Performance of Lemon Verbena (*Aloysia triphylla* L.) for Morphological, Economic and Chemical Traits in Ethiopia

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**Abstract:** Lemon Verbena (*Aloysia triphylla* L.) is a perennial aromatic and medicinal plant that belongs to the family Verbenaceae. It has long been introduced and maintained at Wondo Genet, Southern Ethiopia. Despite its long presence, various potential uses and existence of diverse ecologies, the plant has not evaluated for its performance in agronomic and chemical traits in different parts of Ethiopia. Thus, this activity was designed to contribute in addressing the existing technology gaps and thereby bringing the crop for cultivation in the country. Data plant height, number of branches/plant, number of leaves/plant, dry leaf weight/plant, fresh leaf weight/plant, aboveground biomass/plant, leaf to stem ratio, leaf yield/ha/year, essential oil (EO) content and EO yield/ha/year collected from three replications, four locations and three testing years were analyzed following the procedures of randomized complete block design. Growing location demonstrated a highly significant influence \((P < 0.01)\) on the performance of all the parameters considered. The performance of lemon verbena was influenced significantly \((P < 0.01)\) with testing year and interaction effects of location by year in all the studied parameters except for leaf to stem ratio. The respective average fresh leaf yield/ha/year, EO content and EO yield/ha/year varied from 1.78-6.73 t, 0.19-0.41\% and 2.57-20.12 kg combined over the testing locations. Considering testing years, average annual fresh leaf yield/ha, EO content and EO yield/ha varied from 1.14-8.03 t, 0.19-0.49\% and 4.13-15.99 kg, respectively. The leaf yield and essential oil yield was increased with increasing age from first to second year and it starts to decline then after.

**Key words:** *Aloysia triphylla* - Essential oil - Ethiopia - Lemon verbena - Lominat

**INTRODUCTION**

Lemon verbena (*Aloysia triphylla* L.) is a perennial shrub that belongs to the family Verbenaceae [1]. It has got its name due to the fact that it has whorls of three (tri) leaves (phylla) at each node. Lemon verbena is locally known as Lominat [2]. It is native to Argentina, Paraguay, Brazil, Uruguay, Chile, Bolivia and Peru [3, 4, 5, 6, 7].

The leaves of lemon verbena are the most economical part of the plant that can be used to add a lemony taste in salads, tea, milk, ice creams and jellies [8, 2]. Likewise, the fragrant flowers are also used in tea and culinary concoctions and the essential oil obtained through distillation of the leaves is used in fragrance industries, food flavoring industries, soft drink industries and folk medicine [9]. Traditionally it is used as folk remedy in treatments of spasms, cold and fever [10], asthma, flatulence, colic, diarrhoea, indigestion, insomnia and anxiety [11, 12, 13]. Essential oil of lemon verbena has also anti bacterial and ant-fungal properties [8]. Anti-bacterial and anti-oxidant activity of *A. citriodora* has been demonstrated for the essential oils, tea and tinctures [14, 15]. Due to its diverse uses and applications, lemon verbena has got open and huge market potential for herbal preparation and extraction of essential oils.

Even if it is very useful in food, pharmaceutical, soft drink and stimulant-processing industries, introduced to the country long time ago, increasing interest of farmers and investors for its cultivation in Ethiopia [16] and existence of diverse ecological conditions in the country [17, 18, 19], there exist scanty information about the production, processing and utilization technologies in Ethiopia. This lack of information is the major hindrance to exploit the potential of the plant. Therefore, in order to...
contribute in addressing the existing technology gaps and bringing the crop for cultivation and utilization, this activity was designed with the objective to evaluate the performance of lemon verbena for morphological and economic traits under different ecologies of Ethiopia.

RESULTS AND DISCUSSION

Mean squares from first year, second year, third year and combined analysis of variance for six traits of lemon verbena tested over four locations of Ethiopia are summarized in Tables 2, 3, 4. Location exerted a highly significant influence ($P < 0.01$) on all the parameters considered in the study (Table 2). This indicates these traits were influenced by changing in the environment. The significance of location effect was expected because Wondo genet, Chencha, Wonago and Qoqa vary in their soil type, rainfall and temperature (Table 1). The performance of lemon verbena was highly and significantly influenced ($P < 0.01$) with testing year in all the studied agronomic and chemical traits except for leaf to stem ratio. The interaction effects between the location and years were highly significant ($P < 0.01$) for plant height, number of branches/plant, number of leaves/plant, dry leaf weight/plant, fresh leaf weight/plant, aboveground biomass/plant, leaf yield/plant, leaf yield/ha, essential oil (EO) content and EO yield of lemon verbena thus indicating the expression of these traits were strengthened by the interaction effect between location and year. In agreement to the present study, Fehr [22] reported that every factor that is a part of the environment of a plant has the potential to cause differential performance. Likewise, Frankel et al. [23] and IRRI [24] reported that fluctuating features of the location such as rainfall, relative humidity, temperature, etc. are some of the environmental factors that cause performance variation in plants.

