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Agronomic Characters, Leaf and Essential Oil Yield of Peppermint (*Mentha piperiata* L.) as Influenced by Harvesting Age and Row Spacing

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ABSTRACT

An experiment was conducted with the objective of quantifying the effect of harvesting age and spacing on agronomic and chemical characters of peppermint (*Mentha piperiata* L.) during 2009/2010. Five levels of harvesting ages and four levels of spacing were assigned to sub-plots and main plots, respectively in a split plot design with three replications. Data on fresh leaf yield, dry leaf yield, fresh above-ground biomass yield, dry above-ground biomass yield, fresh leaf/stem ratio, dry leaf/stem ratio, essential oil (EO) content and EO yield were collected and analyzed for the first and second harvests. For both harvests, harvesting age exerted a highly significant influence ($P < 0.01$) on all parameters studied. Row spacing significantly influenced all the parameters except for fresh leaf/stem ratio, dry leaf/stem ratio and EO content during the first harvest. During the second harvest, row spacing affected fresh leaf yield, fresh above-ground biomass yield, dry above-ground biomass yield, fresh leaf/stem ratio significantly ($P < 0.05$) and dry leaf and EO yield highly significantly ($P < 0.01$). The interaction effect of row spacing and harvesting age exerted a significant influence ($P < 0.05$) on dry leaf and EO yield during the second harvest. Fresh leaf and EO yield varied from 3,650.9-10,882.1 and 10.2-18.8 kg/ha, respectively and maximum values were obtained at the harvesting age of 120 days after planting at first harvest. Maximum yield of 9,967.5 kg/ha fresh leaf and 17.88 kg/ha EO was obtained with a 30-cm row spacing.

Keywords: aboveground biomass, essential oil content, leaf/stem ratio, leaf yield

INTRODUCTION

Peppermint (*Mentha piperiata* L.) is a perennial aromatic and medicinal herb that belongs to the Lamiaceae family (Abbaszadeh *et al*. 2009). The family contains around 200 genera and between 2000 and 5000 species of aromatic herbs and low shrubs (Hedge 1992). Peppermint is native to Europe and it is now cultivated in the USA, India, China, the former USSR, Italy, France and Hungary (Aflatuni 2005). Peppermint is grown mainly for its leaves and essential oils. Its leaves are used for herbal preparations (Beemnet *et al*. 2010) and the essential oil (EO) extracted from its leaves are widely and mostly used in pharmaceutical, food, flavor, cosmetics, beverages and allied industries (Verma *et al*. 2010) because of its main components menthol and menthone (Gul 1994).

There are many factors that influence agronomic characteristics, biomass and EO yield of aromatic plants. Among these, harvesting age (Marotti *et al*. 1993) and spacing are primarily mentioned (Yasin *et al*. 2003; Khazaie *et al*. 2007; Al-Ramamneh 2009). Moreover, the genotype and management conditions such as harvesting time, plant age and crop density also influence the qualitative traits of many aromatic plants (Marotti *et al*. 1994).

Despite harvesting age (Aflatuni 2005) and spacing (Rissanini 2002) being important yield-limiting factors in peppermint, there is limited information about their effect on agronomic and economical parameters such as leaf and EO yield in Ethiopia. This lack of information is the major hindrance to exploit this economically important herb more. To help fill the gaps, this experiment was carried out with the objective of studying the effect of harvesting age and row spacing on economic traits such as leaf yield and EO yield of peppermint.

MATERIALS AND METHODS

The experiment was conducted at Wondo Genet, Southern Ethiopia during 2009/2010. Wondo Genet is located at 7° 192 N latitude and 38° 382 E longitude with an altitude of 1780 m.a.s.l. The site receives a mean annual rainfall of 1000 mm with minimum and maximum temperatures of 10 and 30°C, respectively. The soil is a sandy clay loam with an average pH of 7.2. The experiment consisted of a factorial combination of four levels of row spacing (30, 40, 50 and 60 cm) and five levels of harvesting ages (60, 90, 120, 150 and 180 days after planting (DAP)). Treatments of row spacing were assigned to the main plots and harvesting ages to subplots in a split plot design with three replications according to the procedures given by Gomez and Gomez (1984). Stolons 1½-years old and 10 cm in length were planted in rows of a plot 3.6 m wide and 6 m long in an area of 21.6 m^2. During planting and after subsequent harvesting, 20 kg N/ha was applied in the form of urea. During experimentation, all field horticultural practices were performed as required. Two harvests were made during the experiment.

