads in open coffee variety, where as other parameters not significantly influenced by number of verticals and their interaction. Table 1

Yield and yield component

SET I (Open type coffee variety)

According to the analysis of variance, clean coffee yield significantly influenced by different spacing level (except 2014/15 harvesting season). In most harvesting seasons the highest and lowest clean coffee yield were obtained at 4444 trees/ha (Sp3) followed by 2500 trees/ha (SP2) and 1600 coffee trees/ha (SP1) planting density (table 2), respectively. Similarly the pooled mean analysis result showed that, there was a significant variation among different type of spacing, highest (21.52 Q ha^{-1}) and lowest (14.69 Q ha^{-1}) clean coffee yield were recorded at SP3 and SP1, respectively. While population density increased from 1600 trees/ha in Sp1 to 4444 trees/ha in Sp3 mean clean coffee yield of individual trees consistently decreased, at the same time as yield ha–1 increased with increasing population density that means yield was highly associated with plant population density up to certain level. This finding as par with Taye, K., *et al*., 2001 who reported that production per unit area increased along with plant population density increased.

By contrast, the yield per tree usually decreases with closer planting, even though it may be quite variable among environmental sites (Kuguru et al., 1978). Increase in yield per trees at wider spacing is not surprising because lower plant density (in case of wider spacing's) exerts lesser interplant competition for space as well as growth factors. An increase in biological yield with increasing plant population density was also reported by Nekonam and Razmjoo, 2007 and Najafi and Moghadam, 2002 on *Plantago ovata*. According to the study made by Board et al., (1990), narrow-row spacing at normal and high densities had significantly higher yield than wide rows.

In the same way, except pooled mean analysis in all harvesting seasons clean coffee yield significantly influenced by different bearing heads or number of verticals; highest and lowest clean coffee yield were recorded at single and multiple stem, respectively. In addition to that, clean coffee yield significantly ($p<0.05$) influenced by their interaction, highest clean coffee yield was obtained at 4444 trees per ha (SP3) interact with single stem (V1) 23.31 Q ha^{-1}.

SET II (compact type coffee variety)

Alike open type coffee variety, clean coffee yield significantly ($P<0.05$) influenced by different spacing level. In most harvesting seasons, highest and lowest clean coffee yield were recorded at 4444 trees/ha (Sp3) followed by 2500 trees/ha (SP2) and 1600 coffee trees/ha (SP1) planting density (table 3), respectively. Similarly, the pooled mean analysis result showed, clean

Table 1: Factor associated with growth and productivity of individual coffee trees as affected by spacing and number of verticals

Treatments	Plant height		Height up to 1st primary branch		Number of primary branch		Number of Nodes		Inter node length	
	Open	Compact	Open	Compact	Open	Compact	Open	Compact	Open	Compact
SP1	111.36	103.86	30.29	27.44	29.12	27.91	12.48	12.93	28.68	24.03
SP2	109.74	102.74	29.45	27.20	27.71	30.71	12.49	12.81	29.27	22.82
SP3	110.50	101.98	29.68	26.83	30.06	27.65	12.29	12.42	26.83	25.29
LSD at 0.05	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
V1	116.59[a]	101.83	31.35	27.42	27.54	27.89	13.12[a]	12.81	25.75[b]	23.39
V2	104.29[b]	104.02	28.94	27.46	31.12	28.43	11.45[b]	12.47	32.51[a]	23.62
V3	110.73[ab]	102.74	29.13	26.59	28.23	29.94	12.88[a]	12.88	26.52[b]	25.13
LSD at 0.05	7.93	ns	ns	ns	ns	ns	1.35	ns	2.81	ns
Sp*ver	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV	7.18	4.96	6.44	7.73	15.93	12.98	10.92	6.07	9.94	10.49

SP1 = 2.5m X 2.5m spacing (1600 coffee trees/ha), SP2 = 2m X 2m (2500 tree/ha), SP3 = 1.5m X 1.5m (4444 trees/ha), V1 = one vertical growth allowed (single stem), V2 = two vertical growth (two stem), V3 = free growth (several verticals)

Table 2: Clean coffee yields (Q ha^{-1}) as influenced by spacing and number of verticals at Awada in south Ethiopia SET I.

