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# Effect of Inter Row Spacing and Harvesting Time on Growth and Essential Oil Yield of Spearmint (*Mentha spicata* L.)

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**Abstract:** A field study was conducted to determine the effect of different inter row spacing and harvesting time on the growth and essential oil yield of spearmint (*Mentha spicata* L.) during 2009-2010. Split plot design with four levels of inter row spacing (30, 40, 50 and 60 cm) as a main plot and five levels of harvesting time (60, 90, 120, 150 and 180 days after transplanting) as a sub plot was used in three replications. Data on fresh leaf weight, fresh stem weight, leaf to stem ratio, moisture content, fresh biomass yield, essential oil content and essential oil yield were recorded. The response of growth and essential oil yield of the crop to different inter row spacing treatment was consistent throughout different harvesting time. The fresh leaf weight, leaf to stem ratio and moisture content increased significantly with the decreasing inter row spacing. The value of fresh biomass and essential oil yield were significantly ($p<0.01$) reduced with increase of inter row spacing from 30 cm to 60 cm, from 14,995 kg/ha to 8,169 kg/ha and from 25.70 kg/ha to 16.18 kg/ha, respectively. Essential oil content and essential oil yield were significantly increased when harvesting was made on 180 and 150 DAT, respectively. At 60 DAT significantly higher fresh leaf weight (7,478 kg/ha) and leaf to stem ratio (1.98) were obtained. Harvesting after 180 days of planting, however, resulted significantly lower fresh leaf weight (3,087 kg/ha) and leaf to stem ratio (0.66). Generally, essential oil content was concentrated significantly during later periods of harvesting.

**Key words:** *Mentha spicata* L. · Spearmint · Inter row spacing · Harvesting time · Essential oil contents

## INTRODUCTION

Mints comprise a group of species of the genus *Mentha* belonging to the family Lamiaceae [1]. Among mint species, spearmint (*Mentha spicata* L.) is considered industrial crop as it is a source of essential oils enriched in certain monoterpenes like carvol, dihydrocarveole, dihydrocarveylacetate, menthol, menthone, caryophyllene, terpineol and cubebene which is widely used in food [1], flavor [2], cosmetic and pharmaceutical industries [3].

Spearmint is well adapted to climatic conditions in tropical and subtropical areas. A climate with adequate and regular rainfall and good sunshine during its growing period ensures a good yield [4]. Mint in general is succulent crop that has a high water requirement during its active growth period. Water requirements of mints differ from location to location depending on soil type, soil fertility status and climatic factors. Both high soil moisture content and high soil moisture tension (water stress) decreased growth, herb and essential oil yields of mints [4]. In addition, yield and the essential oil composition of mint species were influenced by interaction between the genotype and environment, method of distillation, kind of storage, crop age, time of harvest and season [5, 6, 7]. As illustrated by Verma *et al.* [8], the time of harvest, in general has a close relation to yield and quality of oil and it varies from place to place and genotype to genotype.

In Ethiopia since no study have been conducted on the agronomy of spearmint, it is found important to assess the appropriate production technologies on the crop to maximize herb and essential oil yield. Accordingly the purpose of this research was to evaluate the response of spearmint *Mentha spicata* to different inter row spacing and harvesting time.

## MATERIALS AND METHODS

The experiment was carried out on spearmint at Wondogenet Agricultural Research Center, southern Ethiopia during 2009-2010. The experimental site is located

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Table 1: Detail of inter row spacing and harvesting age treatments

| Treatments | Inter row spacing (cm) | Harvesting time |
|---|---|---|
| $T_1$-$T_5$ | 30 cm | 60, 90, 120, 150 and 180 DAT[1] |
| $T_6$-$T_{10}$ | 40 cm | 60, 90, 120, 150 and 180 DAT |
| $T_{11}$-$T_{15}$ | 50 cm | 60, 90, 120, 150 and 180 DAT |
| $T_{16}$-$T_{20}$ | 60 cm | 60, 90, 120, 150 and 180 DAT |

[1]Days after transplanting

at an elevation of 1767 masl, situated at 7°5'39.91" N and 38°37'15.12" E. The soil of the experimental site is loamy. The annual mean rainfall of the area is 1880 mm and the mean annual maximum and minimum temperatures are 27.8°C and 10.1°C, respectively. A split plot design was used with inter row spacing as the main plot and different harvesting times as the sub plots. The experimental treatments were replicated three times. The plot area was 6.0 m x 3.6 m (21.6 $m^2$). The detail of the experimental treatments is given in Table 1.