Data on fresh leaf yield (kg/ha), dry leaf yield (kg/ha), fresh above-ground biomass yield (kg/ha), dry above-ground biomass yield (kg/ha), fresh leaf/stem ratio, dry leaf/stem ratio, EO content (%) and EO yield (kg/ha) were recorded for each harvest. EO content was determined on a dry weight basis from 250 g of composite leaves harvested from the three middle rows of a plot. Laboratory analyses were performed at Wondo Genet Agricultural Research Center. EO was determined by hydro-distillation (Guenther 1972).

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To statically analyze the differences in agronomic and chemical characteristics caused by harvesting age and spacing treatments, five samples were taken from each plot. Experimental data was statistically analysed by analysis of variance (ANOVA) using SAS PROC GLM (2002) at $P < 0.05$. Differences between means were assessed using the least significance difference (LSD) test at $P < 0.05$.

RESULTS AND DISCUSSION

Variation in agronomic and chemical parameters of peppermint

There was significant variation in agronomic and chemical traits of peppermint in the first and second harvests with respect to harvesting age and row spacing (**Tables 1, 2**). In agreement with the present study, a significant influence of harvesting age and spacing was also reported for different aromatic and medicinal plants: by Zewdinesh (2009) for artemisia (*Artemisia annua* L.), Badi *et al*. (2003) for thyme (*Thymus vulgaris* L.) and Aflatuni (2005) for menthol mint (*Mentha arvensis* L.) and peppermint (*M. piperiata* L.), indicating the significance of identifying optimum requirements of harvesting age and row spacing for aromatic plants in different areas of the world before initiating any kind of economic production.

In both first and second harvests, harvesting age exerted a highly significant influence ($P < 0.01$) on fresh and dry leaf yield, fresh and dry above-ground biomass yield, fresh and dry leaf/stem ratio, EO content and EO yield (**Tables 1, 2**). Row spacing highly significantly influenced ($P < 0.01$) fresh and dry leaf yield, fresh and dry above-ground biomass yield, and fresh and dry leaf/stem ratio, and exerted a significant influence ($P < 0.05$) on EO yield during the first harvest. During the second harvest, row spacing affected fresh leaf yield, fresh above-ground biomass yield, dry above-ground biomass yield, fresh leaf/stem ratio significantly ($P < 0.05$) and dry leaf and EO yield highly significantly ($P < 0.01$). The interaction effect of harvesting age and row spacing exerted a significant influence ($P < 0.05$) for the variation in dry leaf and EO yield during the second harvest.

These results indicate that harvesting age and row spacing play a large role in peppermint cultivation. Therefore, some of the major economical traits of peppermint, such as leaf and EO yield, which are important for processing and trade, can be improved through proper management of harvesting age and row spacing.

Performance of agronomic and chemical parameters of peppermint as affected by harvesting age

During the first harvest, performance of agronomic parameters such as fresh leaf yield, dry leaf yield, fresh above-ground biomass yield and dry above-ground biomass yield of peppermint increased with increasing harvesting age and reached a maximum at 120 DAP; thereafter, their value declined (**Table 3**). The values ranged from 4.55 to 10.88, 1.13 to 2.39, 9.38 to 24.14 and 1.93 to 5.47 t/ha, respectively for fresh leaf yield, dry leaf yield, fresh and dry above-ground biomass yield. Prolonging harvesting age from 60 to 120 DAP increased fresh leaf yield, dry leaf yield, fresh and dry above-ground biomass yield by 66.60, 95.89, 114.73 and 184.26%, respectively, during the first harvest. In the second harvest, maximum values were recorded at 180 DAP for fresh leaf yield, fresh and dry aboveg-round biomass yield (**Table 4**). During the second harvest, minimum values of fresh leaf yield (3.65 t/ha), fresh above-ground biomass yield (5.22 t/ha) and dry above-ground biomass yield (1.24 t/ha) were obtained at 90 DAP (**Table 4**). Fresh leaf yield, fresh above-ground biomass yield and dry above-ground biomass yield increased by 90.81, 125.8 and 74.23% by extending the harvesting age from 90 to 120 DAP, respectively. The performance of peppermint agronomic parameters generally increased with increasing harvesting age up to 4 months after transplanting for the first harvest and 6 months after planting for the second harvest. In agreement with the present study, a similar trend was reported by Zewdenesh (2009) for artemisia and Badi *et al*. (2003) for thyme. Moreover, Marotti *et al*. (1993) reported highest dry biomass yield at a later stage of development (full flowering stage) than the earlier stage (pre- and early-flowering) of development for peppermint.

