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Effect of Plant Spacing and Harvesting Age on Herbal and Oil Yield Oregano (*Origanum vulgare* L.) in Ethiopia

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ABSTRACT

Background and Objective: Oregano (*Origanum vulgare* L.) is important aromatic and medicinal herb used as medicine and spice since ancient. But crop management information is not well investigated in Ethiopia. Therefore, the objective of this study was to evaluate the optimum plant spacing and harvesting age for oregano to maximize herbal and essential oil yield. **Materials and Methods:** The experiment took place at the Wondo Genet Agricultural Research Center in Southern Ethiopia from 2017 to 2019. The experiment followed a Randomized Complete Block Design (RCBD) with three replications. The treatments involved 5 spacing options (30×30, 30×60, 60×60, 60×90 and 90×90 cm) and three harvesting ages (3, 4 and 5 months after transplanting). Data on plant height, fresh leaf weight per plant, fresh stem weight per plant, fresh above-ground biomass per plant, fresh leaf yield per hectare and essential oil yield (kg/ha) were collected from three replications arranged in randomized complete block design and analyzed using R software. **Results:** The results showed that spacing had a very significant influence on fresh leaf weight per plant, fresh leaf yield per hectare and essential oil yield per hectare. It also had a highly significant influence on plant height and a non-significant effect on fresh stem weight and fresh above-ground biomass per plant. Additionally, harvesting age had a very highly significant influence on plant height, fresh leaf weight per plant, fresh stem weight per plant and fresh above-ground biomass per plant. It also had a highly significant influence on fresh leaf yield per hectare and essential oil yield per hectare. Thus, the highest essential oil yield (45.51 and 32.49 kg/ha) was obtained from 30×30 cm spacing and 5 months after planting, respectively. **Conclusion:** The study demonstrated that both the spacing and age at which oregano plants are harvested have a significant impact on their growth and yield of oregano.

KEYWORDS

Origanum vulgare, antibacterial, antifungal properties, medicinal herb, cough, essential oil composition

INTRODUCTION

Oregano (*Origanum vulgare L.*) is important aromatic and medicinal herb that belongs to Lamiaceae family that consists of more than 61 species[1,2]. The *O. vulgare* is cultivated in sub- and temperate regions of India, particularly in the Himalayan Area (Maithani)[3]. Nowadays, it is cultivated and distributed throughout Europe, West and Central Asia up to[4]. Oregano grows in different areas with a wide range of ecologies[5].

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It thrives in a moderate to warm climate, preferring temperatures between 21 to 29°C during the day and not below 10°C at night. Extreme cold temperatures can damage the plant, so it is crucial to avoid frost. A range of soil pH from 4.5 to 8.7 is appropriate for its growth.

For a long time, oregano has been a valuable natural product for maintaining human health, particularly in recent decades[6]. Oregano is the most important culinary herb in world trade. Oregano is believed to be used medicinally due to its biological properties of p-cymene and carvacrol[7]. Oregano's medicinal uses include using fresh leaves and dried herbs, as well as essential oil. The essential oil of oregano has antifungal, antibacterial and antioxidant properties[8-15]. It is also used for respiratory disorders (treating cough, inflammation of bronchial mucous membranes and as an expectorant). Furthermore, oregano herbs and extracts have been added to various foods to enhance their taste and extend their shelf life[16].

Numerous factors affect the agronomic traits and essential oil yield of aromatic crops. Among many factors, plant spacing is one of the main factors that affect crop yield[17]. The effect of spacing was reported by Tilahun *et al*.[18] for lemongrass (*Cymbopogon citratus*). The amount and quality of essential oils in most essential oil-bearing plants can be affected by the plant's harvesting stage. The production and composition of essential oils can vary based on the stage of the plant, plant organs and cells[19]. The influence of harvesting was reported by Tadesse *et al*.[20] for Brachiaria and Ismail *et al*.[21] for lemongrass (*Cymbopogon citratus)*. The oil content and yield of aromatic plants are often altered during harvesting and post-harvesting processes[22]. Among these factors, crop management practices such as plant spacing and harvesting age are included[22,23]. Plant spacing and harvesting age affected herbage yield and essential oil yield of oregano crops. Despite plant spacing and harvesting age influencing the agronomic and chemical characteristics of aromatic plants, there is a gap in information on the effects of plant spacing and harvesting age on agronomic and chemical traits of oregano, in Ethiopia. Thus, the experiment was designed to determine the optimum spacing and harvesting age, for maximizing herbage and essential oil yield of oregano.

MATERIALS AND METHODS

Study area and duration: The experiment took place at the Wondo Genet Agricultural Research Center in Southern Ethiopia from November 2017 to March 2019.

