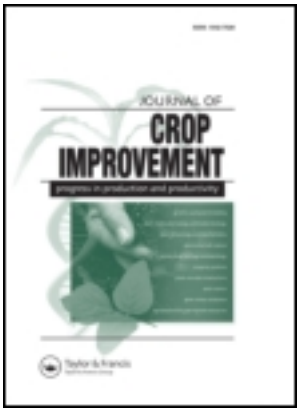

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Prediction of Germination Potential in Seeds of Indian Basil (*Ocimum basilicum* L.)

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*Indian basil (*Ocimum basilicum *L.) is an essential oil and aromatic chemical-producing crop of India. Optimal germination potential and seed vigor are essential for commercial growers and farmers to justify buying premium-priced seed and ensure performance of their crop. Seed germination tests of* Ocimum basilicum *variety CIM-Saumya were carried out in Petri dishes at constant temperatures of 15°, 20°, 25°, 30°, 35°, and 40°C at 16 h light/8 h dark daily regimes. The temperature of 25°C was found to be optimal, and germination percentage and seedling vigor indexes I and II were 75.6, 496.7, and 0.358, respectively. Seeds produced abnormal seedlings at 40°C. Significant decreases in germination percentage and seedling vigor indexes I and II were observed at 15°C, 20°C, 30°C, and 35°C. Days 2–3 and days 6–7 after seed sowing were ideal times for first and final count, respectively, for seed germination of Indian basil.*

KEYWORDS Aromatic crop, germination, Ocimum basilicum*, seed quality, temperature, vigor index*

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INTRODUCTION

Indian basil (*Ocimum basilicum* L.; family Lamiaceae) is an industrially important source of essential oil and aromatic chemicals. Its essential oil is widely used in high-grade perfumes, aromatherapy, flavoring liquors, soups, and sauces, and as herbal spice, fly repellant, and medicine (Bahl et al. 2000; Kumar et al. 2004). Indian basil is extensively cultivated in Indonesia, Egypt, Morocco, France, Greece, Hungary, and the United States (Bahl et al. 2000). In India, it is mainly cultivated in the states of Assam, West Bengal, Bihar, Uttar Pradesh, Madhya Pradesh, Maharashtra, and Jammu (Prakasha Rao et al. 2007). The estimated production of basil oil in India is 250 tons, and this oil has methyl chevicol and linalool as the major constituents (Maheshwari 1995; Bahl et al. 2000).

In a laboratory test, germination of a seed is the emergence and development of a seedling to a stage where the aspect of its essential structures (root system, shoot axis, cotyledons, terminal buds) indicates whether it is able to develop further into a satisfactory plant under favorable soil conditions (International Seed Testing Association 2010). Because seeds are a basic and most important input for crop production, seedling emergence and successful establishment are critical for obtaining vigorous plants. Germination is a complex biological process and several factors must work simultaneously for the emergence of a seedling. Percentage of germination is one of the most important characteristics of the seeds used for cultivation. For development of seed quality standards of Indian basil, information on the optimum germination potential, optimum temperature at which maximum germination percentage is achieved, and the first and final count day for recording of germination percentage are required for seed quality-testing laboratories.

Temperature is one of the most important and critical factors that affect seed germination (Forsyth & Van Staden 1983; Roberts 1988; Bewley & Black 1994; Baskin & Baskin 2001; Verma et al. 2010; Kumar, Verma, & Singh 2011). In *Ocimum basilicum*, germination potential has been studied at 20° to 45°C (Gupta & Shahi 1998), 30°C (Gupta 2002), and 15°, 25°, and 35°C (Ramin 2006). The ISTA (2010) suggested 20°–30°C for germination testing. Only those seeds that germinate rapidly and vigorously under favorable conditions in the laboratory can be capable of producing vigorous seedlings in the field. Effective stand establishment after germination is another important characteristic that gives an idea about the final population. Seed vigor is the sum total of those properties of the seed that determine the level of activity and performance of the seed or seed lot during germination and seedling emergence. Seed vigor is an important seed quality parameter that determines success or failure of a crop (Hampton & TeKrony 1995). The seed's ability to withstand severe germination conditions and subsequent successful seedling establishment depend upon seed vigor. Vigor tests are

essential to both commercial growers and seed production companies for ensuring crop performance (Karlovich 1998), and for pre-and post-harvest processing for premium quality seed production (Oakley, Kester, & Geneve 2004). Because Indian basil is seed propagated and its commercial growers suffer major losses caused by substandard seeds, it is essential to assess the germination potential and vigor for ensuring the crop stand and herb yield. The objectives of the present study were to investigate effects of temperature on seed germination and seedling vigor of Indian basil (Cv. CIM-Saumya). This variety is a high-yielding improved variety that was developed and released by Central Institute of Medicinal and Aromatic Plants and is very popular among growers in northern India where about 100 ha are under basil cultivation.