Treatments	**2010/11**	**2011/12**	**2012/13**	**2013/14**	**2014/15**	**Pooled mean**
SP1	2.18[b]	13.88c	25.19[b]	12.04[b]	20.15	14.69[b]
SP2	2.97[b]	18.03[b]	34.83[a]	14.07[b]	28.59	19.69[a]
SP3	4.98[a]	27.89[a]	31.42[a]	22.42[a]	20.89	21.52[a]
LSD at 0.05	0.97	3.72	6.04	7.03	ns	2.60
V1	4.04 [a]	23.49[a]	37.31[a]	22.82[a]	18.16[b]	19.29
V2	1.93[b]	12.98[b]	23.39[c]	11.16[b]	27.78[a]	18.23
V3	4.15 [a]	23.33[a]	30.74[b]	14.55[b]	23.69[ab]	18.38
LSD at 0.05	0.98	3.72	6.04	7.03	2.81	ns
Sp*Ver	**	*	ns	ns	ns	*
CV	28.85	18.65	19.83	43.47	41.20	33.3

SP1 = 2.5m X 2.5m spacing (1600 coffee trees/ha), SP2 = 2m X 2m (2500 tree/ha), SP3 = 1.5m X 1.5m (4444 trees/ha), V1 = one vertical growth allowed (single stem), V2 = two vertical growth (two stem), V3 = free growth (several verticals)

Table 3: Clean coffee yield (Q ha^{-1}) as influenced by the interaction effects of spacing and number of verticals.

Treatments	**Number of vertical**		
Spacing level	V1	V2	VE
Sp1	14.46[ab]	14.04[ab]	115.57[ab]
Sp2	17.37[ab]	18.72[ab]	22.99[a]
Sp3	23.31[a]	21.93[a]	19.31[ab]
LSD		*	
CV%		33.3	

coffee yield significantly affected by population density. This research finding in line with other authors Browning and Fisher, 1976; Mitchell, 1976; Kumar, 1978 who indicated the improved efficient utilization of closely spaced coffee trees in relation to the use of the major external yield limiting variables such as light, water and plant nutrients.

According to Taye K., *et al*., (2001), it is clear that too narrow and too wide spacing do affect yields through competition (for nutrients, moisture, air, radiation, etc)

Table 4: Clean coffee yields (Q ha^{-1}) as influenced by spacing and number of verticals at Awada in south Ethiopia SET II

Treatments	2010/11	2011/12	2012/13	2013/14	2014/15	Pooled mean
SP1	2.19^{b}	8.53^{b}	25.52^{b}	8.15^{b}	12.22^{b}	11.32^{c}
SP2	2.86^{b}	11.19^{b}	34.67^{a}	11.21^{ab}	16.53^{a}	15.23^{b}
SP3	4.19^{a}	19.84^{a}	34.35^{a}	15.17^{a}	14.68^{ab}	17.71^{a}
LSD at 0.05	0.73	3.6	6.12	4.59	3.29	1.83
V1	3.13^{ab}	13.44^{a}	32.00	8.04^{b}	15.05	14.35
V2	2.57^{b}	12.54^{b}	32.02	13.44^{a}	15.12	15.08
V3	3.53^{a}	13.57^{a}	30.52	13.05^{a}	13.25	14.82
LSD at 0.05	0.73	3.6	ns	4.59	ns	ns
Sp*Ver	*	ns	*	ns	*	ns
CV	23.75	27.34	19.43	39.85	22.74	29.60

SP1 = 2.5m X 2.5m spacing (1600 coffee trees/ha), SP2 = 2m X 2m (2500 tree/ha), SP3 = 1.5m X 1.5m (4444 trees/ha), V1 = one vertical growth allowed (single stem), V2 = two vertical growth (two stem), V3 = free growth (several verticals).

