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Effect of temperature on seed germination and emergence of *Salvia sclarea* L. in sub-tropical climatic condition

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Abstract
Plants are significantly affected by the ambient temperature for regulating their growth and development. *Salvia sclarea* L. is a temperature sensitive plant and prefers a temperate climate and habituate naturally above 2,000 meters above sea level, but it has been introduced successfully in sub-tropical plains as a winter season crop. Seed germination in sub- tropical climatic conditions varied under different temperature. Using laboratory incubation technique, a research investigation was carried out at CSIR-Central Institute of Medicinal and Aromatic Plants, Lucknow, Uttar Pradesh, India, to analyzed and assessed seed germination and emergence in relation to temperature variability. The impact of variability in temperature on germination of seeds and emergence was monitored daily at constant temperatures that ranged from 5 ºC to 30 ºC with 5 ºC increments. Results of the study indicated that temperature had a considerable impact on germination of and emergence of *Salvia sclarea* L. The maximum seed germination (78.50%) was found at 25 ºC, followed by 20 ºC (74.44%), and 15 ºC (65.80%) while lowest at 5 ºC (2.33%). Similarly, first seed emergence was occurred at four days at 25 ºC. Therefore, it was proclaimed that suitable temperature needed for seed germination of *Salvia sclarea* L. is varied between maximum 25 ºC to minimum 15ºC for maximum germination and early emergence.

Keywords: *Salvia sclarea* L., temperature, seed germination, emergence, sub-tropical climate

Introduction
Salvia sclarea L. commonly known as clary, or clary sage, is a biannually or perennial or short-duration herbaceous plant, belonging to the genus Salvia, in the Lamiaceae family It is mainly propagated by seeds. As far back as ancient times, clary sage was cultivated for its essential oil qualities, ornamental plant as well as its therapeutic properties. *Salvia sclarea* L. is primeval of Southern European and central Asia. It was commercially cultivated in Russia, Bulgaria, France, and Morocco [1], mostly adapted in the climatic regions that are temperate and sub-temperate, the crop produces about 150 metric tons of oil each year [2, 3]. Kashmir valley is the only place in India where essential oils are produced but it was in very few amount, so most of India's essential oil is imported [3]. Their phyto-constituents have antioxidant, antibacterial, and cytotoxic activities in the medicinal applications. The whole herb and essential oils are used as seasoning, condiments in foods, aromas, scents, perfumery, aromatherapy and in indigenous medicine [4]. The major oil constituents are linalool and linalyl acetate, which are extracted from the inflorescence of the salvia plant. This plant's sclareol and ambrox are highly valued in the worldwide market. In recognition of its over extravagant oil, attempts were intimidated to introduce it to the subtropical regions, and it was proficiently cultivated and acclimatized at CSIR-CIMAP in Lucknow as an annual rabi season (winter) crop [5]. As a result of its late maturing nature, it could not be integrated into conventional cropping systems and temperature dependent germination of seed.
Among the various germination factors, plant growth and development are largely influenced by temperature as it is the major predominant environmental factor [6]. Different crops exhibit different germination and emergence percentages as a function of temperature (optimum). The influence of temperature on the germination and emergence of crop seeds can be determined by determining the cardinal temperature, because that enables the assessment of how specific crops will respond to low and high temperatures, as well as the climatic conditions that will facilitate their germination and establishment [7].
The information about germination and emergence of seeds under various temperatures of *Salvia sclarea* L. are appears to be limited. Therefore, the current investigation is implicated with the process of seed germination and emergence of *Salvia sclarea* L. under controlled with special reference of temperature.

Material and Methods

Seed source

The seed of *Salvia sclarea* L. were obtained from experimental farm of CSIR- Central Institute of Medicinal and Aromatic Plants, Lucknow, Uttar Pradesh, India, located at 26.5° N latitude and 80.5° E longitude, 120 m above mean sea level. Seeds of *S. sclarea* L. were oval in shape and weight of 1000 seeds was 3.27 g.

Temperature regimes

Temperatures were maintained in incubators at the same level throughout germination and emergence experiments, which ranged from 5 °C to 30 °C (5 °C, 10 °C, 15 °C, 20 °C, 25 °C, and 30 °C) with 5 °C increments under control condition. Using the seed germinators, set to the above mentioned designated temperature and then placed the petri dishes in them. Over the course of 14 days (336 h), all of the tests were incubated. During all of the studies, the seeds were exposed to regular light. Every treatment was replicated three times using 100 seeds each. In controlled incubators, replicates were put in a completely randomized block arrangement.