MATERIAL AND METHODS

Germination and Vigor Index

The seed of *Ocimum basilicum* variety CIM-Saumya was collected in the month of December 2009 from the crops grown at research farm of Central Institute of Medicinal and Aromatic Plants, Resource Centre, Hyderabad, India. The seeds were stored in paper bags at 20°C ± 2°C until needed for experimentation. The experiment was conducted during July–August 2010 at temperatures of 15°C, 20°C, 25°C, 30°C, 35°C, and 40°C at 16 h light (180 lx)/8 h dark daily regimes with 70%–80% relative humidity. Seeds were placed on top of filter paper (TP) (15 cm diameter) soaked with sterile distilled water in Petri dishes (16 cm diameter × 3 cm deep). The experiment was conducted in two sets, and each set had four replicates of 100 seeds. Germination was checked daily and numbers of normal (bearing both root and shoot) and abnormal (lacking either root or shoot or having stunted growth) seedlings recorded from first day of counting until the day of maximum seed germination percentage (Kumar, Verma, & Singh 2011). Numbers of normal seedlings were used for data analysis. Germination percentage, seedling vigor index I, and seedling vigor index II were calculated (ISTA 2010; Khosla, Chhillar, & Kashyap 2006; Kumar, Verma, & Singh 2011) as follows:

$$\text{Germination percentage} = \frac{\text{total number of seeds germinated}}{\text{total number of seeds in all replicates}} \times 100$$

$$\text{Seedling vigor index I} = \text{germination (\%)} \times \text{average seedling length}$$

From each replication, five normal seedlings were selected randomly at the end of germination test, and seedling length (root + shoot length) was measured. Average seedling length (cm) was calculated.

Seedling vigor index II = germination (%) × average seedling dry weight

The same five seedlings were placed in a paper envelope and dried under shade for 16 hr. These dried seedlings were placed in an oven at 75°C ± 5°C for 48 h after which they were weighed to determine average seedling dry mass (g) in each replication.

Statistical Analyses

At the end of the experiment, data were subjected to an analysis of variance (ANOVA) and mean separation. Data were analyzed using GenStat Release 7.21. The least significant difference (LSD) at 5% level was used to compare the means of different test parameters under different temperature conditions.

RESULTS AND DISCUSSION

Temperature significantly affected the germination of Indian basil seeds. The first emergence of seedlings was observed on the first day at 30°, 35°, and 40°C; second day at 25°C; third day at 20°C; and fourth day at 15°C temperatures. The maximum seed germination was found on fifth day at 30° and 35°C, sixth day at 20° and 25°C, and eighth day at 15°C. The mean seed germination percentage across temperatures for number of days to counting varied from 27.4 (15°C) to 60.3 (30°C) (Table 1). Among the temperatures, 25°C was the best with highest mean germination percentage (75.6%), followed by 30°C (70.4%), 20°C (68.1%), 15°C (60.5%), and 35°C (56.9)% (Table 1). At 40°C, seeds germinated as abnormal seedlings (78.8%) and died on the fourth day of counting.

The seedling vigor index I and II varied significantly with temperature. The maximum seedling vigor index I (496.7) and II (0.358) were recorded at 25°C, which was significantly different from seedling vigor index I and II at the other four temperatures (Table 2). Seedling vigor index I and II were lowest (255.8 and 0.226) at 35°C and 15°C temperatures, respectively (Table 2).

Maximum germination (76%) occurred in seeds of variety CIM-Saumya at 25°C, which seemed to be the optimum temperature for germination. Earlier workers also observed similar results in sweet basil (Ramin 2006), Palmarosa (Verma et al. 2010), and Kalmegh (Kumar, Verma, & Singh 2011). Poor germination capacity of the Indian basil variety CIM-Saumya is attributable to its genetic make-up as reported for varieties of Isabgol, Palmarosa, and Marigold (Kumar et al. 2008; Kumar et al. 2009; Verma et al. 2010). Significant reduction in percentage of germination above or below

TABLE 1 Mean germination percentage of variety 'CIM-Saumya' of Indian basil at different temperatures and number of days to counting

