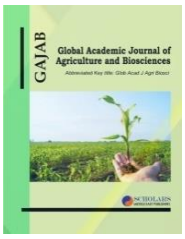
Global Academic Journal of Agriculture and Bio sciences

Available online at https://www.gajrc.com
DOI: https://doi.org/10.36348/gajab.2024.v06i06.005

OPEN ACCESS



ISSN:2706-8978 (P)
ISSN: 2707-2568 (O)

Original Research Article

Growth, Yield and Yield Components of Lavender (*Lavandula angustifolia* L.) as Influenced by Plant Spacing and Harvesting Age

Basazinew Degu[1*], Sulti Amano[1]
[1]Ethiopian Institute of Agricultural Research, Wondo Genet Agricultural Research Center, P.O. Box 198, Shashemene, Ethiopia

***Corresponding Author**
Basazinew Degu
Ethiopian Institute of Agricultural Research, Wondo Genet Agricultural Research Center, P.O. Box 198, Shashemene, Ethiopia

Article History
Received: 06.11.2024
Accepted: 12.12.2024
Published: 14.12.2024

Abstract: Lavender (*Lavandula angustifolia* L.) is the most important aromatic and medicinal plant in the world grown for its essential oil predominantly extracted from its aromatic leaves and inflorescence. The experiment was conducted with irrigation supplement during the 2017, and 2018 cropping seasons at the Wondo Genet Agricultural Research Center experimental field in Southern Ethiopia. One of the study's goals was to investigate the ideal plant spacing and harvesting age for lavender growth, yield, and yield components under supplemental irrigation circumstances. Three levels of harvesting ages following transplant (9, 10, and 11 months after transplanting (MAT)) and four levels of intra-row spacing (45, 60, 75, and 90 cm) with an inter-row spacing of 60 cm made up the experiment. Three replications were used in the factorial arrangement in the Randomized Complete Block Design (RCBD) experiment. The combined analysis's findings showed that the number of branches per plant, fresh leaves and inflorescence weight/plant, fresh leaves and inflorescence yield/ha, and essential oil yield/ha were all significantly impacted by plant spacing. Conversely, it had no discernible impact on the amount of essential oil or plant height. Plant height, fresh leaf, and inflorescence weight/plant, inflorescence yield/ha, and essential oil yield/ha were significantly impacted by harvesting age, but not the number of branches/plants. Fresh leaf and inflorescence yield/ha and essential oil yield/ha were significantly influenced by the interaction of plant spacing and harvesting age. The highest essential oil yield/ha (98.72 kg) and fresh leaf and inflorescence yield/ha (24.56 t) were achieved at 10 MAT and 60*45 cm spacing. Conversely, the 60*90 cm spacing and 11 MAT had the lowest essential oil yield/ha (34.42 kg). Therefore, it is highly recommended to grow Lavender with a supplement of irrigation at Wondo Genet and a place that has the same agroecology with a spacing of 60*45 cm and harvest it at 10 MAT to get the highest essential oil yield/ha.

Keywords: Essential Oil Content, Essential Oil Yield, Harvesting Age, *Lavandula angustifolia* L., Plant Spacing.

INTRODUCTION

Lavender (*Lavandula angustifolia* L.) is a perennial shrub that belongs to the Lamiaceae family. According to Shawl and Kumar (2000), it is a commercial crop in France, Spain, Portugal, Hungary, the United Kingdom, Bulgaria, Australia, China, and the United States. It is indigenous to southern Europe and the Mediterranean region. The essential oil is

extracted from the plant's fragrant inflorescence, which is the main reason it is grown, however both fresh and dried flowers are sold (Renaud *et al*., 2001). Aromatherapy and massage are two prominent uses for lavender essential oil.

The central nervous system is the site of its primary therapeutic advantages (Chu and Kemper, 2001). In addition, the essential oil lavender is widely utilized in the flavor, cosmetic, and perfumery sectors and is renowned for its wonderful aroma. According to Cavanagh and Wilkinson (2005), the oil is recognized to have anti-inflammatory, anti-depressant, carminative, and sedative qualities. Moreover, according to Chu and Kemper (2001), lavender extracts have been used historically as diuretics, antidepressants, antispasmodics, anti-flatulent agents, and antiemetic remedies. They have also been prescribed to treat fever, infection, anxiety, and infertility. In aromatherapy and as a holistic relaxant to treat stress, anxiety, depression, exhaustion, or insomnia, its essential oil has established a solid reputation (Chu and Kemper, 2001). According to studies, the scent of lavender during recess may help Alzheimer's patients' memory and cognition (Adsersen *et al*., 2005) and may also prevent deterioration of work performance (Sakamoto *et al*., 2005).