Method: It consisted of five spacing (30×30, 30×60, 60×60, 60×90 and 90×90 cm) and three levels of harvesting age, namely 3, 4 and 5 months after transplanting. The experiment was conducted in a factorial arrangement in a Randomized Complete Block Design (RCBD) with three replications. There were 15 treatment combinations and each treatment combination was assigned randomly within the block. Plot size was 3.6×3.6 m (12.96 m^2). The distance between the treatments was 1 m. The blocks were separated from each other by 1.5 m. Oregano plants from nursery establishments were used as a test crop for this study. Healthy and uniform seedlings were collected from the nursery for transplanting. Seedlings from the nursery were transplanted in plots on the commencement of the main rainy season in well-prepared soil at spacings of 30×30, 30×60, 60×60, 60×90 and 90×90 cm between plants and rows. Proper hoeing, watering and weeding were carried out as required.

Plant height, fresh leaf weight, fresh stem weight per plant, fresh above-ground biomass per plant, fresh leaf yield per hectare and essential oil yield (kg/ha) were measured critically.

Statistical analysis: During the experiment, data on plant height, fresh leaf weight per plant, fresh stem weight per plant, fresh above-ground biomass per plant, fresh leaf yield per hectare and essential oil yield (kg/ha) were collected and analyzed using R software (version 4.1.0. 2021). Statistical analysis of experimental data were performed by Analysis of Variance (ANOVA) using R software. Differences between means were assessed using the least significance difference (LSD) test at $p<0.05$.

RESULTS AND DISCUSSION

Agronomic and chemical traits of oregano as affected by harvesting age and plant spacing: Analysis of variance showed that plant spacing had a very highly significant ($p \leq 0.001$) influence on fresh leaf weight per plant, fresh leaf yield per hectare and essential oil yield per hectare. Highly significantly ($p \leq 0.01$) influenced plant height. However, plant spacing had no significant effect on fresh stem weight and fresh above-ground biomass per plant. Similarly, harvesting age very highly significantly ($p \leq 0.001$) influenced plant height, fresh leaf weight per plant, fresh stem weight per plant and fresh above-ground biomass per plant and also, highly significantly ($p \leq 0.01$) influenced fresh leaf yield per hectare and essential oil yield per hectare (Table 1).

Plant height: The shortest plant 29.09 cm was recorded at narrow spacing whereas the tallest 33.36 cm was obtained from a wider spacing (Table 2). This result was in agreement with the result of Jimayu and Gebre[24] who reported that higher plant height was obtained at wider spacing for sage crops. This might be due to competition for resources by highly populated plants which can retard the normal plant growth. Plant height increased from 27.73 to 33.22 cm with increasing harvesting age from 3 to 5 months after planting (Table 2). This result was in agreement with the study of Jimayu and Gebre[24] plant height increased from 49.9 to 57.52 cm with increasing harvesting age from 3 to 5 months after planting for sage crop. Likewise, increasing plant height with prolonged harvesting age was also reported by Zigene *et al.*[25] for rosemary (*Rosemary officinalis* L.).

Fresh leaf weight per plant: The fresh leaf weight per plant was affected both by harvesting age and plant spacing of oregano. The fresh leaf weight per plant was increased with increasing plant spacing. The same result was reported by Degu *et al.*[23] and Zigene *et al.*[25] on lavender and rosemary. The minimum value (116.51 g/plant) was obtained at a narrow spacing of 30×30 cm and the maximum value (153.25 g/plant) was recorded from a wider spacing of 90×90 cm (Table 2). This might be due to low competition between plants and as a result maximum branches per plant, which contribute to maximum leaf number, were opined at wider spacing. The fresh leaf weight per plant was increased as harvesting age was delayed. The maximum fresh leaf weight (209.49 g/plant) was recorded 5 months after transplanting. Whereas the minimum (70.07 g/plant) was recorded from the earliest harvesting (3 months after transplanting). This might be due to the plant using all required resources for normal growth as harvesting age was delayed.

Fresh herbal yield per hectare: The fresh herbal yield per hectare of oregano was increased with decreasing plant spacing and the maximum value (6531.52 kg) was obtained at a narrow spacing (30×30 cm). The value ranged from 1190.13 to 6531.52 kg with plant spacing of 90×90 and 30 to 30 cm, respectively. This finding in line with, the decreasing fresh leaf yield per hectare with increasing plant spacing was reported by Degu *et al.*[26], Alemu *et al.*[27] on rosemary (*Rosemary officinalis* L.) and basil (*Ocimum basilicum* L.). In general, the highest leaf yield was obtained from narrow spacing; whereas; the lowest was from wider spacing. This may be due to a higher number of plants per unit area at lower plant spacing, resulting in the highest biomass per specific plot.

Essential oil yield (kg/ha): The essential oil yield recorded ranged from 19.67 to 42.51 kg with a spacing of 90×90 and 30×30 cm, respectively (Table 2). The highest essential oil yield recorded at closer spacing implies that the maximum biomasses recorded at populated plants were contributed by the maximum essential oil yield. This finding was also supported by the results of Alemu *et al.*[27] and Abewoy *et al.*[28] on basil (*Ocimum basilicum*). The increase in essential oil yield at higher densities might be due to the contribution of higher above-ground biomass recorded at the highest population density.