In both first and second harvests, the leaf/stem ratio declined with increasing age and reached a minimum at 180 DAP (**Tables 3, 4**). The respective decrease in fresh leaf/stem ratio and dry leaf/stem ratio were 32.62 and 44.06% during the first harvest and 33.47 and 39.49% during the second harvest. In agreement with the present study, Solomon and Beemnet (2011) reported a decreasing trend of leaf/stem ratio as harvesting age was extended from 90 to 120 DAP for Japanese mint. This indicates that the proportion of leaves obtained from the harvested above-ground biomass is higher at an earlier stage of development than at later stages. This might possibly be due to self-shedding or senescence of leaves during a later stage of development in mints as it was observed during experimentation.

Performance of chemical parameters such as EO content and EO yield varied from 0.80 to 1.39% and 10.23 to 18.8 kg/ha, respectively as harvesting age varied (**Tables 3, 4**). The variation in EO content and EO yield as harvesting age varied was also reported by Rohloff *et al*. (2005) for peppermint, Baydar and Erbas (2005) for lavender (*Lavandula anguistifolia* L.) and Ramezani *et al*. (2009) for four medicinal plants namely eucalypt (*Eucalyptus nicholii* L.), rosemary (*Rosmarinus officinalis* L.), white cedar (*Thuja occidentalis* L.) and lawson cypress (*Chamaecyparis lawsoniana* L.). EO content increased as harvesting age was extended and reached a maximum at 180 and 120 DAP during the first and second harvest, respectively. The respective increase in EO content was 36.47 and 37.62% when harvesting age was prolonged from 60 to 180 DAP for the first harvest and 60 to 120 days for the second harvest. In agreement with the present study, an increasing trend of EO content with increasing harvesting age from 30 to 150 DAP for menthol mint and peppermint was also reported by Verma *et al*. (2010). EO yield increased with increasing harvesting age and reached a maximum value at 120 DAP. EO yield increased by 83.77% when harvesting was prolonged from 60 to 120 DAP. Supporting the result of the present study, increasing trend of EO yield with prolonged harvesting age was also reported by Solomon and Beemnet (2011) for Japanese mint (*Mentha arvensis* L.)

Comparing the first and second harvests with harvesting ages, a higher value was obtained in all agronomic parameters during the first harvest (**Tables 3, 4**). Overall, average fresh and dry leaf yield, and fresh and dry above-ground biomass yield decreased by 43.00, 27.85, 88.01 and 75.70% during the second harvest at 60, 90, 120, 150 and 180 DAP, respectively. In agreement with the present study, Wijesekera (1981) reported higher herbage yield during the first harvest and a decreasing trend in subsequent harvests for peppermint, spearmint (*Mentha spicata* L.) and Japanese mint. However, relatively higher EO content and EO yield were obtained during the second harvest. Ram and Kumar (1999) also reported differences in the yield and quality of EO from seven menthol mint cultivars between the first and the second harvests.

Performance of agronomic and chemical parameters of peppermint as affected by row spacing

Maximum fresh leaf yield (9.97 t/ha), dry leaf yield (2.00 t/ha), fresh above-ground biomass yield (20.29 t/ha) and dry above-ground biomass yield (4.13 t/ha) was obtained at a 30-cm row spacing and decreased with increasing row spacing and reached a minimum value at 60-cm row spacing in both first and second harvests (**Tables 3, 4**). Increasing row

Table 1 Mean squares of agronomic and quality parameters of peppermint as affected by harvesting age and row spacing (first harvest).

