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RESEARCH ARTICLE

Effect of integrated nutrient management on Clary sage (*Salvia sclarea* L.) at mid hills of Himachal Pradesh

Gaisinmeilu Kamei[1], Kulwant Rai Sharma[1], Meenu Sood[1], Nilay Kumar[2*], Sunandani Chandel[3] and Sushma Kerketta[4]

Abstract

A comprehensive investigation was undertaken in 2017-2018 at the Department of Forest Products and Utilization, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Himachal Pradesh, to assess the relative profitability and effectiveness of various nutrient management techniques on clary sage (*Salvia sclarea* L.) for growth parameters and essential oil content (%). A total of ten treatments were evaluated under a Randomized Block Design (RBD) with three replications, as follows: T_1: Control; T_2: NPK; T_3: FYM; T_4: Vermicompost; T_5: FYM + NPK; T_6: Vermicompost + NPK; T_7: Jeevamrit (Jersey Cow); T_8: Jeevamrit (Desi Cow); T_9: Panchgavya (Jersey Cow); and T_{10}: Panchgavya (Desi Cow). The results revealed that the treatment T_6: Vermicompost + NPK recorded the maximum values across growth and yield parameters, including essential oil yield (21.45 l/ha), essential oil content (0.18%), spike yield per plant (107.26 g), and spike yield per hectare (11,917.68 kg/ha), followed by the treatment T_5: FYM + NPK. The result clearly demonstrates that the synergistic use of organic manures and chemical fertilizers significantly outperformed individual treatments in terms of biomass and oil production. The highest yield and beneficial-cost ratio (1.69:1) for growing clary sage has been determined to be achieved with the NPK + Vermicompost treatment (90:60:30 kg/ha + 2 t/ha).

Keywords: Essential oil content, Organic manures, Biofertilizer, Economics.

Introduction

Clary sage (*Salvia sclarea* L.) is a perennial herbaceous plant classified under the family Lamiaceae, renowned for its essential oil content. The crop, which is indigenous to the Mediterranean region, especially southern Europe and Central Asia, has become more popular in commercial cultivation because of its therapeutic and fragrant qualities (Simon et al., 1984). Bulgaria is one of the top suppliers of clary sage essential oil, together with France, Russia, and Morocco (Vasilev, 1930). The market for clary sage essential oil is mostly driven by the pharmaceutical, cosmetics, perfumery, and aromatherapy industries, with an estimated 1,500 tons produced year worldwide (Anonymous, 2005). Clary sage remains a small fragrant crop with little commercial growth in India. As part of early domestication efforts, germplasm from Bulgaria was introduced in 1978 at the CSIR-Central Institute of Medicinal and Aromatic Plants (CIMAP) research farm in Kashmir (Husain, 1980). The region's potential for successful cultivation was demonstrated by early research showing that the oil produced in Kashmir satisfied worldwide quality criteria (Tajuddin et al., 1982). In spite of the ideal agro-climatic conditions found in areas such as Himachal Pradesh, Kashmir, and portions of Uttarakhand, large-scale farming has not proven to be popular. Therefore, imports continue to be the main source of supply for India's internal demand for clary sage oil. The lack of structured market connections, the scarcity of superior planting material, the lack of farmer knowledge, and the paucity of research on regional agro-techniques are some of the obstacles impeding its growth in India. However, clary sage has a lot of potential to be a high-value crop in the Indian aromatic and medicinal plant industry, particularly in

[1]Department of Forest Products and Utilization, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India.

[2]Department of Forest Products and Utilization, College of Horticulture and Forestry, Central Agricultural University (I), Pasighat, Arunachal Pradesh, India.

[3]Department of Forest Products and Utilization, College of Forestry, Kerala Agricultural University, Thrissur, Kerala, India.

[4]Department of Farm Forestry, Sant Gahira Guru Vishwavidyalaya, Surguja, Ambikapur, Chhattisgarh, India.

***Corresponding Author:** Nilay Kumar, Department of Forest Products and Utilization, College of Horticulture and Forestry, Central Agricultural University (I), Pasighat, Arunachal Pradesh-791 102, India., E-Mail: nilay_fpr@rediffmail.com

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light of the increasing global demand for natural and organic products. Organic farming methods, such as using farmyard manure, vermicompost, and biostimulants like Jeevamrit and Panchagavya, are being investigated recently for their potential to increase output and oil quality in temperate and mid-hill regions (Palekar, 2006 and Natarajan, 2007). There is still a dearth of scientific information regarding the ideal dosage and effectiveness of managing both organic and inorganic nutrients in Indian agro-ecological conditions. As a result, the current study was conducted to assess how well organic and inorganic fertilizers worked to increase the yield of clary sage and the overall production of essential oil.