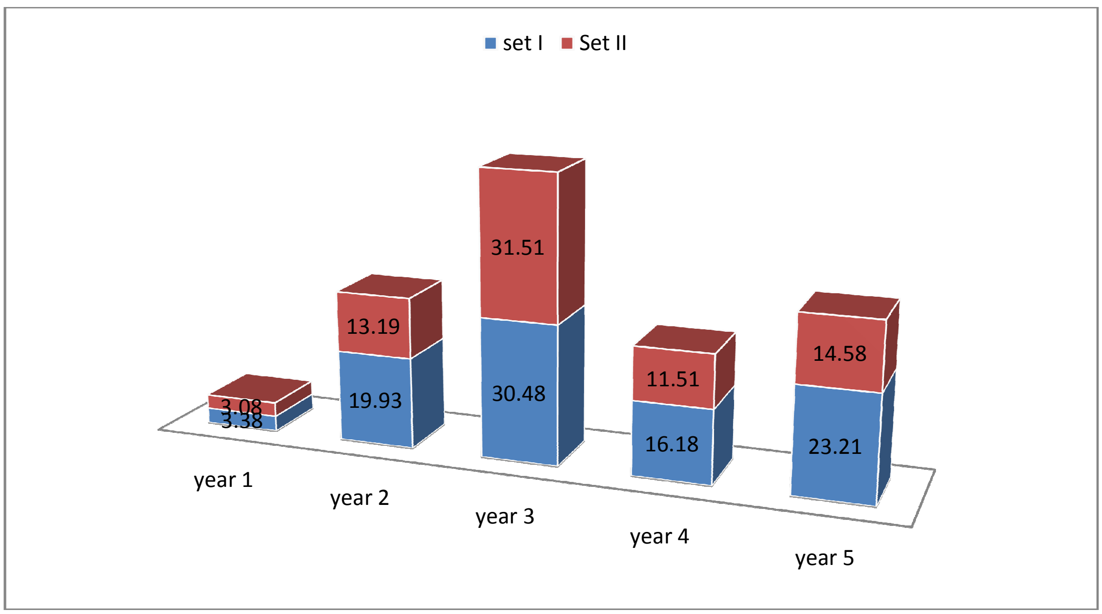

Figure 1. Clean Coffee yield (Q ha-1) as affected by Cropping seasons

and in efficient utilization of the growth factors, respectively. The low yield level obtained at the lowest populations could partly be attributable to the reduced efficiency of coffee trees in terms of exploiting natural resources under such micro-climates (Gathara and Kiara, 1985; Terene *et al*., 1991). Population density is also dependant on the moisture availability and nutrient status of the soil.

In spite of number of verticals or bearing heads, except 2012/13 and 2014/15 harvesting seasons, other showed significance difference in clean coffee yield. The highest and lowest clean coffee yield were recorded at multiple and single stem, respectively. Besides spacing, canopy special arrangement of a crop or a variety also determines the optimum plant population per unit area of land (Yacob *et al*., 1996; Tesfaye *et al*., 1998). Unlike open type coffee variety, lowest clean coffee yield was obtained at single stem rather than multiple and free growth. This could be due to the compact branch nature of variety that requires closer spacing than open type.

However, pooled mean analysis didn't show significant difference among bearing heads. Moreover, interaction effect was not observed between spacing and number of verticals or bearing heads. Table 4

The results of the combined analysis of variance also revealed highly significant yield variations among crop seasons and showed interactions effect with spacing and number of verticals (Fig. 1). The yield performance of coffee trees due to spacing and number of verticals were exhibited biennial bearing nature in both canopy classes. The highest and lowest clean coffee yield were obtained in 2012/13 and 2010/11 cropping seasons, respectively. Accordingly, the overall mean yields ranged between 3.38 Q ha^{-1} and 30.48 Q ha^{-1} in open type and between 3.08 Q ha^{-1} and 31.51 Q ha^{-1} in compact type coffee verities.