Plant genetics (Shafie *et al*., 2009), climate, edaphic, elevation, topography, and the interplay of multiple factors all influence the growth, yield, and yield components of plants (Rahimmalek *et al*., 2009). Crop management techniques like plant spacing and harvesting age are among these variables. The growth, biomass, and oil yield of lavender (Basazinew and Sulti, 2020), rose-scented geranium (Haileslassie and Kebede, 2015), and artemisia (Zewdinesh *et al*., 2011) were influenced by plant spacing and harvesting age. Lemongrass yield and yield-related characteristics were impacted by harvesting age (Jimayu *et al*., 2016; Lulie and Chala, 2016; Jimayu and Gebre, 2017).

Despite its numerous applications, little is known about the agronomic management techniques of lavender growing under supplemental irrigation conditions globally, including in Ethiopia. This would lead to the crop being grown without knowledge of the proper management techniques. Lavender production and productivity are lowered as a result. To minimize the decline in lavender's growth, yield, and yield components, research is helpful. Thus, the aim of this study was to examine the ideal plant spacing and harvesting age for L. angustifolia L. growth, yield, and yield component under conditions of supplemental irrigation.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted at the Wondo Genet Agricultural Research Center experimental field, Southern Ethiopia during the 2017 and 2018 cropping seasons with the supplement of irrigation. The center is located at latitude 7°19'N and longitude 38°38' E with an altitude of 1780 meters above sea level (m.a.s.l.). The area receives mean annual rainfall of 1128 mm with mean maximum and minimum temperatures of 26.2 ^{0}C and 11 ^{0}C, respectively. The soil textural class of the study area is sandy loam with a pH of 6.4 (Abayneh *et al.,* 2006). These environmental conditions are conducive for lavender cultivation.

Plant Materials, Experimental Design, and Field Management

Lavender (Variety WG-Lavender-II) was planted at different intra-spaced (45, 60, 75, and 90 cm) with the inter-raw spacing of 60 cm at Hawassa in South Ethiopia were harvested at three different months after transplant (9, 10, and 11 months after transplanting (MAT)) used for the study. The experiment was laid out by using a randomized complete block design with three replications as a factorial arrangement. The gross plot size of each treatment was 3.6m x 3.6m. The distance between plots and replications was 1 m and 2 m, respectively. Healthy and uniform seedlings were transplanted from the nursery to the open field condition after two months of establishment. Transplanting of seedlings took place at the commencement of the main rainy season after the land was prepared well. Proper hoeing, watering, and weeding were carried out as required.

Data Collection

During the study the following data were collected. The characters that demonstrated for data collection are:

Plant Height (Cm):

It was measured in centimeter from the base of the randomly selected plants to tip of the main stem by using a tape meter; then the average height was determined.

Number of Branches per Plant:

The total numbers of branches arising from the main stem were counted manually and the average value was determined.

Fresh Leaf and Inflorescence Weight/Plant (g):

The average fresh leaf and inflorescence weight of the randomly selected plants was immediately recorded after the leaves and inflorescence were separated from the stem.

Fresh Leaves and Inflorescence Yield (t/ha):

All plants from the central rows of each plot were harvested and fresh leaf and ***inflorescence*** yield per net plot was estimated and then converted into tons per hectare.

Essential Oil Content (%):

Essential oil content was obtained by hydro-distillation, according to the procedure described by Daniel *et al*., (2009). The fresh leaves and inflorescence of lavender were placed in the round bottom flask and subjected to hydro-distillation in a Clevenger apparatus. Then, harvested plants were separated into leaves, inflorescence, and stem, fresh leaves and inflorescence having biomass of 300 g composite sample were charged in the Clevenger apparatus along with 700 ml of water and trapped for 3 hours. Water was poured into the flask until the plant part was submerged completely. The flask was placed on the heating mantle and the water and plant sample could boil for 3 hours the essential oil were collected and measured by using a pipette reading. The percentage of essential oil content was determined by the following formula:

$$Essential\ oil\ content\ \left(\%\frac{w}{w} fresh\ basis\right) = \frac{Weight\ of\ oil}{Weight\ of\ sample}\ X\ 100 \quad (1)$$

Essential Oil Yield (kg/ha):

The volume of essential oil collected in the collecting tube of the apparatus dehydrated, measured, and expressed on weight by weight (%w/w) fresh basis. Then the essential oil yield/ha was determined by the following formula.

$$EOY\ \left(\frac{kg}{ha}\right) = \frac{FLIY\ \left(\frac{kg}{ha}\right) X\ EOC\ (\%\ w/w)}{100} \quad (2)$$

Where, EOY = Essential oil yield, FLFY = Fresh leaves and inflorescence yield, and EOC = Essential oil content.