A uniform amount of 60 Kg N/ha was applied in the form of urea. In order to minimize the loss of N by volatilization, the plots were irrigated immediately after fertilizer application as was done in other experiments [9]. Uniform weeding, watering and hoeing were made whenever required.

Fresh leaf weight, fresh stem weight, leaf to stem ratio, moisture content, fresh biomass yield, essential oil content and essential oil yield were measured at each harvest. Essential oils were extracted from air dried leaf samples for 2:30 hrs distillation time by hydro distillation in Clevenger apparatus. Spearmint essential oil from each treatment was weighed and the oil yield was calculated as the weight (g) of oil per weight (g) of dry spearmint leaf as was described by Zheljazkov *et al.* [10].

All statistical analysis was performed by analysis of variance (ANOVA) procedure using SAS PROC GLM as described by SAS [11].

## RESULT AND DISCUSSION

**Fresh Leaf Weight:** Analysis of variance has indicated the presence of a highly significant difference ($p < 0.01$) between main effects of spacing and harvesting time (Table 6). There was a highly significant fresh leaf weight per unit area reduction with increasing spacing between rows (Table 2). The value of fresh leaf weight was ranged between 4,231 kg/ha for row spacing of 60 cm to 7,480 kg/ha for row spacing of 30 cm. Progressive reduction in fresh leaf weight was observed with delaying harvesting time (Table 3). Harvesting after sixty days, which is statistically at par with 90 DAT, resulted a significantly higher ($p < 0.01$) fresh leaf weight than harvesting in later months. This result was in contrary with the findings of Rohloff *et al.* [12] who reported that the increase of peppermint leaf biomass resulted in with delaying harvesting. The least value of fresh leaf weight, which is 58.7% lower than the maximum record, is when harvesting was made after six months of planting. The progressive reduction of fresh leaf weight of spearmint was recorded with delaying time of harvesting may be due to drop of matured leaves in later periods.

**Leaf to Stem Ratio:** Analysis of variance has indicated that leaf to stem ratio was not significantly affected with the variation in inter row spacing and the interaction between spacing and harvesting time. This result contradicts with the findings of Aflatuni [13], who described the existence of significant planting density effect in leaf to stem ratio. Leaf to stem ratio, however, was significantly ($p<0.01$) affected by harvesting age (Table 6). The highest ratio was obtained at 60 DAT and gets reduced when harvesting was delayed. The least leaf to stem ratio, which was 66% lower than the highest at 60 DAT, was observed at 150 DAT. This result indicated that the contribution of leaf to the overall fresh biomass yield of spearmint is higher during early growth stages and its contribution becomes reduced significantly by development of stems and above ground runners.

**Fresh Stem Weight:** Results of the experiments showed that inter row spacing and harvesting date had significant effect on fresh stem weight (Table 6). Similar to fresh leaf weight the value of fresh stem weight was reduced with increasing inter row spacing. It was reduced significantly by 22.5% and 44.6% when inter row spacing was increased from 30 cm to 40 cm and from 30 cm to 50 cm, respectively. The reason could be high number of planting material used in low spacing treatments. Generally late harvesting has resulted in increase of stem weight up to 150 DAT, after which the result indicated a sharp reduction in the parameter. The maximum fresh stem weight (8,233 kg $ha^{-1}$) was observed at 150 DAT and was progressively reduced by 16%, 41.4% and 53.8% when harvesting was made 120, 90 and 60 DAT.

Table 2: Effect of inter row spacing on important parameters of Spearmint (*Mentha spicata* L.)

| | Parameters | | |
|---|---|---|---|
| Inter row spacing | Fresh leaf weight (kg/ha) | Fresh stem weight (kg/ha) | Fresh biomass yield (kg/ha) |
| 30 cm | 7,480 a | 7,515 a | 14,995 a |
| 40 cm | 6,273 b | 5,823 b | 11,367 b |
| 50 cm | 4,648 c | 4,167 c | 8,815 c |
| 60 cm | 4,231 c | 3,939 c | 8,169 c |

Means with the same letter within a column are not significantly different at 1% level of probability

Table 3: Effect of harvesting time on important parameters of Spearmint (*Mentha spicata* L.)

| | Parameters | | | | |
|---|---|---|---|---|---|
| Harvesting | Fresh leaf weight (kg/ha) | Leaf to Stem ratio | Fresh stem weight (kg/ha) | Fresh biomass yield (kg/ha) | Moisture content (%) |
| 60 DAT | 7,478 a | 1.98 a | 3,801d | 11,280 ab | 86.71a |
| 90 DAT | 6,993 a | 1.55 b | 4,824 c | 11,088 b | 79.68b |
| 120 DAT | 5,574 b | 0.81 cd | 6,915 b | 12,489 ab | 75.76c |
| 150 DAT | 5,157 b | 0.66 d | 8,233 a | 13,391 a | 71.71d |
| 180 DAT | 3,087 c | 1.06 c | 3,032 d | 5,937 c | 70.51d |

Means with the same letter within a column are not significantly different at 1% level of probability.