Performance of Lemon Verbena for Morphological Traits as Influenced by Growing Location and Years: Plant height was found statistically different over the testing locations (Table 2). It varied form 61.67-87.14 cm over the testing locations and years and the highest value was recorded at Wondo Genet and lowest at Chencha (Table 3). An overall mean plant height value of 76.53 cm was recorded over the testing locations and years (Tables 3, 4). Number of branches was influenced with testing location, testing years and intercom effect of location by year. The highest value of branches number (24) was recorded at Wondo Genet and the lowest value (15) was recorded at Chencha. An overall average number of branches/plant (21) was recorded over the testing years and locations. Number of leaves produced by lemon verbena over the testing locations and years was varied.

MATERIALS AND METHODS

The experiment was conducted in four locations at Chencha, Wondo Genet, Qoqa and Wonago testing sites for three years in 2010/2011, 2011/2012 and 2012/2013 cropping season of Ethiopia. The ecological descriptions of the testing locations are summarized in Table 1.

Hard stem bottom cuttings with 5 nodes were taken from one year old disease free mother plants of Wondo Genet Agricultural Research Center botanical garden for seedling preparation. Seedlings were raised in the nursery for three months in polyethylene bags before being transplanted to the field experimental plots in three replications. A row and plant spacing of 60 cm was used. During experimentation, all field horticultural practices were performed as required. No chemical or fertilizer was applied during experimentation. Harvesting was made four and half months after transplanting.

Data on plant height (cm), number of branches/plant, number of leaves/plant, dry leaf weight/plant (g), fresh leaf weight/plant (g), aboveground biomass/plant (g), leaf to stem ratio, leaf yield/ha/year (kg), essential oil (EO) content and EO yield/ha/year (kg) were collected and analyzed. EO content was determined on a fresh weight basis from 300 g of composite leaves harvested from the three middle rows of a plot. EO was determined by hydro-distillation according to the procedures of Guenther [20]. Hydro distillation is a distillation method in which the plant material to be distilled comes in direct contact with the boiling water. Heat was provided by electro mantle. The emerging vapor from the flask containing the volatile essential oil was led to a condenser for condensation and collected in the oil separate unit. Laboratory analysis was performed at Wondo Genet Agricultural Research Center.

To statically analyze the differences in agronomic and chemical characteristics of lemon verbena caused by testing locations, five samples were taken from each plot. Experimental data was statistically analyzed by analysis of variance (ANOVA) using SAS PROC GLM [21] at $P < 0.05$. Differences between means were assessed using the least significance difference (LSD) test at $P < 0.05$.
Table 1: Summary of site descriptions used for adaptation testing of lemon verbena for yield and yield component traits

<table>
<thead>
<tr>
<th>Testing locations</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Soil pH</th>
<th>Soil type</th>
<th>Rainfall (mm)</th>
<th>Altitude (m.s.s.l)</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wondo Genet</td>
<td>7°19’ N</td>
<td>38°38’ E</td>
<td>6.4</td>
<td>Sandy clay loam</td>
<td>1000</td>
<td>1876</td>
<td>12.02</td>
<td>26.72</td>
</tr>
<tr>
<td>Chencha</td>
<td>6°13’ N</td>
<td>37°34’ E</td>
<td>4.9</td>
<td>Mollic nitisol</td>
<td>873</td>
<td>2618</td>
<td>6</td>
<td>16.3</td>
</tr>
<tr>
<td>Wonago</td>
<td>6°18’ N</td>
<td>38°13’ E</td>
<td>-</td>
<td>Clay loam</td>
<td>1499</td>
<td>1926</td>
<td>10.88</td>
<td>25.37</td>
</tr>
<tr>
<td>Qoqa</td>
<td>8°26’ N</td>
<td>39°1’ E</td>
<td>-</td>
<td>Clay soil</td>
<td>830.9</td>
<td>1604</td>
<td>13.68</td>
<td>28.30</td>
</tr>
</tbody>
</table>

Table 2: Mean squares from combined analysis of variance for ten agronomic and chemical traits of Lemon verbena tested for three years over four location of Ethiopia

