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Effects of Plant Spacing and Harvesting Age on Growth and Yield of Sage (Salvia officinalis L

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ABSTRACT

The experiment was conducted at Wondo Genet Agricultural Research Center, Southern Ethiopia from 2015 to 2017 cropping seasons to determine the optimum harvesting age and plant spacing of sage to maximize essential oil yield. The experimental design was RCBD in factorial arrangement with three replications. The treatments were four harvesting ages (3, 4, 5 and 6) months after planting and three plant spacing (30 cm × 30 cm, 60 × 60 cm and 90 × 90 cm). The study showed that spacing had a highly significant ($p \leq 0.001$) influence on fresh leaf weight per plant, dry leaf weight per plant and essential oil yield per hectare; highly significantly ($p \leq 0.01$) influenced plant height and dry herbage yield per hectare, significantly ($p \leq 0.05$) influenced fresh herbage yield and non-significantly influenced essential oil content. On the other hand, harvesting age highly significantly ($p \leq 0.001$) influenced plant height, fresh leaf weight per plant, dry herbage yield per hectare, essential oil content and essential oil yield; and also, significantly ($p \leq 0.05$) influenced dry leaf weight per plant. The highest essential oil yield (98.16 and 106.73 kg/ha) were obtained from 30 × 30 cm spacing and five months after planting respectively.

Key words: Essential oil, Leaf yield, Herbage yield.

INTRODUCTION

Sage can refer to plants in the genus Salvia, Family Lamiaceae (formerly Labiatae), which contains around 750 species of herb, sub-shrub and shrub growing in dry, stony areas around the world (Hortus, 1976). Sage has been cultivated as a spice plant for many centuries (Prakash, 1990), with reports of its medicinal properties dating back to the Middle Ages (Low *et al.*, 1994). Common or Garden Sage is native to the Mediterranean area, and can be found spreading profusely over the hillsides and shores of southern Europe (Prakash, 1990).

Sages are used as a culinary herb and are now naturalized throughout the world. It is produced commercially in a number of countries for both its essential oil and dried herbage. Sage is recognized as an important herb in western cooking, and is used in the making of poultry stuffings and the flavouring of meat and fish dishes. The food industry uses dried Sage to flavour meats, sausages and poultry stuffings (Prakash, 1990). Sage oil is used in perfumes, as deodorant, insecticidal treatments for thrush and gingivitis, and as a calmative (Prakash, 1990). Sage is used for excessive sweating, nervous disorders, as a calmative, and to reduce nursing mothers' milk when weaning. It is also recommended as a gargle, and lotions for wounds. Scientific research has confirmed the use of Sage as a calmative, and possibly, for lowering fever (Low *et al.*, 1994).

There are many factors that influence agronomic traits and essential oil yield of aromatic crops. Among many factors, plant population density is the main factors which affect the crop yield. The influence of spacing was reported by Lulie and Chala (2016) for lemongrass (Cymbopogon citratus), Zewdinesh and Beemnet (2012) for palmarosa (Cymbopogon martini), and Solomon and Beemnet (2011a) for spearmint (Mentha spicata L.). Harvesting stage of plant has an influence on quantity and quality of essential oil in most essential oil-bearing plants (Ramezani *et al.*, 2009). Essential oil yield and composition vary with developmental stage of the whole plant, plant organs and cells (Sangwan *et al.*, 1982; Gora *et al.*, 2002).

According to Kothari *et al*. (2004), biomass yield was greater in the first harvest and gradually declined in subsequent harvest of Ocimum tenuiflorem, but the

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methods of harvesting have no significant effect on biomass yield. Contrary to the decrease in biomass yields, the essential oil content is lower in the first harvest and increased gradually in the subsequent harvests to reach maximum in the fourth harvest. The oil content and yield of aromatic plants are often altered during harvesting and post harvesting processes (Motsa *et al*., 2006).

The growth, yield and yield components of plants are determined by a series of factors including plant genetic (Shafie *et al.*, 2009), climate factor, soil factor and crop management.

Among these factors, crop management practices such as harvesting age and plant spacing are included (Degu and Amano, 2019). Plant spacing and harvesting age had an effect on growth, biomass and oil yield of Rose-scented geranium (Haileslassie and Kebede, 2015). Despite harvesting age and plant spacing influencing agronomic and chemical characteristics of aromatic plants, there is gap in information on the effects of harvesting age and plant spacing on agronomic and chemical traits of sage, in Ethiopia. Thus, the experiment was designed to determine the optimum harvesting age and plant spacing, for maximize essential oil yield of sage.