Table 4: Effect of inter row spacing and harvesting time on essential oil content (%) of Spearmint (*Mentha spicata* L.)

| | Inter row spacing | | | | |
|---|---|---|---|---|---|
| Harvesting | 30 cm | 40 cm | 50 cm | 60 cm | Mean |
| 60 DAT | 0.27 gh | 0.35 efgh | 0.55 abc | 0.48 cde | 0.41 |
| 90 DAT | 0.27 gh | 0.29 gh | 0.30 gh | 0.19 h | 0.26 |
| 120 DAT | 0.38 defg | 0.35 efgh | 0.32 fgh | 0.35 efgh | 0.35 |
| 150 DAT | 0.47 cde | 0.51 bcd | 0.50 bcd | 0.43 cdef | 0.48 |
| 180 DAT | 0.62 ab | 0.44 cde | 0.67 a | 0.44 cde | 0.54 |
| Mean | 0.40 | 0.39 | 0.48 | 0.38 | |

Means with the same letter within a column are not significantly different at 1% level of probability.

Table 5: Effect of inter row spacing and harvesting time on essential oil yield (kg $ha^{-1}$) of Spearmint (*Mentha spicata* L.)

| | Inter row spacing | | | | |
|---|---|---|---|---|---|
| Harvesting | 30 cm | 40 cm | 50 cm | 60 cm | Mean |
| 60 DAT | 25.33 abc | 15.47 efghi | 18.63 efg | 29.53 a | 22.24 |
| 90 DAT | 25.08 abcd | 16.73 efgh | 13.32 fghi | 9.67 i | 16.20 |
| 120 DAT | 26.16 ab | 19.36 cdef | 14.51 fghi | 12.48 ghi | 18.13 |
| 150 DAT | 31.05 a | 26.46 ab | 21.07 bcde | 17.90 efg | 24.12 |
| 180 DAT | 20.86 bcde | 15.02 efghi | 15.52 efghi | 11.31 hi | 15.68 |
| Mean | 25.70 | 18.61 | 16.61 | 16.18 | |

Means with the same letter within a column are not significantly different at 1% level of probability

Table 6: Analysis of Variance for effect of inter row spacing and harvesting time on major parameter of spearmint (*Mentha spicata* L.)

| | | MS | | | | | | |
|---|---|---|---|---|---|---|---|---|
| SOV | d.f | FLW | Leaf: Stem | FSW | FBY (kg/ha) | MC (%) | EOC (%) | EOY |
| Rep | 2 | 17962520.0 | 0.19 | 45023984.7 | 149217851 | 30.2 | 0.07142 | 12.9984 |
| Sp | 3 | 33499351.2** | 0.09 ns | 41349830** | 143675486** | 2.04ns | 0.02391ns | 291.5982* |
| Err (a) | 6 | 4477221.3 | 0.13 | 6456108.9 | 17940317 | 6.51 | 0.01819 | 49.3058 |
| Hst | 4 | 32345985.5** | 3.55** | 53532592 ** | 87697157** | 497.20** | 0.13198** | 0.9789** |
| Rep*Hst | 8 | 5305100.7 | 0.21 | 3830365 | 8911983 | 7.99 | 0.00990 | 9.9199 |
| Sp*Hst | 12 | 2342210.3 ns | 0.04 ns | 1810394 ns | 5374765.0ns | 4.69ns | 0.01917** | 54.6844** |
| Err(b) | 23 | 2189499.3 | 0.19 | 1289211.2 | 4596409 | 6.12 | 0.00599 | 14.0269 |
| CV (%) | | 26.1 | 28 | 21 | 19.6 | 3.21 | 19.0 | 19.33 |

** and *; Significant at 1 and 5% levels respectively. ns; non significant at 1 and 5% level of probability

Rep, Replication; Err, Error; Hst, Harvest; FLW, Fresh leaf weight; FSW, Fresh stem weight; FBY, Fresh biomass yield; MC, Moisture content; EOC, Essential Oil Content; EOY, Essential Oil Yield.