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>df</th>
<th>PH</th>
<th>NBBPL</th>
<th>NLPPL</th>
<th>FLWPPL</th>
<th>DLWPPL</th>
<th>LS</th>
<th>AGBPPL</th>
<th>LYH</th>
<th>EOC</th>
<th>EOY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replicatio</td>
<td>2</td>
<td>281.85</td>
<td>2.12</td>
<td>416734.07</td>
<td>2254.01</td>
<td>29.09</td>
<td>44532.75</td>
<td>805517</td>
<td>0.03</td>
<td>551608.99</td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>3</td>
<td>1395.52**</td>
<td>305.59**</td>
<td>7178413.6**</td>
<td>18621.99**</td>
<td>99.53**</td>
<td>234478**</td>
<td>54095827**</td>
<td>0.07**</td>
<td>5408982**</td>
<td></td>
</tr>
<tr>
<td>year</td>
<td>2</td>
<td>457.76**</td>
<td>1601.43**</td>
<td>16715179**</td>
<td>32598.51**</td>
<td>522.10**</td>
<td>632594**</td>
<td>143355803**</td>
<td>0.30**</td>
<td>4397671**</td>
<td></td>
</tr>
<tr>
<td>Loc*year</td>
<td>6</td>
<td>705.19**</td>
<td>614.11**</td>
<td>2100165**</td>
<td>13317.24**</td>
<td>89.64**</td>
<td>271805**</td>
<td>32055206**</td>
<td>0.08**</td>
<td>2770371**</td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>22</td>
<td>39.39</td>
<td>27.49</td>
<td>199528.14</td>
<td>919.60</td>
<td>10.17</td>
<td>6179.95</td>
<td>1469776</td>
<td>0.01</td>
<td>121768.25</td>
<td></td>
</tr>
</tbody>
</table>

R 0.92 0.93 0.94 0.91 0.90 0.71 0.96 0.95 0.90 0.94

Cv% 8.20 25.32 28.22 41.30 30.37 25.53 22.64 27.33 26.45 32.44

**= highly significant at P<0.01; ns= non significant at P<0.5; PH= plant height, NBBPL= number of branches/plant, NLPB= number of leaves/plant, DLWPPL= dry leaf weight/plant, FLWPPL= fresh leaf weight/plant, LS= leaf to stem ratio, LYPPL= leaf yield/plant, LYH= leaf yield/ha/year, EOC= essential oil (EO) content and EOY= EO yield/ha/year

Table 3: Over all mean performance of lemon verbena for morphological and chemical characters over the testing locations evaluated for three years

<table>
<thead>
<tr>
<th>Location</th>
<th>PH</th>
<th>NBBPL</th>
<th>NLPPL</th>
<th>FLWPPL</th>
<th>DLWPPL</th>
<th>LS</th>
<th>AGBPPL</th>
<th>LYH</th>
<th>EOC</th>
<th>EOY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wondo Genet</td>
<td>87.14</td>
<td>27.91</td>
<td>2154.00</td>
<td>95.98</td>
<td>14.48</td>
<td>1.82b</td>
<td>373.00</td>
<td>6726.40</td>
<td>0.19</td>
<td>1369.7a</td>
</tr>
<tr>
<td>Qoqa</td>
<td>86.49</td>
<td>22.80</td>
<td>2510.50</td>
<td>126.54</td>
<td>11.61</td>
<td>1.28</td>
<td>420.40</td>
<td>6302.00</td>
<td>0.41</td>
<td>2012.3a</td>
</tr>
<tr>
<td>Chencha</td>
<td>61.67</td>
<td>14.94</td>
<td>628.40</td>
<td>33.11</td>
<td>6.70</td>
<td>2.30</td>
<td>114.41</td>
<td>1780.60</td>
<td>0.32</td>
<td>257.3c</td>
</tr>
<tr>
<td>Wonago</td>
<td>70.83</td>
<td>17.19</td>
<td>1039.50</td>
<td>38.05</td>
<td>9.21</td>
<td>1.35</td>
<td>481.16</td>
<td>2935.20</td>
<td>0.33</td>
<td>664.0a</td>
</tr>
</tbody>
</table>

Mean 76.53 20.71 1583.10 73.42 10.50 1.69 347.24 4436.05 0.31 1075.83

LSD 6.14 5.13 436.19 29.67 2.70 0.42 76.85 1185.20 0.08 341.15

CV% 8.20 25.32 28.22 41.30 30.37 25.53 22.64 27.33 26.45 32.44

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

Table 4: Over all mean performance of lemon verbena for agronomic and chemical characters over the testing years evaluate at four locations

<table>
<thead>
<tr>
<th>Year</th>
<th>PH</th>
<th>NBBPL</th>
<th>NLPPL</th>
<th>FLWPPL</th>
<th>DLWPPL</th>
<th>LS</th>
<th>AGBPPL</th>
<th>LYH</th>
<th>EOC</th>
<th>EOY</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010/2011</td>
<td>69.93</td>
<td>8.89</td>
<td>222.3</td>
<td>13.51</td>
<td>7.08</td>
<td>1.67</td>
<td>82.12</td>
<td>1135</td>
<td>0.49</td>
<td>4.13</td>
</tr>
<tr>
<td>2011/2012</td>
<td>82.17</td>
<td>21.27</td>
<td>2198.8</td>
<td>108.31</td>
<td>18.11</td>
<td>1.67</td>
<td>480.82</td>
<td>8029</td>
<td>0.19</td>
<td>15.99</td>
</tr>
<tr>
<td>2012/2013</td>
<td>77.51</td>
<td>31.97</td>
<td>2328.2</td>
<td>98.45</td>
<td>6.32</td>
<td>1.72</td>
<td>478.78</td>
<td>4144</td>
<td>0.25</td>
<td>12.15</td>
</tr>
</tbody>
</table>