Germination study

When the cotyledons were visible, it was considered that seeds had emerged and radicle had protruded [6, 8]. When the fungal growth appeared in seeds, it was immediately removed from the population. The germination of seeds at different temperature regimes shown in Fig. 1. The germination was calculated according to the following formula [9, 10]:

[Germination (%) = (Number of germinating seeds/ number of seeds) × 100]

Germination associate parameters were calculated by using following formulas:

Speed of germination

Speed of germination was calculated by the following formula given by [11].

$$[\text{Speed of germination} = \sum(\frac{n1}{d1} + \frac{n2}{d2} + \cdots . \frac{nx}{dx})]$$

Where, n = number of germinated seeds, d= number of days.

Mean germination Time (MGT)

Mean germination time was calculated by the formula given by [12].

$$[MGT = \frac{\sum(n \times d)}{N}]$$

Where, n= number of germinated seed, d = number of days, and N= total number of seeds germinated at the termination of the experiment.

Mean daily germination (MDG)

Mean daily germination can be calculated by the following formula given by [11].

[MDG = Total number of germinated seeds/ Total number of days]

Peak Value (PV)

Peak value was calculated by the following formula given by [11].

[PV = Highest seed germinated/ Number of days]

Germination Value (GV)

Germination value was calculated by the following formula given by [11].

[GV = PV X MDG]

Statistical analysis

Data (n=3) were analyzed using SPSS 20 software package for Windows and subject to one -general linear model ANOVA (analysis of variance). The Duncan's test was used for post-hoc comparisons to determine difference between means at $p \leq 0.05$ level of significance.

Results and Discussion

Germination of seeds was affected by a wide range of temperature variation, similarly, seeds of *Salvia sclarea* L. had showed a significant effect with the variation in temperature conditions that has been depicted in Fig. 2. The maximum germination percentage (78.50%) was found significantly higher at 25 °C, followed by 20 °C (74.44%) and 15 °C (65.80%) while lowest were recorded at 5 °C (2.33%). Similarly, with the germination percentage, the first emergence was occurred at four days/96 hours at 25 °C, followed by 20 °C (7 days/ 168 hours) and 15 °C (8 days/ 192 hours) while maximum time 14 days (336 hours) was recorded for seed emergence at 5 °C. The findings of the study revealed that germination of salvia seed is temperature sensitive and shows variation in alteration of temperature. Almost no germination took place at 5 °C temperature, as the seed was failed to germinate at low temperature, and the percent of germination continually decreased as the temperature was reduced.

Similar to germination percent, substantial differentiation was also measured in distinct parameters associated with germination of seeds at varying temperature regimes (Fig. 3). The germination speed of *Salvia sclarea* seeds was notably high at 25 °C (11.11) and found low at 5 °C (0.16). Although, the mean daily germination was observed highest (5.62) at 25 °C and lowest (0.16) at 5 °C. In different temperatures, there was a statistically significant difference in both daily germination and germination speed. Mean germination time in seed at varying temperatures differs from the minimal 7.64 at 25 °C to the maximum 14 at 5 °C and the divergences across the temperature were statistically highly significant. Based on these results, the excessive germination percentage was observed at 25 °C and the highest mean germination time was recorded at 5 °C. Therefore, the present investigation proclaimed that the quintessential temperature of 25-15 °C preferred seed germination in *Salvia sclarea* L.

As a key controlling factor regarding the physiological development of plants, temperature performs a substantial role in seed germination. However, the effect of temperature on each stage of the germination process is considerably distinct, which means that other factors must be considered as well. If the temperature is too cold germination of seed will be very slow to sprout and a warm environment will also reduce germination speed. Germination will be very slow if the temperature becomes too hot. At far too cold or hot temperature seed fail to germinate. The perusal of data related to temperature regimes, it was discerned that temperature influenced the seed germination of *Salvia sclarea*, and suitable temperature for sub- tropical climatic condition ranges from 25-15 °C. While considering these temperature

range October-November months are found to be favorable for seed germination. It depends on the species or cultivar of seed how hot it needs to be for seed germination to take place. From the previous study [13], reported that the suitable temperature for germination and development of plants in the tropical region are at 15 °C to 30 °C; plants in the temperate region germinate at 8 °C to 25 °C; and alpine plants germinate at 5 °C to 30 °C. With the confirmatory of present investigation results, [14] also mentioned in the study that, *Salvia dicroantha* germinated at the highest rate at 20 °C. Researchers [15], found that the optimal temperature for *S. sclarea* was 15-20 °C in temperate conditions when evaluating the effect of 12 temperature treatments (between 5 and 40 °C) on germination in light (12 h) and darkness on S. officinallis and S. sclarea. Changing day/night temperatures of 30 °C/20 °C were as effective as a constant 25 °C for *S. officinalis*, but they were less desirable for *S. sclarea* than a consistent 15-20 °C. From the previous studied [16] the germination of 5-year-old *S. officinalis* seed at temperatures of 20, 25, and 30 degrees Celsius under continuous light or in the dark, and discovered that the highest rate of germination (63 percent) was achieved at 25 degrees Celsius with continuous light. Researchers [17], examined the impacts of several temperatures and germination medium on *J. curcas* seeds and found that the ideal temperature for germination of *J. curcas* seeds was 30 °C and that vermiculite was the best germination media.