Materials and Methods

The study was carried out at the Experimental Farm of the Forest Products and Utilization Department at Dr. Y.S. Parmar University of Horticulture and Forestry in Nauni, H.P., between November 2017 and August 2018 (Figure 1). The farm is located at 1250 meters above sea level at latitude 30°52′N and longitude 77°11′E. Over the course of the experiment, the highest recorded temperature was 30.7°C in May and the lowest was 2.1°C in January; the highest recorded rainfall was 340.2 mm in July and the lowest was 2.4 mm in November; the highest recorded relative humidity was 81% in July and the lowest was 42% in May. The soil's physicochemical properties included a silt loam texture, neutral pH of 6.92, high organic carbon (0.78%), EC of 0.63 d/Sm, available N (285 kg/ha), available P_2O_5 (14.40 kg/ha), and available K_2O (136.63 kg/ha). The experiment was conducted under Randomized Block Design (RBD) with three replications and ten treatments, viz., T_1: Control, T_2: NPK (90:60:30 kg/ha), T_3: FYM (15 t/ha), T_4: Vermicompost (2 t/ha), T_5: FYM + NPK (15 t/ha + 90:60:30 kg/ha), T_6: Vermicompost + NPK (2 t/ha + 90:60:30 kg/ha), T_7: Jeevamrit (Jersey Cow) (125 l/ha, 5%), T_8: Jeevamrit (Desi Cow) (125 l/ha, 5%), T_9: Panchgavya (Jersey Cow) (50 l/ha, 3%), and T_{10}: Panchgavya (Desi Cow) (50 l/ha, 3%). The seedlings were transplanted during November 2017 in the field beds of size 2.7m x 1.8m at 30cm x 30cm spacing, and all the intercultural operations were carried out uniformly and in a timely manner across all plots. The data were statistically analyzed following the method outlined by Panse and Sukhatme (1984) to assess the significance of mean differences among treatments and to determine simple correlations between the parameters. The economics of producing clary sage under various nutrient management conditions were calculated using the cost of cultivation per hectare. The essential oil yield per hectare was multiplied by the amount in rupees per kilogram to determine the income from clary sage (Anonymous, 2018). The total cost of cultivation was the sum of the management component and fixed cost per hectare. The cost of cultivation and returns per hectare were used to construct the benefit-cost ratio (Gittinger, 1982).

Results and discussion

Plant growth

A similar trend in Figure 2 illustrates the significant impact of various organic manures, fertilizers, and their combinations on plant development indices. The application of NPK+Vermicompost @ 90:60:30 kg/ha + 2 t/ha produced the highest plant growth parameters, including plant height (103.78 cm), number of leaves (79.00), plant spread (99.31 cm), spike length (65.13 cm), number of flowering branches per plant (5.93), number of branches in a spike at harvest time (16.13), and number of flowers per spikelet (28.00). This was statistically equal to and still superior to the other treatments. Singh (2011) reported similar results, noting that in the first harvest, the plant growth parameters in geranium (*Pelargonium graveolens* L 'Herit ex Aiton) performed best with the application of NPK alone. However, in the second harvest, the combination of NPK and vermicompost outperformed all other treatments, highlighting the long-term and cumulative benefits of vermicompost, which improves soil quality, better retains moisture, increases beneficial microbes and enzymes, releases nutrients gradually, and supports natural plant growth hormones like auxins and gibberellins. Singh et al. (2012) also noted that adding vermicomposting to tomatoes (*Solanum lycopersicum* L.) increased the growth parameter. The present results are also reliable with the findings of Anwar et al. (2005) in *Ocimum basilicum* and Sharma and Kumar (2012) in Clary sage (*S. sclarea* L.).