The minimum essential oil yield of 20.78 kg was recorded at harvesting 3 months after transplanting. Essential oil yield increased with increasing growth stage of the plant and reached maximum value 32.49 kg at 5 months after transplanting (Table 2). The present study was in line with the study of Tadesse *et al.*[20] who reported that higher essential oil yield, was obtained at prolonged

Table 1: Mean square of agronomic and chemical traits of oregano as affected by spacing and varieties

Source of variation	DF	PH	FLWPP	FSWPP	FAGBPP	FLYPH	EOYPH
Rep	2	63.85^{ns}	721^{ns}	136.4^{ns}	10284^{ns}	63148^{ns}	76.67^{ns}
Spacing	4	30.16**	1812***	44.7^{ns}	2301^{ns}	29417463***	89494***
Harvesting age	2	162.95***	70783***	10774.7***	113776***	10036883**	514.08**
SP×HG	8	6.07^{ns}	2173^{ns}	77.2^{ns}	1518^{ns}	3079215^{ns}	2.26^{ns}
Error	28	9.54	1196.12	127.87	3322.07	1519030	87.25
CV		10.01	24.8	23.37	33.01	27.88	32.03

***Significant at p<0.001, **Significant at p<0.01, *Significant at p<0.05, ns: Non significant at p<0.05, PH: Plant height, FLWPP: Fresh leaf weight per plant, FSWPP: Fresh stem weight per plant, FAGBPP: Fresh above ground biomass per plant, FLYPH: Fresh leaf yield per hectare, EOYPH: Essential oil yield per hectare, SP: Spacing and HG: Harvesting age

Table 2: Performance of agronomic and chemical traits of oregano as affected by spacing and harvesting age

Spacing (cm)	PH	FLWPP	FSWPP	FAGBP	FLYPH	EOYPH
30×30	29.03^{b}	116.51^{b}	44.67^{a}	149.58^{a}	6531.52^{a}	42.51^{a}
30×60	29.09^{b}	136.27^{ab}	50.28^{a}	183.64^{a}	5655.25^{ab}	28.96^{b}
60×60	31.07^{ab}	144.39^{ab}	48.45^{a}	190.24^{a}	4800.57^{b}	20.44^{bc}
60×90	31.67^{ab}	146.80^{ab}	46.48^{a}	168.83^{a}	2615.48^{c}	20.14^{bc}
90×90	33.36^{a}	153.25^{a}	49.13^{a}	180.68^{a}	2499.31^{c}	19.67^{c}
LSD (0.05)	2.98	33.4	10.79	55.65	1190.13	8.93
Harvesting age						
3 MAP	27.73^{c}	72.07^{c}	25.59^{c}	89.28^{c}	5353.21^{a}	20.78^{b}
4 MAP	31.27^{b}	136.84^{b}	40.24^{b}	171.13^{b}	4082.66^{b}	25.77^{ab}
5 MAP	33.22^{a}	209.49^{a}	77.57^{a}	263.37^{a}	3825.38^{b}	32.49^{a}
LSD (0.05)	2.31	25.86	8.36	43.11	921	6.92

PH: Plant height, FLWPP: Fresh leaf weight per plant, FSWPP: Fresh stem weight per plant, FAGBPP: Fresh above ground biomass per plant, FLYPH: Fresh leaf yield per hectare, EOYPH: Essential oil yield per hectare, 3 MAP: Three months after planting, 4 MAP: Four months after planting and 5 MAP: 5 months after planting. Numbers having a common letter(s) do not differ significantly at p<0.05

harvesting age of Brachiaria. Similar to this finding, lower essential oil yield at a younger age and an increased value of these parameters with increasing age were reported for rosemary[25]. The trend of increasing essential oil with increasing plant age was reported by Alemu *et al*.[27] and Sigaye *et al*.[29] on basil (*Ocimum basilicum*). The maximum essential oil yield per hectare obtained at prolonged harvesting age may be due to the maximum above-ground biomass produced at this stage.

CONCLUSION

The study also showed that both the amount of herbage and essential oil produced were significantly affected by the age at which the plants were harvested. This could be because the plants need a certain amount of time to grow to produce a high yield. Overall, the study demonstrated that both the spacing and age at which oregano plants are harvested have a significant impact on their growth and yield. The highest essential oil yield (42.51 and 32.49 kg/ha) was obtained from plants spaced 30×30 cm apart and harvested five months after planting. Since the experiment was only carried out in one location and season, it is recommended that it be repeated in different seasons and agricultural environments.

SIGNIFICANCE STATEMENT

The medicinal uses of oregano are significant because of its antimicrobial, antifungal, antioxidant, antibacterial, antithrombin, antimutagenic, angiogenic, antiparasitic and antihyperglycemic actions. This study aimed to determine the optimal plant spacing and harvesting age to maximize the production of herbal and essential oils from oregano. The result confirmed that narrow spacing and 5 months after planting yielded the highest essential oil yield. Further investigation, including different locations, is recommended in the future.

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