CONCLUSION AND RECOMMENDATION

The impact of planting density and number vertical on yield and yield components of promising coffee varieties had been studied to determine appropriate plant density and number of verticals for south Ethiopia coffee selection. The above mentioned result concluded that, in both canopy classes clean coffee yield significantly influenced by different spacing level; highest and lowest clean coffee yield were obtained at 4444 trees/ha (Sp3) followed by 2500 trees/ha (SP2) and 1600 coffee trees/ha (SP1) planting density, respectively. Regardless of number of verticals or bearing heads, except pooled mean analysis in most harvesting seasons clean coffee yield significantly influenced by different number of verticals or bearing heads; highest clean coffee yield was recorded at single stem for open type and multiple stem for compact type coffee varieties. These indicated that, the two varieties required different bearing heads based on their canopy nature.

The combined analysis of variance also revealed highly significant yield variations among crop seasons and showed interactions effect with spacing and number of verticals. Moreover, open type coffee variety was showed interaction effect among spacing by number of verticals; highest clean coffee yield was obtained at 4444 trees per ha (SP3) interact with single stem (V1) 23.31 quintals ha^{-1} but compact type coffee variety not yet influenced by interaction effect. Generally, these finding suggest that close spacing with their required number of verticals significantly promoted the yield responses of Arabica coffee cultivars under two contrasting coffee varieties. Therefore, 1.5m X 1.5m (SP3) spacing with single stem (V1), and 1.5m X 1.5m (SP3) spacing with multiple stems (V2) treatments combinations were recommended for open and compact coffee varieties to enhance yield and yield components, respectively.

ACKNOWLEDGEMENTS

We would like to acknowledge Land and Water Resource Research Directorate, Jimma and Wondo Genet Agricultural Research Centers for providing all the necessary facilities and supports during the whole experimentation. Our heartfelt thanks also go to Awada Agricultural Research Sub-center research staffs particularly Amare Boku for their help in field and data collection.

REFERENCES

- Board JE, Harville BG, and Saxton AM (1990). Narrow-row seed-yield enhancement in determinate soybean. Agron. J. 82: 64-68.
- Browning, G. and Fisher, N. M. 1976. High density coffee yield results for the first cycle from systematic plant spacing designs. *Kenya Coffee* 41:209-217.
- Carr, M.K.V. (2001). The water relation and irrigation requirements of coffee. Experimental Agriculture 33:1-36.
- Cassidy D.S.M., Kumar D (1984) Root distribution of *Coffea arabica* L. in Zimbabwe. I. The effect of plant density, mulch, cova planting and shade in Chipinge. Zimbabwe J. Agric. Res. 22:119-132.
- Coffee Research Institute, Coffee History. Coffee research. Org 2006a 1-2
- DaMatta FM (2004a) Ecophysiological constraints on the production of shaded and un shaded coffee: a review. Field Crops Res. 86:99-114.
- DaMatta, F.M., Ronchi, C.P., Maestri, M. and Barros, R.S., 2007. Ecophysiology of coffee growth and production. Brazilian Journal of plant physiology, 19(4), pp. 485-510.
- Davies AP, Govaerts R, Bridson DM, Stoffelen P (2006) An annotated taxonomic conspectus of genus Coffea (Rubiaceae). Bot. J. Linn. Soc. 152:465-512.
- Gathara, M.P.H. and Kiara, J.M. 1985. Factors that influence yield in close spaced coffee III: Yield components. *Kenya Coffee* 50:385-392.
- Institute of Agricultural Research (IAR). 1996. Recommended production technologies for coffee and associated crops. Research-extension task force of Jima Research Center, Jima, Ethiopia. 18 pp.
- Kuguru FM, Fisher NM, Browning G, Mitchell HW (1978). The effect of tree density on yield and some yield components of arabica coffee in Kenya. Acta Hort. 65:101-113.
- Kumar, D. 1978. Investigation into some physiological aspects of high density planting of coffee (*Coffea arabica*). *Kenya Coffee* 43:263-272.
- Kumar D (1979a) some aspects of the physiology of *Coffea arabica* L. A review. Kenya Coffee 44:9-47.
- Mitchell, H.M. 1976. Research on close spacing of intensive coffee production in Kenya. *Kenya Coffee* 41:168-174.
- Najafi F. and Moghadam PR (2002). Effect of irrigation regimes and plant density on yield and agronomic