Source	Df	Fresh leaf yield	Dry leaf yield	Fresh aboveground biomass yield	Dry aboveground biomass yield	Fresh leaf/stem ratio	Dry leaf/stem ration	Essential oil content	Essential oil yield
Replication (REP)	2	8008762.8	208250.54	59230741	2251636.34	0.07	0.12	0.19	81.57
Row spacing (RS)	3	2060128.7**	2221119.85**	259050957**	10908858.04**	0.02NS	0.05NS	0.24NS	150.49*
Harvesting age (HA)	4	63999298.8**	3216186.88**	390656506**	23468364.84**	0.56**	1.93**	0.28**	120.45**
REPxRS (Error a)	6	3058898.7	180987.86	15545442	1082091.82	0.01	0.03	0.04	30.36
RSxHA	12	57147247.1NS	133980.39NS	11409047NS	648671.26NS	0.02NS	0.04NS	0.09NS	19.80NS
Error b	32	1909526.9	3413074.12	7684255	429314.0	0.02	0.05	0.06	689.97
CV (%)		18.71	21.94	18.44	21.16	14.92	20.77	26.22	33.82

**and * Significant at $P < 0.01$ and $P < 0.05$ probability level, respectively; NS= non significant at $P < 0.05$

Table 2 Mean squares of agronomic and quality parameters of peppermint as affected by harvesting age and row spacing (second harvest).

Source	Df	Fresh leaf yield	Dry leaf yield	Fresh aboveground biomass yield	Dry aboveground biomass yield	Fresh leaf/stem ratio	Dry leaf/stem ration	Essential oil content	Essential oil yield
Replication (REP)	2	8771358.9	323319.9	44337681.8	1294355.7	1.44	0.77	0.16	38.39
Row spacing (RS)	3	10088198.2*	630673.5**	28962225.1*	2110472.8*	0.48*	0.50NS	0.05NS	84.24**
Harvesting age (HA)	4	780253.2**	718523.5**	78788057.9**	3082939.86**	1.97**	2.55**	0.31**	168.75**
REPxRS (Error a)	6	1160693.1	29981.4	4115479.1	253712.6	0.07	0.19	0.01	7.67
RSxHA	12	18203405.2NS	130030.7*	6136483.2NS	497505.9NS	0.11NS	0.12NS	0.08NS	39.56*
Error b	32	623802.4	47016.6	3394611.4	182497.4	0.11	0.15	0.06	535.99
CV (%)		15.29	18.62	23.05	24.24	16.09	17.42	19.65	28.71

* * and * Significant at $P < 0.01$ and $P <0.05$ probability level, respectively; NS= non significant at $P < 0.05$

Table 3 Mean performance of agronomic and chemical parameters of peppermint as affected by harvesting age and row spacing at Wondo Genet (first harvest).

Treatments	Parameters							
	Fresh leaf yield (kg/ha)	Dry leaf yield (kg/ha)	Fresh aboveground biomass yield (kg/ha)	Dry aboveground biomass yield (kg/ha)	Fresh leaf/ stem ratio	Dry leaf/ stem ratio	Essential oil content (w/w)	Essential oil yield (kg/ha)
Harvesting ages (days)								
60	6531.7 c	1220.2 bc	11244 c	1925.4 d	1.41 a	1.77 a	0.85 c	10.23 b
90	7879.5 b	1449.3 b	15829 b	3060.5 b	1.02 b	0.91 b	0.93 bc	13.65 b
120	10882.1 a	2390.3 a	24144 a	5473.2 a	0.85 c	0.81 b	0.80 c	18.8 a
150	7077.1b c	1255.8 bc	14540 b	2752.6 bc	0.95 bc	0.84 b	1.09 ab	13.32 b
180	4550.2 d	1126.3 c	9379 c	2270.1 cd	0.95 bc	0.99 b	1.16 a	12.57 b
LSD 0.05	1149.1	271.58	2305.2	544.86	0.13	0.19	0.21	3.86
Row spacing (cm)								
30	9967.5 a	1999.9 a	20292 a	3462.8 a	1.02	1.05	0.92	17.88 a
40	7821.6 b	1569.9 b	16390 b	4127.5 b	0.99	0.99	0.89	13.57 b
50	5844.7 c	1185.0 c	11345 c	2336.8 c	1.10	1.13	0.89	10.18 b
60	5902.7 c	1198.7 c	12082 c	2458.2 c	1.03	1.09	1.15	13.26 b
LSD0.05	1027.8	242.91	2061.8	487.34	NS	NS	NS	3.45
CV (%)	18.71	21.94	18.44	21.16	14.92	20.77	26.22	33.82