MATERIALS AND METHODS

Field experiment was conducted at southern nations and nationality people's regional state (SNNPRS) of Ethiopia, in Wondo Genet Agricultural Research Center. The trial consisted of four levels of harvesting age, namely 3, 4, 5 and 6 months after transplanting and three levels of plant spacing (30 × 30 cm, 60 × 60 cm and 90 × 90 cm) between rows and plants. The experiment was conducted in a factorial arrangement in randomized complete block design (RCBD) with three replications. There were 12 treatment combinations and each treatment combination was assigned randomly within the block. Unit plot size was 3.6 m x 3.6 m (12.96 m2). The distance between the treatments was 1 m. The blocks were separated from each other by 1.5 m. Sage plants from nursery establishment 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 a well-prepared soil at spacings of 30 × 30 cm, 60 × 60 cm and 90 × 90 cm between plants and rows. Proper hoeing, watering and weeding were carried out as required.

During the experiment, data on plant height, fresh leaf weight, dry leaf weight, fresh herbage yield, dry herbage yield, essential oil content and essential oil yield (kg/ha) were collected and analyzed using SAS computer software. Statistical analyses of experimental data were performed 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

Agronomic and Chemical Traits of Sage as Affected by Harvesting Age and Plant Spacing

Analysis of variance showed that harvesting age had a highly significant ($p \leq 0.001$) influence on plant height, fresh leaf weight per plant, dry herbal yield per hectare, essential oil content and essential oil yield. Similarly, harvesting age influenced highly significantly ($p \leq 0.01$) fresh herbal yield (Table 1). Spacing exerted a highly significant ($p \leq 0.001$) influence on fresh leaf weight per plant, dry leaf weight per plant, fresh stem weight per plant, fresh biomass per plant and essential oil yield per hectare. It had a highly significant ($p \leq 0.01$) effect on plant height and dry herbal yield per hectare. On the other hand, fresh herbage yield was significantly ($p \leq 0.05$) influenced by plant spacing. However, plant spacing had no significant influence on essential oil content of sage (Table 1).

Plant Height (cm)

Plant height increased from 49.9 to 57.52 cm with increasing harvesting age from 3 to 5 months after planting (Table 2). Plant height at 6 months after transplanting had no significant difference with plant height at 5 months after transplanting.

This result is in agreement with the study of Zewdineash (2010), who reported incremental increases in plant height with increasing age of Artemisia crop. Similarly, increasing of plant height with prolonged harvesting age was also reported by Zigene *et al*. (2012) for Rosemary (Rosemary officinalis L.). The shortest plant (49.76 cm) was recorded at narrow spacing; whereas the tallest (56.60 cm) was obtained from a wider spacing (Table 2). This might be due to competition for resources by highly populated plants which can retard the normal plant growth. In contradiction to this finding, lower plant height increases at narrower spacing was reported by Taddese *et al*. (2016) on Stevia (Stevia rebaudiana Bertoni L.).

Fresh Leaf Weight (g/plant)

Fresh leaf weight was affected both by harvesting age and population density of sage. The fresh leaf weigh per plant was increased with decreasing plant population. The same result was reported by Taddese *et al*. (2016) on Stevia and Degu and Amano (2019) on Lavender. The minimum value (191.75 g/plant) was obtained at narrow spacing of 30 cm x 30 cm and the maximum value (477.70 g/plant) was recorded from wider spacing of 90 cm x 90 cm (Table 2). The fresh leaf weigh was increased by 149% as spacing increased from 30 cm x 30 cm to 90 cm x 90 cm. This might be due low competition between plants and as a result maximum branches per plant, which contribute to maximum leaf number, were obtained at wider spacing.

The fresh leaf weight was increased as harvesting age was delayed. The maximum fresh leaf weigh (324.96 g/plant) was recorded 6 months after transplanting. Whereas the minimum (265.13 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. On the other hand, when plants were harvested before it reached maximum growth stage, dry matter accumulation was lower.

Dry Leaf Weight (g/plant)

Plant spacing significantly affected dry leaf weight per plant whereas harvesting age had no significant effect on dry leaf weight per plant. Dry leaf weight per plant was increased with an increase in plant spacing and the highest dry leaf weight (148.87 g/plant) was obtained from the maximum plant spacing of 90 cm x 90 cm (Table 2).