Mean 76.53 20.71 1583.10 73.42 10.50 1.69 347.24 4436.05 0.31 1075.83

LSD 5.31 4.44 378.19 25.67 2.70 0.34 66.56 1026 | 0.07 2.95

CV% 8.20 25.32 28.22 41.30 30.37 25.53 22.64 27.33 26.45 32.44

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

from 628 at Chencha to 2510 at Qoqa. The overall mean number of leaves produced by a plant was 1583. The proportion of leaves produced from the total biomass of lemon verbena averaged over the testing locations and years was 1.69. It ranged from 1.28 at Qoqa to 2.3 at Chencha. A relatively lower range of leaf number/plant from 185-1290 was reported by Azarmi et al. [25] evaluated under soil and floating system in Iran.

Performance of Lemon Verbena for Economic Traits as Influenced by Growing Location and Years:
The mean performance of lemon verbena for economic traits including fresh leaf yield/plant, dry leaf yield/plant and fresh leaf yield/ha over the testing locations and years are summarized in Tables 3 and 4. Above ground biomass yield of lemon verbena ranged from 114.41 to 481.18 kg/plant over the different testing locations. The highest values were recorded at Wonago and Qoqa and the lowest at Chencha. The overall mean above ground biomass produced by a single plant was 347.21 kg over the testing years. The values for fresh leaf yield/plant, dry leaf yield/plant and fresh leaf yield/ha were increased with increasing testing years up to second year and starts to decline then after. Compared with the first testing year,
a respective increased percent value of 701.7, 155.8 and 607.4 was recorded for dry leaf yield/plant, fresh leaf yield/plant and fresh leaf yield/ha during the second testing year. An increasing trend of leaf yield from first year to second year was also reported by Karik and Azkan [26] for studies conducted under Yalova ecological conditions for lemon verbena. The respective overall average fresh leaf yield/plant and dry leaf yield/plant were 73.42 g and 10.50 g. The highest value of fresh leaf yield/plant (126.54 g) was obtained at Qoqa and dry leaf yield/plant (14.48 g) was recorded at Wondo Genet. The least value of fresh leaf yield/plant (33.11 g) and dry leaf yield/plant (6.7 g) was recorded at Chencha. Fresh and dry leaf yield/plant obtained in the present study are within the range of values reported by Azarmi et al. [27] who reported a range of values from 18.1-250.3 g for fresh leaf yield/plant and 4.9-58 g for dry leaf yield/plant tested under different production system in Iran. The overall average value of 4.44 t was recorded for fresh leaf yield/ha over the testing locations and years. The highest (6.73 t) fresh leaf yield/ha was obtained at Wondo Genet and the lowest (1.78 t) was recorded at Chencha. A range of 3.23-3.36 t/ha fresh leaf yield was reported by Mohammadi et al. [28] tested under different rates of biological fertilizers in Iran. The variation in the performance of economic traits in lemon verbena compared with different reports may be due to the existence of variation in different factors. Allard [29] and Poehlman and Sleper [30], also reported the occurrence of performance variation in any plant is due to hereditary differences in the plants, difference in the environments in which the plants are grown, or a combination of both.

The respective overall mean essential oil content and essential oil yield of lemon verbena over the testing locations and years was 0.33% and 10.76 kg/ha. The value varies from 0.19 to 0.41% for essential oil content and 2.57-20.12 for essential oil yield/ha. The highest essential oil content and essential oil yield were recorded at Qoqa. The essential oil yield range obtained in this study is within the range of essential oil content from 0.08 to 0.8% for experiment conducted in Portugal [1]. A comparable range of essential oil content from 0.23 to 0.47% was reported for experiments conducted under different biological fertilizer treatments in Iran [28]. Study conducted in Brazil demonstrated an essential oil content range between 0.58 and 1.49% on dry weight basis [31]. As the essential oil content obtained in is study is comparable to the different reports, it can be said that lemon verbena is adaptable to the different parts of Ethiopia and hence it can be cultivated for the production of herbal essential oil.

**CONCLUSION**

Generally, the value recorded for morphological and economic traits in the present study are within the ranges of world reports. Indicating the adaptability of lemon verbena for agronomic and yield traits in the country for its commercial cultivation. Therefore, lemon verbena can be cultivated for the production of herbal leaves and for the extraction of essential oils in mid highland to highland parts of Ethiopia.

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