Data Analysis

The collected data were subjected to analysis of variance (ANOVA) using SAS version 9.0 (SAS, 2000) statistical software packages. Means were separated using the Least Significant Difference (LSD) procedure at the 5% and 1% level of significance. The following meteorological data were collected from the Hawassa substation during the 2017 to 2018 cropping seasons (Figure 1).

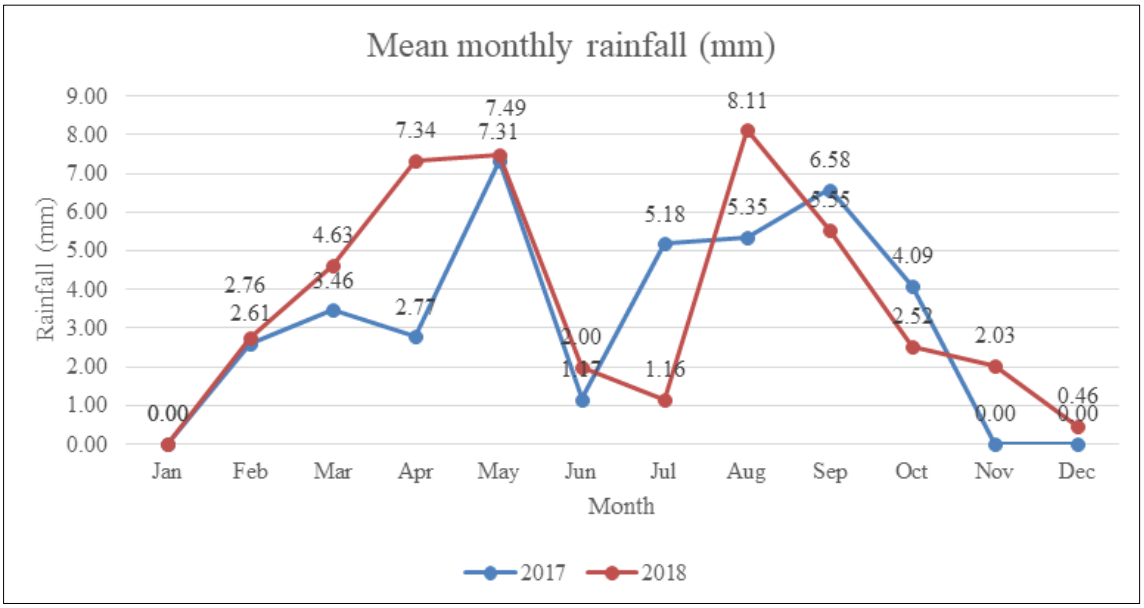


Figure 1: Mean monthly rainfall (mm) at Wondo Genet during 2017 and 2018 cropping seasons- (Source: NMA Hawassa Branch)

RESULT AND DISCUSSION

Plant Height (cm)

Plant height was not significantly ($p>0.05$) affected by the main effect of plant spacing. Supporting results by El Naim *et al*., (2012) and Basazinew and Sulti (2020) reported that crop density had no significant effect on plant height of roselle and lavender plants, respectively. The contrary result reported by Zewdinesh *et al*., (2011) on Artemisia and Degu and Tesfaye (2015) on roselle plants reported an increase in plant population markedly increase plant height.

However, in the 2018 cropping season and the combined analysis result, the main effect of harvesting age had a significant ($p<0.001$) effect on plant height (Table 1). Similar results were reported by Zewdinesh *et al*., (2011) on Artemisia and Haileslassie and Kebede (2015) on rose-scented geranium. From the combined analysis of results, the highest (84.03cm) and the least (64.63 cm) plant height was obtained at 10 and 9 MAT, respectively (Table 1). As the harvesting age increased up to 10 MAT, plant heights also increased, and then declined when harvested at a later age. This might be due to the drying of the flower stalk at 11 MAT. The interaction effect of plant spacing and harvesting age did not significantly ($p>0.05$) affect plant height (Table 1). A similar result was reported by Haileslassie and Kebede (2015) on rose-scented geranium. This means that the same letter in the same column is not significantly different.