Table 1: Mean square of agronomic and chemical traits of sage as affected by spacing and harvesting age.

Source of variation	DF	PH	FLWPP	DLWPP	FHYPH	DHYPH	EOC	EOY
Rep	2	80.22^{ns}	40.05^{ns}	626.90^{ns}	2631385.95^{ns}	656937.92^{ns}	0.034^{ns}	1916.17^{ns}
SP	2	570.68**	1182.37***	16873.66***	17243.12*	1233785.50**	0.023ns	2244.82***
HG	3	1092.70***	850.02***	697.69^{ns}	17600127.32**	1989464.25***	0.037***	4330.67***
SP*HG		34^{ns}	3654.911^{ns}	565.78^{ns}	2334672.65^{ns}	2591741.22^{ns}	0.026^{ns}	1457.61^{ns}
Error	22	10	7493	707.2	4661763.3	2112344.4	0.013	1893.88
CV		18.99	29.41	24.38	28.91	32.47	15.96	30.00
LSD0.05		4.08	34.96	10.74	871.93	586.93	0.05	17.57

*** = 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, DLWPP=dry leaf weight per plant, FHYPH=fresh herbage yield per hectare, DHYPH= dry herbage yield per ha, EOC=essential oil content, EOY= essential oil yield, SP= Spacing and HG= Harvesting age.

Table 2: The performance of agronomic and chemical traits as affected by harvesting age and plant spacing.

Parameter	PH	FLWPP	DLWPP	FHYPH	DHYPH	EOC	EOY
Spacing							
30 x 30 cm	49.76^{c}	191.75^{c}	55.90^{c}	11784^{a}	3843.6^{a}	0.75	98.16^{a}
60 x 60 cm	53.05^{b}	209.82^{b}	93.76^{b}	8365^{b}	2917.2^{b}	0.74	67.81^{b}
90 x 90 cm	56.66^{a}	477.70^{a}	148.87^{a}	8602^{b}	3333.2^{ab}	0.71	49.20^{c}
HA1	49.9^{c}	265.13^{b}	78.9	6304^{b}	2217.5^{b}	0.72^{b}	82.37^{b}
HA2	51.65^{b}	281.69^{b}	108.75	10569^{a}	3911.5^{a}	0.71^{b}	87.56^{ab}
HA3	57.45^{a}	305.36^{ab}	103.93	10358^{a}	3531.2^{a}	0.78^{a}	106.73^{a}
HA4	57.52^{a}	324.96^{a}	106.46	11104^{a}	3798.5^{a}	0.73^{b}	98.6^{ab}
LSD 0.05	2.61	3.32	NS	28.078	1107.8	0.07	23.99
CV	18.99	29.41	24.38	28.91	32.47	15.96	30.00

PH = plant height, FLWPP=fresh leaf weight per plant, DLWPP=dry leaf weight per plant, FHYPH=fresh herbage yield per hectare, DHYPH= dry herbage yield per ha, EOC=essential oil content and EOY= essential oil yield, HA1= harvesting age 3 months after transplanting, HA2= harvesting age 4 months after transplanting, HA3= harvesting age 5 months after transplanting and HA4= harvesting age 6 months after transplanting

However, the lowest dry leaf weight per plant (55.90 g/plant) was recorded from the narrowest plant spacing (30 cm x 30 cm). Dry leaf weight per plant was increased 90 cm x 90 cm. This could be due to the low competition for resources such as light, moisture, nutrient and other at the widest plant spacing.

Fresh Herbage Yield (kg/ha)

The fresh herbage yield was increased with increasing age and attained maximum value (10358 kg) at 5 months after transplanting. However, the minimum fresh leaf herbage yield per hectare (6304 kg) was recorded at the earlier harvesting stage of the crop. The fresh herbage yield per hectare at 6 months after transplanting had no significant difference with fresh herbage yield at 5 months after transplanting. The incremental increase in fresh leaf yield with increasing age was also reported by Kassahun *et al*. (2011) for peppermint; Zewdinesh and Beemnet (2012) for Rosemary (R. officinalis L.) and Getachew and Aynalem (2017) for Lemongrass (C. citratus L).