Spike, essential oil and seed yield

The effects of various fertilizers, organic manures, and their combinations had a substantial impact on the production of seeds, essential oil, and spike (Table 1). The highest spike yield per plant (107.26 g) and essential oil content (0.18%) were recorded by the application of NPK and vermicompost @ 90:60:30 kg/ha + 2 t/ha (T_6). This was followed by the application of NPK+FYM @ 90:60:30 kg/ha + 15 t/ha (T_5), which was statistically comparable and found to be significantly better than other treatments and the control because of the improved nutrition provided by the combination of NPK and organic manures. The amounts of enzymes crucial to the manufacture of terpenoids in aromatic plants are similarly influenced by macronutrients. The highest estimated essential oil yield per hectare and the highest predicted spike yield per hectare were 21.45 l/ha and 11917.68 kg/ha for NPK and vermicompost @ 90:60:30 kg/ha +2t/ha (T_6), followed by 11135.54 kg/ha and 17.74 l/ha for NPK+FYM @ 90:60:30 kg/ha +15 t/ha (T_5), while the control group had the lowest. The development and yield of essential oils in aromatic plants were found to be positively impacted by NPK. These factors also affect the concentrations of enzymes crucial to terpenoid production. According to Sharma and Kumar (2012), nitrogen is a crucial

Figure 1: Field trial of clary sage

nutrient for plants since it is a component of protein, nucleic acid, protoplasm, and chlorophyll, all of which help plants bloom profusely and produce more biomass and essential oils. However, vermicompost, an earthworm exudate, contains certain plant growth regulators that improve the plant's metabolism throughout the reproductive stage. It also enhances the physicochemical characteristics of the soil to support improved root development and nutrient absorption by the plant, making it a significant source of plant nutrients. The findings of this study are consistent with those of other research on geranium (Chand et al., 2011; Singh, 2011) and clary sage (Mishra and Negi, 2009; Verma et al., 2010).

The maximum weight of 1000 seeds (4.38 g) and number of seeds per spike (1804.18) were observed in T_6 (NPK+Vermicompost @ 90:60:30 kg/ha +2 t/ha), which was statistically equal to T_5 (NPK+FYM @ 90:60:30 kg/ha +15 t/ha) and substantially higher than other values. In contrast, T_1 (Control) showed a minimum weight of 1000 seeds (3.64 g) and a number of seeds per spike (1148.09). The ability of the plant to produce seeds is a sign that the reproduction process is fully successful. Because clary sage is a cross-pollinated crop, the mutualistic relationship between insects and the plant is important for seed generation. In addition, current environmental factors like temperature, precipitation, and soil nutrient levels have a big impact on seed production. The combination use of both organic and inorganic fertilizers produced improved seed production results in the current experiments because it allowed the plant to properly operate metabolically by providing an adequate supply of both macro and micronutrients. Vermicompost application combined with NPK increases mineral uptake, which benefits appropriate biomass formation. This, in turn, promotes soil biological activity and increases mineral absorption. The current findings are consistent with those of Darzi et al. (2012), who used vermicompost and nitrogen-fixing bacteria to improve the quality of oil from seed and produce dill seeds. According to Sharma and Kumar (2012), the maximum biomass production of clary sage was attributed to an adequate supply of nitrogen. The combination of FYM and NPK treatment produced the highest spike yield, according to Mishra and Negi (2009), indicating significant seed production in clary sage.

Correlation analysis

The analysis of the factors affecting essential oil content and spike yield per plant showed that key economic traits have a positive relationship with plant height, number of leaves, plant spread at maturity, spike length, number of branches per spike, seed weight, and number of flowers per spike. The dendrogram (Figure 3) and the correlation matrix (Table 2) showed a high and substantial positive association ($p = 0.01$) between the number of spikes per plant, plant spread (r =

Table 1: Yield parameters of clary sage as influenced by different inorganic fertilizers and organic manure

Treatments	*Spike yield/ plant (g)*	*Essential oil content (%)*	*Spike yield (kg/ha)*	*Essential oil yield (l/ha)*	*Weight of 1000 seeds (g)*	*No of seeds per spike*
T_1	40.30	0.08	4444.44	3.91	3.64	1148.09
T_2	74.20	0.16	8242.78	14.14	4.15	1692.36
T_3	44.43	0.12	4936.21	5.91	3.95	1244.63
T_4	51.73	0.12	5746.90	7.39	4.03	1324.81
T_5	100.21	0.17	11135.54	17.74	4.30	1768.03
T_6	107.26	0.18	11917.68	21.45	4.38	1804.18
T_7	44.06	0.10	4895.05	6.13	3.75	1220.74
T_8	56.66	0.12	6296.28	8.04	4.06	1496.00
T_9	47.83	0.12	5312.75	6.79	4.02	1364.51
T_{10}	72.40	0.13	8044.43	10.46	4.11	1572.69
SE (d) ±	2.69	0.01	29.81	0.14	0.08	2.29
$CD_{0.05}$	5.69	0.02	63.11	0.30	0.18	4.85