Table 1: Effect of plant spacing and harvesting age on plant height (cm) and number of branches per plant of *L. angustifolia* L. at Wondo Genet from 2017 to 2018

Treatment & Statistics	Plant height (cm)			Number of branches per plant		
	2017	2018	Combined mean	2017	2018	Combined mean
Plant spacing (cm)						
60*45	91.31	57.09	74.2	90.24^{b}	168.62	129.43^{b}
60*60	92.09	57.29	74.69	106.09^{a}	177.29	141.69^{ab}
60*75	97.98	54.18	82.19	116.87^{a}	195.04	155.96^{a}
60*90	90.91	55.22	73.07	114.91^{a}	202.09	158.5^{a}
LSD (0.05)	5.65	5.38	10.4	12.84	33.11	19.8
Significance	NS	NS	NS	***	NS	*
Harvesting age (MAT)						
9	91.88	37.37^{b}	64.63^{b}	86.60^{c}	171.17^{b}	128.88^{b}
10	93.02	65.88^{a}	84.03^{a}	111.23^{b}	163.05^{b}	137.14^{b}
11	94.32	64.58^{a}	79.45^{a}	123.25^{a}	223.07^{a}	173.16^{a}
LSD (0.05)	4.89	4.66	9.01	11.12	28.68	17.15
Significance	NS	***	***	***	***	***
Spa * HA	NS	NS	NS	NS	NS	NS
CV (%)	6.21	9.84	14	12.28	18.23	13.84

Where, MAT = Months after Transplanting, LSD = Least Significance Difference, CV = Coefficient of Variation, Spa = Plant spacing, HA= Harvesting age, NS= Nonsignificant at 0.05 probability level, * = Significant at 0.05 probability level, and *** =Significant at0.001 probability level.

Number of Branches per Plant

The number of branches per plant varied in the 2017 and 2018 cropping seasons. In the 2017 season, the number of branches per plant was significantly ($p<0.001$) affected by the main effect of plant spacing, but not affected in 2018. However, the combined analysis result showed, that plant spacing had a significant ($p<0.05$) effect on the number of branches per plant (Table 1). In line with the result reported by Zewdinesh *et al*., (2011) on Artemisia, Haileslassie and Kebede (2015) on rose-scented geranium, and Basazinew and Sulti (2020) on Lavender. The highest (116.87 and 158.5) number of branches per plant was obtained when the tested crop was planted at a spacing of 60*75 cm (in 2017) and 60*90 cm (on the combined result), respectively. Based on the combined result, the number of branches per plant increased in wider spacing (Table 1). This could be due to, at wider spacing there will be a reduced competition of plants for available resources such as light, water, and nutrients. This creates favorable conditions to increase and develop the number of branches in a given plant. Likewise, harvesting age had a significant ($p<0.001$) effect on number of branches per plant (Table 1). This result is in line with the finding of Haileslassie and Kebede (2015) on rose-scented geranium. A contrasting result was reported by Zewdinesh *et al*., (2011) on Artemisia. Combined analysis results revealed that the highest (173.16) and the least (128.88) number of branches per plant was obtained at 11 and 9 MAT, respectively (Table 1). As later harvesting age, the number of branches per plant increased. This might be due to the development of branches on the main stem from the existing lateral buds.

The interaction effect of plant spacing and harvesting age did not significantly ($p>0.05$) affect the number of branches per plant (Table 1). Similar results were reported by Zewdinesh *et al*., (2011) on Artemisia, Haileslassie and Kebede (2015) on rose-scented geranium, and Basazinew and Sulti (2020) on Lavender.

Fresh Leaves and Inflorescence Weight per Plant (g)

At each cropping season and combined analysis result, fresh leaves and inflorescence weight

per plant were significantly (p≤0.01) affected by plant spacing (Table 2). A similar result was reported by Basazinew and Sulti (2020) on Lavender. Based on the combined analysis result, the highest (644.67 g) and least (454.89 g) fresh leaves and inflorescence weight per plant was obtained at 60*90 cm and 60*45 cm plant spacing, respectively (Table 2). At the widest plant spacing competition of plants for light, water, and minerals is reduced. This would be attributed to the increase in fresh leaves and inflorescence weight per plant.

Likewise, harvesting age had a significant (p<0.001) effect on fresh leaves and inflorescence weight per plant (Table 2). Similar results were reported by Beemnet *et al*., (2011) on pepper mint, Tadesse *et al*., (2016) on stevia, and Basazinew and Sulti (2020) on Lavender. Based on the combined analysis result, the highest (749.79 g) and least (450.29 g) fresh leaves and inflorescence weight per plant were obtained at 10 and 9 MAT, respectively (Table 2). At later harvest (11 MAT), the fresh leaves and inflorescence weight per plant started to decline. This could be due to the drying of most of the already-developed inflorescence stalks and older leaves on each plant.