Fresh herbal yield per hectare of sage was increased with increasing plant population density and the maximum value (11784 kg) was obtained at a narrow spacing (30 cm x 30 cm). The value ranged from 860 to 11784 kg with plant spacing of 90 cm x 90 cm and 30 cm to 30 cm, respectively. In line with this finding, the decreasing of fresh herbal yield per hectare with increasing plant spacing was reported by Jimayu *et al*. (2016) on Lemongrass (C. citratus L); Taddese *et al*. (2016) on Stevia (S. rebaudiana Bertoni L.); Nigussie *et al*. (2015) on Artemisia (Artemisia annua L.); Zewdinesh *et al*. (2011) on Artemisia (A. annua L.); and Solomon and Beemnet (2011b) on Japanese mint. In general, the highest herbage yield was obtained from narrow spacing; whereas; the lowest was from wider spacing. This may be due to higher number of plants per unit area at lower plant spacing, resulting in highest biomass per specific plot.

Dry Herbage Yield (kg/ha)

The maximum dry herbage yield (3843.6 kg/ha) was obtained at narrow spacing of 30 cm x 30 cm, whereas the minimum dry herbage yield (2917.2 kg/ha) was recorded from spacing of 60 cm x 60 cm (Table 2). The highest dry herbage yield recorded from the narrowest spacing could be due to the fresh herbage yield which contributes to dry herbage yield that was obtained from highly populated plants.

Dry herbage yield was increased as harvesting age increased and the maximum value was recorded at six months after transplanting; whereas the minimum value was obtained at earlier harvesting age (three months after transplanting). This might be due to maximum biomass obtained at delayed harvesting age. It implies that the plants could accumulate more dry matter as the plant age increased. The finding is supported by Getachew and Aynalem (2017), who reported that; the highest value of dry herbage yield was recorded at delayed harvesting age for lemongrass.

Essential Oil Content

Essential oil content of sage was significantly influenced by main effects of harvesting age (Table 2). The highest essential oil content (0.78%) was obtained from 5 months after transplanting whereas the lowest (0.71%) was recorded from 4 months after transplanting. This implies that early harvesting and prolonged harvesting age above 5 months could decrease its essential oil content.

Essential Oil Yield (kg/ha)

Minimum essential oil yield (82.37 kg) was recorded at harvesting of 3 months after transplanting. Essential oil yield increased with increasing growth stage of the plant and reached maximum value (106.73 kg) at 5 months after transplanting (Table 2), and thereafter declined to 98.6 kg at 6 months after transplanting. The present study is in line with the study of Getachew and Aynalem (2017), who reported that higher essential oil yield, was obtained at prolonged harvesting age of lemongrass. Similar to this finding, lower essential oil yield at a younger age and an increased value of these parameters with increasing age was reported for Rosemary (Zewdinesh and Beemnet 2012).

The trend of increasing essential oil with increasing plant age was reported by Solomon and Beemnet (2011a) on Spearmint and Zewdinesh and Beemnet (2012) on Artemisia (A. annua L.). 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.

The essential oil yield recorded ranged from 49.20 to 98.16 kg with spacing of 90 cm x 90 cm and 30 cm x 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 maximum essential oil yield. Similar results were reported by Jimayu *et al*. (2016) who reported that the closer plant population produced the highest amount of essential oil yield. This finding is also supported by the results of Beemne (2012) on Geranium; Nigussie *et al*. (2015) on Artemisia (A. annua L.); Zewdinesh and Beemnet (2012) on palmarosa (C. martini (Roxb.) wats); Sigaye *et al*. (2016) on Vernonia (V. galamensis Cass). The increase in essential oil yield at higher densities might be due to the contribution of higher above ground biomass recorded at highest population density.

Conclusion

The study indicated that harvesting age and plant population density significantly affected dry herbage yield and essential oil yield of sage crop. It implies that crop managements play vital role in increasing of crop yield. The highest essential oil yield was obtained at closer plant spacing due to highest herbage yield from populated plants, which finally contribute to essential oil yield. Plant needs optimum spacing to give high yield. This was ensured by using all important resources such as light, nutrient, moisture and others. Similarly, the result showed both herbage and essential oil yield were significantly affected by harvesting age. This might be due to plant needing optimum growth time to give high yield. Sage plant accumulated highest dry matter as the crop growth stage increased. Generally, the result indicated that both harvesting age and plant spacing significantly influenced growth and yield of sage crop. The highest essential oil yield (98.16 and 106.73 kg/ha) were obtained from 30 × 30 cm spacing and five months after planting respectively. Since the experiment was conducted at single location and season, it should be repeated at different season and agro ecologies.

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