Means followed by the same letter with in the same column are statistically non significant at $P < 0.05$; NS= non significant at $P < 0.05$ according to least significant difference (LSD) test.

spacing from 30 to 60 cm decreased the respective value of fresh and dry leaf yield, and fresh and dry above-ground biomass yield by 40.78, 40.06, 40.45 and 29.01% for the first harvest and by 24.18, 25.92, 22.25 and 27.06% for the second harvest. In agreement with the present study, Solomon and Beemnet (2011) reported a decreasing trend of fresh and dry leaf yield and fresh biomass yield with increasing spacing from 30 to 60 cm for Japanese mint. Aflatuni (2005) also reported a higher value of fresh and dry yields with narrow row spacing in peppermint. A similar pattern was also reported for pelargonium species (Rao 2002; Badi *et al.* 2004). Maximum biomass was reported at highest density of 20 plants m^{-2} by Laughlin (1993), 30 cm^2 by Simon *et al.* (1990), 25 plants m^{-2} by Woerdenbag *et al.* (1994) and 45 cm^2 by Zewdinesh (2009) for artemisia. Likewise, Yasin *et al.* (2003) also reported highest forage yield with narrow spacing (45 cm^2) rather than wider spacing (75 cm^2) for mott elephant grass (*Pennisetum purpureum* Schum. cv. 'Mott'). Similarly, Al-Ramamneh (2009) reported higher fresh and dry herbage yield of thyme with narrow intra row-spacing of 15 cm.

The fresh and dry leaf: stem ratio was similar at all spacings during the first harvest. This result agrees with the report of Solomon and Beemnet (2011). However, fresh leaf to stem ratio was highest when spacing was narrowest and lower when spacing was widest during the second harvest. Unlike the result obtained during the second harvest presenting this study, Aflatuni (2005) reported a higher value of leaf: stem ratio in wider spacing for peppermint. The difference between these findings might be due to variations in genetic, environmental and interaction effect of genetic and environmental factors existing between tested locations.

EO content was not affected by the variation in row spacing in both the first and second harvests. This result is consistent with the previous reports of Aflatuni (2005) for peppermint and Sanini *et al.* (2002) for Japanese mint. EO yield varied with row spacing and ranged from 10.18 to 17.88 kg/ha when row spacing was 50 and 30 cm, respectively (**Tables 3, 4**). EO yield decreased with increasing row spacing and reached a minimum at 50 cm. EO yield decreased by 25.83 and 27.46%, respectively when peppermint plants were grown at an inter-row spacing of 60 cm rather than 30 cm. The present study is in agreement with the findings of El-Gandi *et al.* (2001) who reported higher total EO yield at higher plant density of 15 cm for sweet basil (*Ocimum basilicum* L.) and Solomon and Beemnet (2011) who reported higher EO yield under narrow (30 cm) inter-row spacing for Japanese mint. Zewdinesh (2009) also reported higher EO yield of artemisia tested under narrow (45 cm) inter-row spacing.

Table 4 Performance of agronomic and chemical parameters of peppermint as affected by harvesting age and row spacing at Wondo Genet (second harvest).

Treatments	Parameters					
	Fresh leaf yield (kg/ha)	Fresh aboveground biomass yield (kg/ha)	Dry aboveground biomass yield (kg/ha)	Fresh leaf/stem ratio	Dry leaf/stem ratio	Essential oil content (w/w)
Harvesting age (days)						
60	4794.7 c	6980.7 c	1433.0 b	2.33 a	2.76 a	1.01 c
90	3650.9 d	5219.8 d	1240.8 b	2.36 a	2.57 ab	1.19 bc
120	4761.3 c	6733.3 cd	1548.5 b	2.47 a	2.32 b	1.39 a
150	5644.7 b	9241.0 b	2427.1 a	1.79 b	1.86 c	1.14 c
180	6966.4 a	11788.1 a	2161.8 a	1.55 b	1.67 c	1.37 ab
LSD 0.05	656.79	1532.1	355.25	0.28	0.33	0.20
Row spacing (cm)						
30	6281.9 a	9909.8 a	2273.9 a	2.13 a	2.15	1.18
40	5222.7 b	7772.1 b	1740.3 b	2.25 a	2.30	1.28
50	4387.1 c	6583.5 b	1376.2 c	2.19 a	2.46	1.26
60	4762.8 bc	7705.0 b	1658.6 bc	1.84 b	2.04	1.15
LSD0.05	587.45	1370.4	317.74	0.25	NS	NS
CV (%)	15.29	23.05	24.24	16.09	17.42	19.65

Means followed by the same letter with in the same column are statistically non significant at $P < 0.05$; NS = non significant at $P < 0.05$ according to least significant difference (LSD) test

Table 5 Interaction effect of harvesting age and plant spacing on dry leaf yield of peppermint at Wondo Genet (second harvest).