The interaction effect of plant spacing and harvesting age did not significantly (p>0.05) influence fresh leaves and inflorescence weight per plant (Table 2).

Fresh Leaves and Inflorescence Yield (t/ha)

Plant spacing had a significant (p<0.001) effect on fresh leaves and inflorescence yield/ha (Table 2). Similar results were reported by Haileslassie and Kebede (2015) on rose-scented geranium, Jimayu *et al*., (2016) on Lemongrass, and Basazinew and Sulti (2020) on Lavender. Based on the combined analysis of results, the highest (16.85 t) and least (11.94 t) fresh leaves and inflorescence yield/ha were obtained at 60*45 cm and 60*90 cm plant spacing, respectively. At the closest spacing, there are many plants per unit area. This would be attributed to the increase in fresh leaves and inflorescence yield/ha.

Likewise, harvesting age had a significant (p<0.001) effect on fresh leaves and inflorescence yield/ha (Table 2). Similar results were reported by Beemnet *et al*., (2011) on peppermint, Haileslassie and Kebede (2015) on rose-scented geranium, and Basazinew and Sulti (2020) on Lavender. The combined analysis result revealed that, the highest (19.59 t) and least (11.44 t) fresh leaves and inflorescence yield/ha was obtained at 10 and 9 MAT, respectively (Table 2). At later harvest (11 MAT), the fresh leaves and inflorescence yield/ha started to decline. As to fresh leaves and inflorescence weight per plant, this could be due to the drying of most of the already-developed inflorescence stalks and older leaves on each plant.

The interaction effect of plant spacing and harvesting age did not significantly (p>0.05) affect fresh leaves and inflorescence yield/ha in 2018. Whereas, it had a significant (p≤0.05) effect on fresh leaves and inflorescence yield/ha in 2017 and combined result, respectively (Table 2). The result obtained in this study is consistent with the report of Haileslassie and Kebede (2015) on rose-scented geranium and Jimayu and Gebre (2017) on Lemongrass. Based on the combined analysis result, the highest (24.56 t) fresh leaves and inflorescence yield/ha was obtained when lavender was planted at 60*45 cm plant spacing and harvested at 10 MAT; whereas, the least (9.79 t) fresh leaves and inflorescence yield/ha was obtained when it was planted at 60*90 cm plant spacing and harvested at 9 MAT followed by 11 MAT (Table 4).

Table 2: Effect of plant spacing and harvesting age on fresh leaves and inflorescence weight per plant (g) and fresh leaves and inflorescence yield (t/ha) of *L. angustifolia* L. at Wondo Genet during 2017 and 2018 cropping seasons

Treatment & Statistics	Fresh leaves and inflorescence weight per plant (g)			Fresh leaves and inflorescence yield (t/ha)		
	2017	2018	Combined mean	2017	2018	Combined mean
Plant spacing (cm)						
60*45	451.04^{b}	458.73^{c}	454.89^{c}	16.70^{a}	16.99^{a}	16.85^{a}
60*60	617.92^{a}	539.48^{b}	578.7^{b}	17.17^{a}	14.99^{a}	16.07^{a}
60*75	651.48^{a}	546.87^{ab}	599.18^{ab}	15.08^{a}	12.66^{b}	13.87^{b}
60*90	672.17^{a}	617.17^{a}	644.67^{a}	12.45^{b}	11.43^{b}	11.94^{c}
LSD (0.05)	98.23	76.99	57.03	2.45	2.09	1.53
Significance	***	**	***	***	***	***
Harvesting age (MAT)						
9	577.45^{b}	323.12^{c}	450.29^{c}	14.62^{b}	8.27^{c}	11.44^{c}
10	712.71^{a}	786.88^{a}	749.79^{a}	18.71^{a}	20.47^{a}	19.59^{a}
11	504.30^{b}	511.68^{b}	507.99^{b}	12.72^{b}	13.31^{b}	13.02^{b}

Treatment & Statistics	Fresh leaves and inflorescence weight per plant (g)			Fresh leaves and inflorescence yield (t/ha)		
	2017	2018	Combined mean	2017	2018	Combined mean
LSD (0.05)	85.24	66.67	49.39	2.12	1.81	1.32
Significance	***	***	***	***	***	***
Spa * HA	NS	NS	NS	*	NS	**
CV (%)	16.83	14.57	10.24	16.33	15.27	10.65

Means with the same letters in the same column are not significantly different.

Where, MAT = Months after transplanting, LSD = Least significance difference, CV = Coefficient of variation, Spa = Plant spacing, HA= Harvesting age, NS = Nonsignificant at 0.05 probability level, * = Significant at 0.05 probability level, ** = Significant at 0.01 probability level and *** =Significant at 0.001probability level.