0.919), and number of leaves per plant (r = 0.965) and spike yield per plant. These correlations imply that higher spike yield may be directly influenced by vegetative growth and floral characteristics. Spike length (r = 0.686), number of branches per spike (r = 0.833), and plant height (r = 0.760) were all positively connected, but to a significantly lesser extent. Additionally, the dendrogram (Figure 4) and the correlation matrix (Table 3) showed a significant positive correlation ($p = 0.01$) between the essential oil content and the number of leaves per plant (r = 0.828) and spikes per plant (r = 0.804), highlighting their significance in promoting oil biosynthesis. However, there was also a moderately favorable association between characteristics such as plant height (r = 0.796), spike length (r = 0.756), and seed weight (r = 0.773). These results indicate that plant vigor and reproductive biomass, in addition to floral density, affect essential oil content.

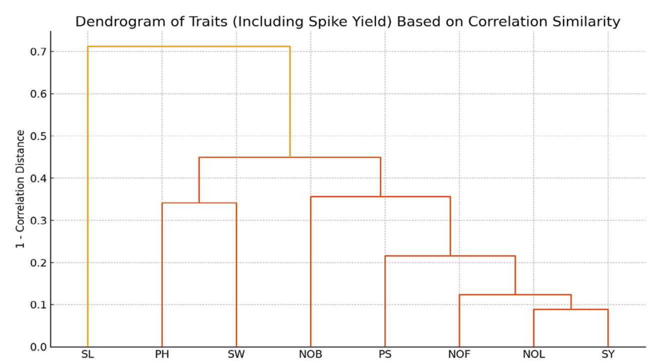
The current findings aligned with the earlier research on clary sage published by Mishra and Negi (2009).

Economics

Cost and return are the two most crucial metrics for assessing economic viability. Table 4 shows the cost of growing and producing clary sage under various conditions. The fixed cost and management factor per hectare were added up to determine it. It shows that the cost of cultivation ranged from Rs. 92546.25 to Rs. 231834.81 for the various treatments. To ensure that all treatments are assessed on the same economic parameters, regardless of changes in actual market conditions, an average price of Rs. 10808.15/kg was adopted for the current analysis. The production of essential oils per hectare multiplied by the rate in rupees per kilogram was used to determine the income from clary sage (Anonymous, 2018). The Benefit Cost Ratio (BCR) for each treatment ranged from 0.43 to 1.69, indicating that the treatments were profitable. According to Gittinger (1982), the benefit-cost ratio was computed using the cost of cultivation and returns per hectare. In view of the better yield output and lower cost of NPK, the application of NPK and vermicompost at 90:60:30 kg/ha + 2t/ha produced the highest benefit:cost ratio of 1.69:1, followed by NPK at 90:60:30 kg/ha (1.53:1). However, due to the greater cost of FYM, the minimum benefit:cost ratio was reported at 15 t/ha (0.43:1), which was lower than the control (0.46:1).

Conclusion

Integrated nutrition management significantly enhanced clary sage's biomass, growth, and output of essential oils. Comparing NPK and vermicompost to other treatments, the results showed that the combination application produced the highest levels of plant growth, biomass, and essential oil. The highest B:C ratio (1.69) was found in plants treated with vermicompost (2 t/ha) and NPK (90:60:30 kg/ha) according to the economic analysis. Thus, it is determined that this combination is the most effective for growing clary sage in Himachal Pradesh's mid-hill environments.



(PH – Plant height; NOL – Number of leaves; PS - Plant spread; SL - Spike length; NOB - Number of branches per spike; SW - Seed weight; NOF – Number of flowers per spike; SY - Spike yield per plant)

Figure 3: Dendrogram showing cluster analysis based on morphological traits

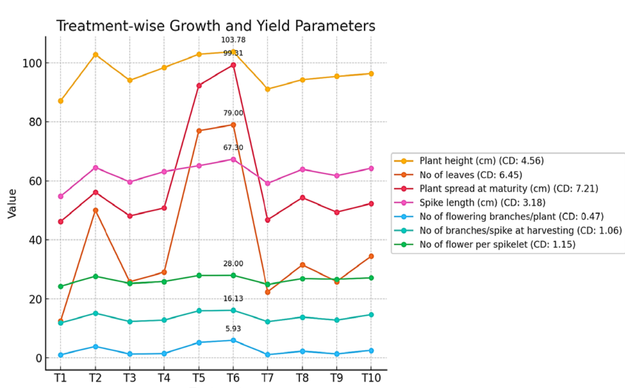
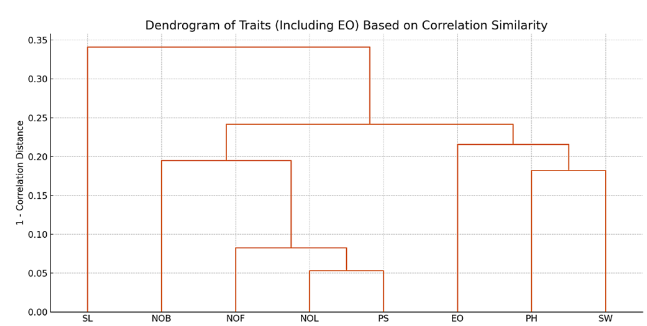