**Fresh Biomass Yield:** The fresh biomass yield (FBY) continuously decreased with a significant value ($P<0.01$) with increasing inter row spaces up to 50 cm, after which no statistical difference recorded. The trend of decrease in FBY with increase of planting space is similar with the decrease in fresh leaf and stem weight observed (Table 2). Accordingly, there was 24.2% FBY drop when spearmint inter-row spacing was increased from 30 cm to 40 cm. It was further reduced by 22.45% when spacing was kept 50 cm. This may be due to the increase in number of planting materials in the area with minimum inter row spacing. Similar results of increase fresh biomass with increasing peppermint density was reported by Aflatuni [13]. Due to the opposite response of fresh leaf and stem weights of spearmint towards time of harvesting (Table 2), the result for FBY has showed inconsistent values. The high FBY result (13,391 kg $ha^{-1}$) at 150 DAT was statistically at par with 12,489 kg $ha^{-1}$ at 120 DAT and 11,280 kg $ha^{-1}$ at 60 DAT. These values were, however, significantly different from 11,088 kg $ha^{-1}$ at 90 DAT and 5,937 kg $ha^{-1}$ at 180 DAT. With some variation, this result is in close agreement with those of Jahangir *et al.* [14], who reported an increase of herbage yield of spearmint was observed with delaying harvesting up to 130 days.

**Moisture Content:** Mean squares of analysis of variance indicated the existence of significant ($p<0.01$) difference in moisture content caused due to variation in harvesting time (Table 6). The average moisture content of spearmint is 76.9%. Its value reduced with delay in harvesting time by 7%, 3.92%, 4.05% and 1.2% at 90 DAT, 120 DAT, 150 DAT and 180 DAT, respectively (Table 3). This result indicated high moisture content of spearmint during early growth stages and its value gets was reduced with time.

**Essential Oil Content:** Main effects of harvesting time and its interaction with inter row spacing significantly affected essential oil content (EOC) of spearmint (Table 6). Similar to the report by Aflatuni [13] no significant differences were found in the comparison between plant densities. The value of EOC was ranged from 0.19% at 60 cm inter row spacing harvested 90 DAT to 0.67% when planted at 50 cm of inter row spacing, harvested on 180 DAT. The least EOC was observed when harvesting was made 90 days after planting and this was similar in all inter row spacings. There was a highly significant ($p<0.01$) increment of EOC with an average value of 9% when DAT increases in one level after 90 DAT (Table 4). This may be due to the increase in secondary metabolites concentration with the age of the plant. While, Jahangir *et al.* [14] recorded similar results of essential oil content, Aflatuni [13] reported the presence of no significant difference between EOC at different stage of harvesting for corn mint.

**Essential Oil Yield:** The main effects of inter row spacing and harvesting time and their interaction have shown a highly significant ($p < 0.01$) effect on essential oil yield (EOY) of spearmint (Table 6). Except for 60 cm inter row spacing at 60 DAT, for all inter row spacing the maximum values were recorded when harvesting was made at 150 DAT. This result was in consistence with reported by Rohloff *et al.* [12] and Randhawa and Kaur [15]. When harvesting was made 150 days after planting, EOY was reduced by 14.8%, 20.4% and 15% when inter row spacing was increased from 30 to 40, 40 to 50 and 50 to 60 cm, respectively This result of increase in essential oil yield with high density is consistent with reported by Aflatuni [13] for peppermint and [16] for bergamot mint. At 30 cm inter row spacing the EOY was ranged between 20.86 kg $ha^{-1}$ at 180 DAT to 31.05 kg $ha^{-1}$ at 105 DAT. In the same inter row spacing, the value was statistically similar when harvesting was made at 60, 90 and 120 DAT. For 40 cm row spacing, the minimum and maximum EOY were 15 and 26 kg $ha^{-1}$ at 180 and 150 DAT, respectively. 13.32 kg $ha^{-1}$ and 14.51 kg $ha^{-1}$ were the minimum EOY values observed at 50 cm when harvesting was made at 90 and 120 DAT, whereas the maximum value (21.07 kg $ha^{-1}$) was recorded at 150 DAT. The two extreme results of EOY in this experiment (9.67 kg $ha^{-1}$ at 90 DAT and 29.53 kg $ha^{-1}$ at 60 DAT) were observed when planting was made at 60 cm inter row spacing.

## CONCLUSIONS

Main effect of inter row spacing did not significantly affect leaf to stem ratio, moisture content and essential oil content of spearmint. Harvesting time however had affected significantly all parameters measured. Fresh leaf weight, leaf to stem ratio and moisture content were significantly reduced with increase of inter row spacing. Fresh stem weight was found increased with delayed harvesting. Essential oil content and essential oil yield were significantly increased when harvesting was made on 180 and 150 DAT. This study provided basic information with respect to some agronomy of spearmint useful for further investigation.

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