characteristics of blond psyllium (*Plantago ovata*). J. Agricultural Science and Technol., 16: 59-65.

- Nekonam MS, and Razamjoo KH (2007). Effect ofplant density on yield, Yield components and Effective medicinal ingredients of Blod Psyllium (*Plantago ovata* F.). J. Agriculture and Biol., 9(4): 607-609.
- Singh NP and Singh RA (2002). Scientific crop production, X press Graphics, Delhi-28,1 st ed., India
- Taye Kufa, 1996. Cova planting favors coffee production at Melko. *Institute of Agricultural Research Newsletter, Agricultural Research* 12:5-6.
- Taye Kufa, Tesfaye Shimber, Anteneh Netsere, Alemseged Yilma and Endale Taye. 2001. The impact of close spacing on yield of Arabica coffee under contrasting Agro-ecologies of Ethiopia. *African Crop Science Journal* 9(2): 401-409.
- Terene, I., Robinson, Lakso, A.N. and Carpenter, S.G. 1991. Canopy development, yield and fruit quality of empire and "delicious" apple trees grown in four orchard production systems for ten years. *Journal of American Society Horticultural Science* 116:179-187.
- Tesfaye Shimber; Yacob Edjamo; Alemseged Yilma and Taye Kufa. 1998. Research Achievements and Transferable Technologies in coffee Agronomy. In Beyene, S. and Aberra, D. (eds.). Proc. Of the Third Technology Generation, Transfer and Gap Analysis Workshop. 12-14 Nov. 1996, Nekemt, Ethiopia. Pp. 70-79.
- Van der Vossen, H.A.M., 2005. A critical analysis of agronomic and economic sustainability of organic
-

coffee production. Experimental agriculture, 41(04), pp 449-473.

- Waller, J.M., Bigger, M. and Hillocks, R.J. eds., 2007. Coffee pests, disease and their management. CABI.
- Workafes Woldetsadik and Kassu Kebede, 2000. Coffee production systems in Ethiopia. In: *Proceedings of the workshop on control of coffee berry disease (CBD) in Ethiopia*, Addis Ababa (Ghion Hotel), 13-15 August 1999. pp. 99-106.
- Wringley, G. 1988. *Coffee*. Tropical Agricultural Series, London, John Wiley & Sons Inc., N.Y.
- Yacob Edjamo, Tesfaye Shimber, Gibramu Temesegen and Alemseged Yilma 1993. Effect of canopies and bearing heads on density and yield of CBD resistant Arabicas (*Coffea arabica* L.). In: *Proceedings of the 15th International Scientific Colloquium on Coffee*, Motpellier, 6-11 June 1993. ASIC (Paris), pp. 322-328.
- Yacob Edjamo, Tesfaye Shimber, Taye Kufa, Alemseged Yilma, Takele Negewo , Anteneh Netsere and Bekele Bogale 1996. Advances in coffee agronomy research in Ethiopia. In: *Proceedings of IACO Workshop*, Kampala, Uganda, 4-6 September 1995. Tenywa, J.S., Adipala Ekwamu and Ogenga-Latigo, M.W. (Eds.), pp. 40-55.
- Yilma Yemane-Berhan. 1985. Close spacing for planting coffee. Ministry of Coffee and Tea Development (MCTD). 44 pp.