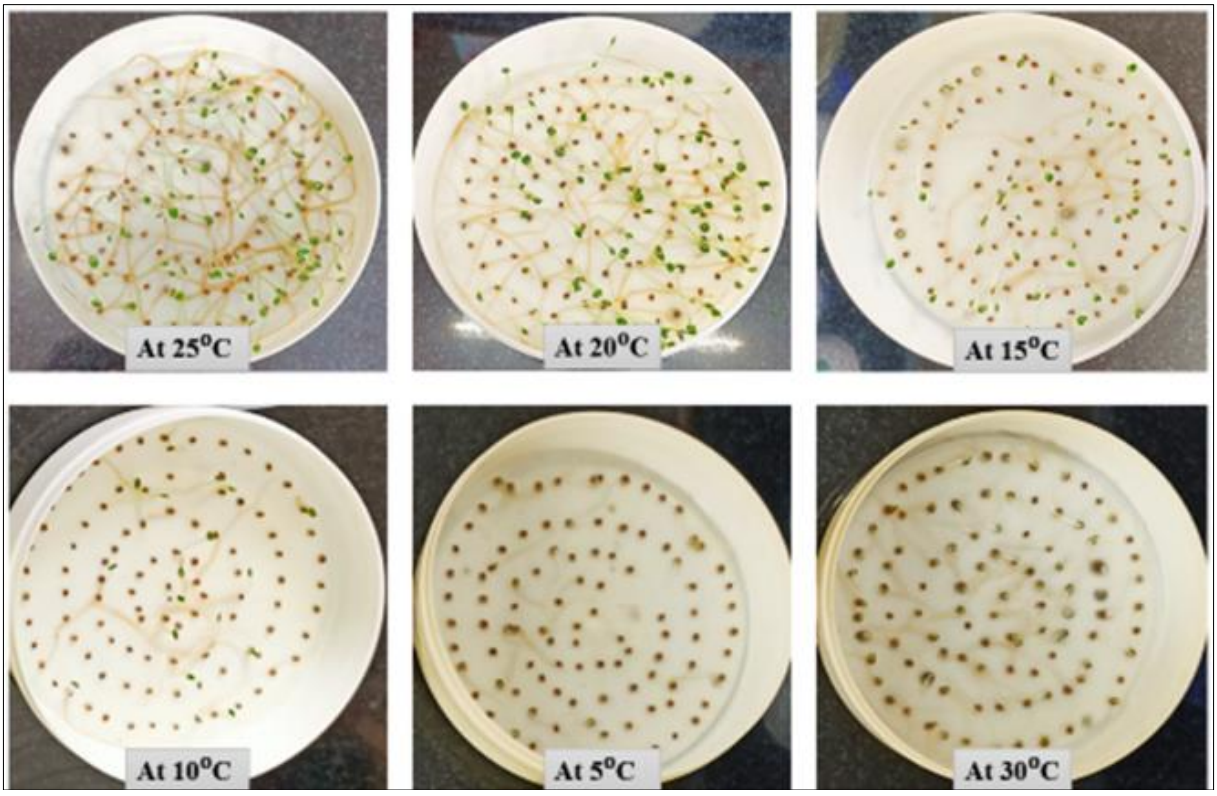

Fig 1: Germination of *Salvia sclarea* L. seeds at different temperature regimes

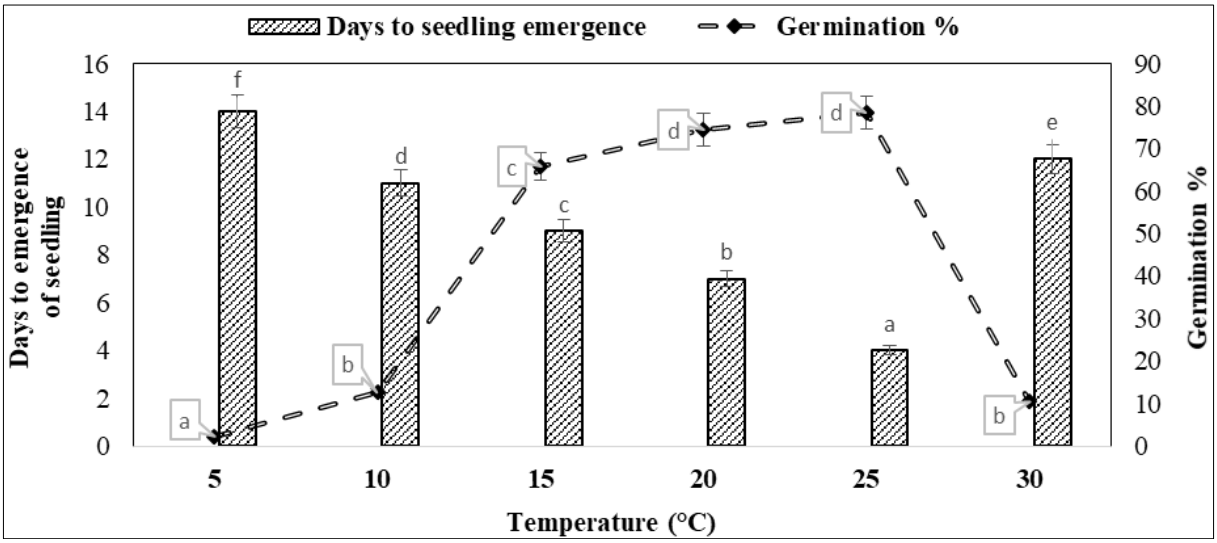

Fig 2: Effect of temperature on seed germination and emergence of *Salvia sclarea* L

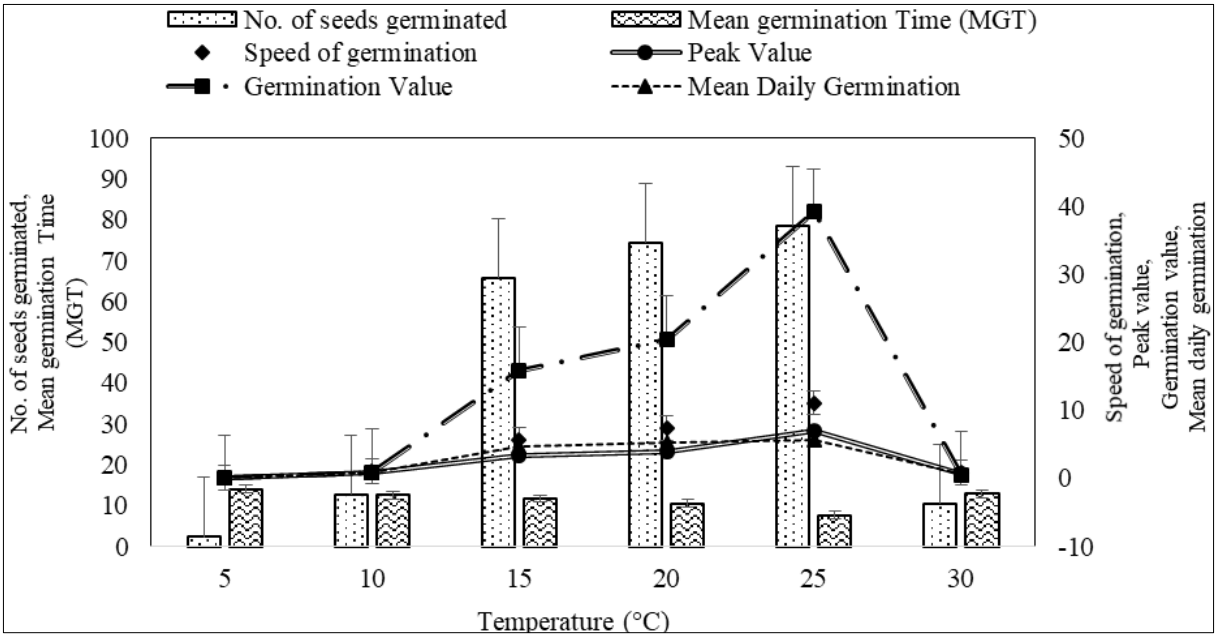

Fig 3: Influence of temperature regimes on *Salvia sclarea* L. seeds in different germination associated parameters

Conclusion

Germination of seed is affected by various environmental factors, temperature is the most prominent among them and is fundamental for development and advancement of seedlings that influence the final production of the salvia crop. The researcher must identify the preferable temperature for salvia seed germination and emergence. It is evident from the present investigation that maximum germination percentage, speed of germination was found better in 25 °C and mean germination time was highest at 5 °C. Hence, it is concluded from the studies that optimum temperature for germination of salvia seed was maximum at 25 °C to minimum 15 °C. Amend with this knowledge, it can also be suggested that October- November are best sowing month for the farmer's field in sub-tropical regions of India.

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Declaration of Competing Interest

The authors declare that they have no competing interest or personal conflicts that could appeared to influence the work.

Highlights

- An ambient temperature is necessary for regulating plant growth.
- *Salvia sclarea* L. is a temperature sensitive crop and prefers temperate climatic conditions.
- Assessment of suitable temperature for germination and emergence of seed in sub-tropical climatic conditions is required for proficient cultivation of the crop.
- October-November months are most favorable for seed germination in sub-tropical climatic condition.

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