Figure 2: Line graph showing various plant growth parameters of clary sage under different inorganic fertilizer and organic manure treatments



(PH - Plant height; NOL - Number of leaves; PS - Plant spread; SL - Spike length; NOB - Number of branches per spike; SW - Seed weight; NOF - Number of flowers per spike; EO - Essential oil content)

Figure 4: Dendrogram showing cluster analysis based on spike yield and essential oil content

Table 2: Correlation coefficients between morphological characters and spike yield per plant in clary sage

Characters	*PH*	*NOL*	*PS*	*SL*	*NOB*	*SW*	*NOF*	*SY*
PH	1.000	0.814**	0.665**	0.631**	0.718**	0.818**	0.754**	0.760**
NOL		1.000	0.947**	0.650**	0.818**	0.835**	0.942**	0.965**
PS			1.000	0.562**	0.764**	0.756**	0.893**	0.919**
SL				1.000	0.600**	0.805**	0.609**	0.686**
NOB					1.000	0.787**	0.834**	0.833**
SW						1.000	0.808**	0.819**
NOF							1.000	0.941**
SY								1.000

** Correlation is significant at the 0.01 level (2-tailed).
(PH – Plant height; NOL – Number of leaves; PS - Plant spread; SL - Spike length; NOB - Number of branches per spike; SW - Seed weight; NOF – Number of flowers per spike; SY - Spike yield per plant)

Table 3: Correlation coefficients between morphological characters and essential oil content in clary sage

Characters	*PH*	*NOL*	*PS*	*SL*	*NOB*	*SW*	*NOF*	*EO*
PH	1.000	0.814**	0.665**	0.631**	0.718**	0.818**	0.754**	0.796**
NOL		1.000	0.947**	0.650**	0.818**	0.835**	0.942**	0.828**
PS			1.000	0.562**	0.764**	0.756**	0.893**	0.677**
SL				1.000	0.600**	0.805**	0.609**	0.756**
NOB					1.000	0.787**	0.834**	0.653**
SW						1.000	0.808**	0.773**
NOF							1.000	0.804**
EO								1.000

** Correlation is significant at the 0.01 level (2-tailed)

(PH - Plant height; NOL - Number of leaves; PS - Plant spread; SL - Spike length; NOB - Number of branches per spike; SW - Seed weight; NOF - Number of flowers per spike; EO - Essential oil content)

Table 4: Cost of cultivation and benefit cost ratio under integrated nutrient management of clary sage

Treatments	*VC*	*RMC*	*MC*	*FC*	*IFC*	*TIC*	*TOC*	*B:C ratio*
T_1	41043.8	1200	10138.5	17387.5	5389	92546.3	42259.9	0.46
T_2	45168.8	2896.5	11535.7	17387.5	5389	99764.9	152827	1.53
T_3	45168.8	42450	21028.5	17387.5	5389	148811	63876.2	0.43
T_4	45168.8	31200	18328.5	17387.5	5389	134861	79872.2	0.59
T_5	45168.8	44146.5	21435.7	17387.5	5389	150915	191737	1.27
T_6	45168.8	32896.5	18735.7	17387.5	5389	136965	231835	1.69
T_7	61943.8	1832.32	13656.3	17387.5	5389	117596	66254	0.56
T_8	61943.8	1832.32	13656.3	17387.5	5389	117596	86897.5	0.74
T_9	61943.8	3210	13959.4	17387.5	5389	119277	73387.3	0.62
T_{10}	61943.8	3210	13959.4	17387.5	5389	119277	113053	0.95

(VC - Variable cost; RMC - Raw material cost; MC - Miscellaneous cost; FC - Fixed cost; IFC Interest on fixed capital @ 6.25% pa; TIC - Total input cost; TOC - Total output cost)w

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