Essential Oil Content (%)

Essential oil content was not significantly (p>0.05) affected by plant spacing in both cropping seasons and combined result (Table 3). Supporting results were reported by Lule and Chala (2016), and Basazinew and Sulti (2020) who showed that spacing would not affect the essential oil content of lemongrass and Lavender, respectively.

Whereas, harvesting age exerted a significant (p<0.05) effect on essential oil content in the 2018 cropping season. A similar result was reported by Haileslassie and Kebede (2015) on rose-scented geranium. The highest (0.51%) and least (0.33%) essential oil content was obtained at 9 and 11 MAT, respectively (Table 3). This could be due to the senescence/drying of most of the ***inflorescence*** and older leaves of the plant when it was harvested at 11 MAT. However, harvesting age did not significantly (p>0.05) affect essential oil content in 2017 and combined result (Table 3).

Essential oil content was not significantly (p>0.05) affected by the interaction effect of both factors (Table 3). This result is in line with, the findings of Beemnet *et al*., (2011) on peppermint and Zewdinesh *et al*., (2011) on Artemisia. A contrasting result was reported by Haileslassie and Kebede (2015) on rose-scented geranium.

Essential Oil Yield/Ha (kg)

Essential oil yield/ha was not significantly (p>0.05) affected by plant spacing in the 2017 cropping season. However, it had a significant (p≤0.01) effect on essential oil yield/ha in the 2018 cropping season and combined result (Table 3). Similar results were reported by Zewdinesh *et al*., (2011) on Artemisia, Haileslassie and Kebede (2015) on rose-scented geranium, Jimayu *et al*., (2016) on Lemongrass, and Basazinew and Sulti (2020) on Lavender. Based on the combined result, the highest (65.04 kg) and least (41.47 kg) essential oil yield/ha was obtained at 60*45cm and 60*90 cm plant spacing, respectively (Table 3). This might be due to an increase in fresh leaves and inflorescence yield/ha in closest spacing would be attributed to an increase in essential oil yield/ha.

Table 3: Effect of plant spacing and harvesting age on essential oil content (%) and essential oil yield/ha (kg) of *L. angustifolia* L. at Wondo Genet during 2017 and 2018

Treatment & Statistics	Essential oil content (%)			Essential oil yield/ha (kg)		
	2017	2018	Combined mean	2017	2018	Combined mean
Plant spacing (cm)						
60*45	0.36	0.42	0.39	59.41	70.67^{a}	65.04^{a}
60*60	0.32	0.46	0.39	54.58	71.30^{a}	62.94^{a}
60*75	0.33	0.48	0.41	49.4	58.17^{ab}	53.79^{ab}
60*90	0.32	0.39	0.36	39.88	43.06^{b}	41.67^{b}
LSD (0.05)	0.12	0.11	0.08	20.88	19.72	13.06
Significance	NS	NS	NS	NS	*	**
Harvesting age (MAT)						
9	0.33	0.51^{a}	0.42	48.59	42.48^{b}	45.43^{b}
10	0.31	0.47^{a}	0.39	60.08	96.07^{a}	78.08^{a}
11	0.35	0.33^{b}	0.35	43.79	44.06^{b}	43.92^{b}
LSD (0.05)	0.1	0.09	0.07	18.08	17.08	11.31
Significance	NS	**	NS	NS	***	***
Spa * HA	NS	NS	NS	NS	NS	*
CV (%)	36.42	24.56	20.86	42.02	33.18	23.94

Means with the same letters at the same column are not significantly different.

Where, MAT = Months after transplanting, LSD = Least significance difference, CV = Coefficient of variation, Spa = Plant spacing, HA= Harvesting age, NS = Nonsignificant at 0.05 probability level, * = Significant at 0.05probability level, ** = Significant at 0.01 probability level and *** =Significant at 0.001probability level.

Likewise, harvesting age did not significantly ($p>0.05$) affect essential oil yield/ha in the 2017 cropping season. However, it had a significant ($p<0.001$) effect on essential oil yield/ha in the 2018 cropping season and combined result (Table 3). A similar result was reported by Haileslassie and Kebede (2015) on rose-scented geranium, and Basazinew and Sulti (2020) on Lavender. From the combined result, the highest (78.08 kg) and least (43.92 kg) essential oil yield/ha was obtained when lavender was harvested at 10 and 11MAT, respectively (Table 3). This could be due to the senescence/drying of most of the *inflorescence* and older leaves of the plant when it was harvested at 11 MAT. This would result in the decline of essential oil yield/ha.