Harvesting age (days)	Row spacing (cm)				Means
	30	40	50	60	
	Dry leaf yield (kg/ha)				
60	1157.32 cdefghi	1165.89 cdefgh	948.54 efghijk	874.46 ghijk	1036.553
90	977.82 defghijk	1026.89 defghijk	699.98 k	854.93 hijk	889.905
120	1220.03 cdefg	992 defghijk	1034.09 defghijk	1040.86 cdefghijk	1071.745
150	2275.25 a	1409.19 bc	1013.76 defghijk	1320.32 bcd	1504.63
180	1597.00 b	1263.33 bcde	1147.08 cdefghij	1263.08 bcdef	1317.623
Means	1445.484	1171.46	968.69	1070.73	

Over all mean = 1488.38 kg/ha
CV% = 21.94
Means followed by the same letter are statistically non significant at $P < 0.05$ according to least significant difference (LSD) test

Table 6 Interaction effect of harvesting age and plant spacing on essential oil yield of peppermint at Wondo Genet (second harvest)

Harvesting age (days)	Row spacing (cm)				Means
	30	40	50	60	
	Essential oil Yield (kg/ha)				
60	11.58 defgh	8.72 h	9.65 h	12.87 cdefgh	10.71
90	28.72 a	18.31 bc	11.98 cdefgh	14.40 cdefgh	18.35
120	21.54 b	18.77 bc	16.00 bcdef	16.81 bcd	18.28
150	10.18 h	15.05 bcdefg	13.95 cdefgh	10.28 efgh	11.85
180	14.30 cdefgh	14.18 cdefgh	9.41 h	8.22 h	12.04
Means	17.26	15.01	12.20	12.52	

Over all mean = 14.25 kg/ha
CV% = 28.71
Means followed by the same letter are statistically non significant at $P < 0.05$ according to least significant difference (LSD) test

Performance of agronomic and chemical parameters of peppermint as affected by interaction effects of row spacing and harvesting age

In both first and second harvests, all parameters considered in the present study were not significantly influenced by the interaction effects of harvesting age and inter row spacing except for dry leaf and EO yield in the second harvest (**Tables 1, 2**). The interaction effect of row spacing and harvesting age influenced the dry leaf and EO yield during the second harvest (**Table 5**). At a row spacing of 30, 40 and 60 cm dry leaf yield increased with increasing age up to 150 DAP. At a row spacing of 50 cm, maximum dry leaf yield was obtained at 180 DAP. EO yield increased with increasing age up to 120 days for an inter-row spacing of 40, 50 and 60 cm. At an inter-row spacing of 30 cm, maximum EO yield was obtained at a harvesting age of 90 DAP (**Table 6**). In the present study, maximum dry leaf and EO yield was obtained at 30 cm inter-row spacing when harvesting age was 90 and 150 DAP, respectively. Thus, dry leaf and EO yield varied with the variation in harvesting age and inter-row spacing. Variation in dry leaf and EO yield in relation to growth age variation from the beginning of blooming, full blooming and to fruit set and planting density from 15 to 45 cm was also reported by Badi *et al.* (2003) in thyme.

Overall, mean dry leaf and EO yield varied as harvesting age and inter-row spacing changed. Regardless of density, the highest mean dry leaf and EO yield was recorded at 150 and 90 DAP, respectively. Dry leaf and EO yield responded positively to decreasing row spacing. Mean dry leaf and EO yield averaged across harvesting age increased with decreasing row spacing, reaching the highest value at an inter-row spacing of 30 cm for dry leaf yield and 30 and 40 cm for EO yield. The result of the present study agrees with that of Zewdinesh (2009) and Solomon and Beemnet (2011) who reported the influence of interaction effects of harvesting age and row spacing on the variation in dry leaf yield and EO yield for artemisia and Japanese mint, respectively

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