The interaction effect of plant spacing and harvesting age did not significantly ($p>0.05$) affect essential oil yield/ha in the 2017 cropping season. Whereas, it had a significant ($p<0.05$) effect on essential oil yield/ha in the 2018 cropping season and combined result (Table 3). Similar results were reported by Haileslassie and Kebede (2015) on rose-scented geranium, and Basazinew and Sulti (2020) on Lavender. The highest (98.72 kg) essential oil yield/ha was obtained when lavender was planted at 60*45 cm plant spacing and harvested at 10 MAT; whereas, the least (34.42 kg) essential oil content was obtained when it was planted at 60*90 cm plant spacing and harvested at 11 MAT (Table 4).

Table 4: Interaction effect of plant spacing and harvesting age on fresh leaves and inflorescence yield (t/ha) and essential oil yield (kg/ha) of *L. angustifolia* at Wondo Genet during 2017 and 2018 cropping seasons

Treatment & Statistics	Fresh leaves and inflorescence yield (t/ha)			Essential oil yield (kg/ha)		
	Harvesting age (MAT)			Harvesting age (MAT)		
	9	10	11	9	10	11
Plant spacing (cm)						
60*45	11.67^{efg}	24.56^{a}	14.32^{d}	44.55^{bc}	98.72^{a}	53.73^{bc}
60*60	12.88^{def}	21.14^{b}	14.20^{de}	49.41^{bc}	98.27^{a}	41.14^{bc}
60*75	11.43^{fg}	17.46^{c}	12.71^{def}	51.50^{bc}	61.58^{b}	48.28^{bc}
60*90	9.79^{g}	15.20^{cd}	10.83^{fg}	36.26^{c}	53.73^{bc}	34.42^{c}
LSD (0.05)	2.65			22.62		

Means with the same letters in the same column are not significantly different.

CONCLUSION AND RECOMMENDATION

The combined result revealed that plant spacing had a significant effect on the number of branches per plant, fresh leaves and inflorescence weight/plant, fresh leaves and inflorescence yield/ha, and essential oil yield/ha. The highest number of branches per plant (158.5) and fresh leaves and inflorescence weight/plant (644.67 g) was obtained at the spacing of 60*90 cm; fresh leaves and inflorescence yield/ha (16.85 t) and essential oil yield/ha (65.04 kg) was obtained at a spacing of 60*45cm. Whereas, harvesting age had a significant effect on all tested parameters except essential oil content. The highest plant height (84.03 cm), fresh leaves and inflorescence weight/plant (749.79 g), fresh leaves and inflorescence yield/ha (19.59 kg), and essential oil yield/ha (78.08 kg) were obtained at 10 MAT; however, the least plant height (64.63cm), fresh leaves and inflorescence weight/plant (450.29 g), fresh leaves and inflorescence yield/ha (11.44 kg) were obtained at 9 MAT; and essential oil yield/ha (43.92 kg) was obtained at 11 MAT followed by 9 MAT. Moreover, the interaction effect did not significantly affect all the tested parameters except fresh leaves and inflorescence yield/ha and essential oil yield/ha. The highest fresh leaves and inflorescence yield/ha (24.56 t) and essential oil yield/ha (98.72 kg) were obtained when lavender was planted at 60*45 cm and harvested at 10 MAT. Whereas, the least essential oil yield/ha (34.42 kg) was obtained when it was planted at 60*90 cm and harvested at 11 MAT. Therefore, to get the highest essential oil yield/ha of lavender at Wondo Genet and a place that has the same agroecology under supplemental irrigation conditions, it is better to plant it at a spacing of 60*45 cm and harvest at 10 MAT is highly recommended.

ACKNOWLEDGMENT

Ethiopian Institute of Agricultural Research (EIAR) and Wondo Genet Agricultural Research Center are acknowledged for financial and technical support of this study. We are also grateful to Mr. Yigermal Molla and Mr. Admasu Usur for their technical support.

REFERENCES

- Abayneh, E., Demeke, T., & Ashenafi, A. (2006). Soils of Wondo Genet Agricultural Research Center. *National soil Research Center. 67pp*.
- Adsersen, A., Gauguin, B., Gudiksen, L., & Jäger, A. K. (2006). Screening of plants used in Danish folk medicine to treat memory dysfunction for acetylcholinesterase inhibitory activity. *Journal of ethnopharmacology*, *104*(3), 418-422.
- Beemnet, M. K., Solomon, A. M., & Jaime, A. T. da Silva. (2011). Agronomic Characters, Leaf and Essential Oil Yield of Peppermint (*Mentha piperita* L.) *As Influenced by Harvesting Age and Row Spacing. Medicinal and Aromatic Plant Science and Biotechnology*, *5*(1) 49 – 53.
- Cavanagh, H. M., & Wilkinson, J. M. (2005). Lavender essential oil: a review. *Australian infection control*, *10*(1), 35-37.
- Chu, C. J., & Kemper, K. J. (2001). Lavender (*lavandula* ssp.). Retrieved July 24, 2008 from http://www.longwoodherbal.org/lavender/lavender.pdf.
- Damtew, Z., Tesfaye, B., & Bisrat, D. (2011). Leaf, essential oil and artemisinin yield of artemisia (Artemisia annua L.) as influenced by harvesting age and plant population density. *World Journal of Agricultural Sciences*, *7*(4), 404-412.
- Degu, B., & Amano, S. (2020). Effect of harvesting age and plant spacing on growth, yield and yield component of Lavender (Lavandula angustifolia L.) under Rainfed condition at Hawassa, Southern Ethiopia. *International Journal of Research Studies in Agricultural Sciences*, *6*(6), 17-24.
- Degu, B., & Tesfaye, B. (2016). Effects of inter and intra row spacing on growth, yield and yield components of Roselle (*Hibiscus sabdariffa* L.). *International Journal of Advanced Biological and Biomedical Research, 5*(1), 260-274.
- El-Naim, A. M., Khaliefa, E. H., Ibrahim, K. A., Ismaeil, F. M., & Zaied, M. M. B. (2012). Growth and yield of Roselle (Hibiscus sabdariffa l.) as influenced by plant population in arid tropic of Sudan under rain-fed.
- Haileslassie, G., & Kebede, W. (2015). Effect of plant spacing and harvesting age ongrowth, biomass and oil yield of rose-scented geranium (*Pelargonium graveolens* L. Herit). *Basic Research Journal of Agricultural Science and Review, 4*(3), 094-101.
- Jimayu, G., & Gebre, A. (2017). Influence of harvesting age on yield and yield related traits of lemongrass (Cymbopogon Citratus L.) varieties at Wondo genet, southern Ethiopia. *Academic Research Journal of Agricultural Science and Research*, *5*(3), 210-215.
- Jimayu, G., Gebre, A., & Mengesha, B. (2016). Response of lemongrass (Cymbopogon citratus L) varieties for different intra and inter row spacing at Wondo genet, Southern Ethiopia. *Academic Research Journal of Agricultural Science and Research*, *4*(6), 279-284.
- Lulie, B., & Chala, M. (2016). Influence of Plant Population Density on Growth and Yield of Lemon Grass (Cymbopogon citratus L.) at Wondo Genet, South Ethiopia. *Academic Research Journal of Agricultural Science and Research*, *4*(3), 76-84.
- Rahimmalek, M., Bahreininejad, B., Khorrami, M., & Sayed Tabatabaei, B. E. (2009). Genetic variability and geographic differentiation in Thymus daenensis subsp. daenensis, an endangered medicinal plant, as revealed by inter simple sequence repeat (ISSR) markers. *Biochemical genetics*, *47*, 831-842.
- Renaud, E. N. C., Charles, D. J., & Simon, J. E. (2001). Essential oil quantity and composition from 10 cultivars of organically grown lavender and lavandin. *J. Essent. Oil Res, 13*, 269–273.
- Sakamoto, R., Minoura, K., Usui, A., Ishizuka, Y., & Kanba, S. (2005). Effectiveness of aroma on work efficiency: lavender aroma during recesses prevents deterioration of work performance. *Chemical Senses*, *30*(8), 683-691.
- SAS inst., 2000. SAS (Statistical Analysis System), 1996. SAS/STAT. Guide Version 9. SAS, Institute Inc. Raleigh, North Carolina: USA.
- Shafie, M. S. B., Zain, H. S. M., & Shah, M. S. (2009). Study of genetic variability of Wormwood capillary (*Artemisia capillaris*) using inter simple sequence repeat (ISSR) in Pahang region, Malaysia. *Plant Omics J, 2*(3), 127–134.
- Shawl, A. S., & Kumar, S. (2000). Potential of lavender oil industry in Kashmir. *Journal of Medicinal and Aromatic Plant Sciences*, *22*, 319-321.
- Tadesse, N., Gebere, A., Lulie, B., & Hordofa, M. (2016). Influence of plant population density on growth and yield of Stevia (Stevia rebaudiana Bertoni L.) at Wondo Genet South Ethiopia. *Acad. Res. J. Agri. Sci. Res*, *4*(6), 321-329.