	Number of days to counting								
Temperatures	1	2	3	4	5	6	7	8	Mean
15°C									
Set I	0.00	0.00	0.00	17.00	38.00	50.25	57.50	59.50	27.78
Set II	0.00	0.00	0.00	18.75	31.50	47.75	56.50	61.50	27.00
Mean of Set	**0.00**	**0.00**	**0.00**	**17.87**	**34.75**	**49.00**	**57.00**	**60.50**	**27.39**
20°C									
Set I	0.00	0.00	40.00	56.00	69.00	70.50	70.50	69.75	46.97
Set II	0.00	0.00	38.75	59.25	65.25	65.75	65.00	64.25	44.78
Mean of Set	**0.00**	**0.00**	**39.38**	**57.62**	**67.12**	**68.12**	**67.75**	**67.00**	**45.85**
25°C									
Set I	0.00	26.00	54.25	70.25	76.25	79.25	79.50	78.75	58.03
Set II	0.00	25.25	41.75	60.50	68.75	71.75	71.75	72.00	51.47
Mean of Set	**0.00**	**25.62**	**48.00**	**65.38**	**72.50**	**75.50**	**75.63**	**75.38**	**54.75**
30°C									
Set I	4.00	58.00	66.00	66.75	66.75	66.50	65.75	64.75	57.31
Set II	3.25	66.75	71.50	72.75	74.00	73.50	73.00	72.25	63.37
Mean of Set	**3.63**	**62.37**	**68.75**	**69.75**	**70.37**	**70.00**	**69.37**	**68.50**	**60.34**
35°C									
Set I	8.00	47.00	50.00	52.25	54.25	54.75	54.25	53.25	46.72
Set II	8.25	47.25	57.75	59.50	59.50	58.25	58.00	57.50	50.75
Mean of Set	**8.13**	**47.12**	**53.88**	**55.88**	**56.88**	**56.50**	**56.13**	**55.38**	**48.73**

LSD at 5%: Set of experiment: 4.054; number of days to counting: 1.679; temperature: 1.232; set of experiment x temperature: 3.709; set of experiment x number of days to counting: 3.822; temperature x number of days to counting: 3.519; set of experiment x number of days to counting x Temperature: 5.600.

TABLE 2 Effect of temperature on seedling vigor index I (SVI-I) and seedling vigor index II (SVI-II) at final count day in India basil cv. 'CIM-Saumya.'

	Temperatures					
Variates	15°C	20°C	25°C	30°C	35°C	Mean
Seedling vigor index I						
Set I	289.6	435.7	493.7	377.8	259.5	371.2
Set II	279.9	336.8	499.7	479.0	252.1	369.5
Mean of set	**284.8**	**386.2**	**496.7**	**428.4**	**255.8**	**370.38**
Seedling vigor index II						
Set I	0.2044	0.3548	0.3566	0.2748	0.2324	0.2846
Set II	0.2478	0.2504	0.3594	0.3181	0.2430	0.2838
Mean of set	**0.2261**	**0.3026**	**0.3580**	**0.2965**	**0.2377**	**0.2842**

LSD at 5%: Temperature: 32.38 (SVI-I), 0.04424 (SVI-II); set: 20.248 (SVI-I), 0.02798 (SVI-II); set × temperature: 45.79 (SVI-I), 0.06257 (SVI-II).

25°C is an indication of the threshold high and low cut-off between studied ranges of temperatures, i.e., 15°–40°C (Kumar, Verma, & Singh 2011). In the present study, seeds germinated (78.8%) as abnormal seedlings at 40°C, and the primary site of high temperature sensitivity in germinating seeds may

be closely associated with the low rate of protein synthesis by the embryo as reported in Maize (Riley 1981). Gupta and Shahi (1998) reported 85% to 88% seed germination at 40°–45°C and 98% at 30°C in *Ocimum basilicum*, but their high percentage may be because of their inclusion of abnormal seedlings. According to our study, day 2–3 was the first count day and day 6–7 was final count day. Differential behavior of variety CIM-Saumya under different temperature regimes indicates that germination capacity of the seeds was affected by temperature. Temperature can affect the percentage and rate of germination through its effect on the low rate of protein synthesis by the embryo due to non-availability of active mRNA as reported in *Zea mays* (Riley 1981). Reduced temperature and critical high temperature would be expected to retard the metabolic rate to the point where pathways essential for the onset of germination would cease to operate (Roberts 1988; Kumar, Verma, & Singh 2011).

Seeds are highly sensitive to relative humidity and temperature. High relative humidity and temperature lower the seed's viability and vigor. Seed vigor can be influenced by genetic constitution of variety, environment, and nutrition of mother plant; maturity at harvest; seed size and mass; mechanical injury; aging; and pathogen factors. Intuitively, uniformity would seem to be an essential component of seed vigor (Oakley, Kester, & Geneve 2004). Rapid and uniform stand establishment is one objective of evaluating seed lots for vigor. The finding of the present study regarding maximum seedling vigor index I and II at 25°C was in agreement with the results that Khatun, Kabir, and Bhuiyan (2009) obtained for *Lens culinaris*. Seeds of Indian basil showing higher seedling vigor index are considered to be more vigorous for ensuring best buying of premium-priced seeds, good crop stand, and economic yield than those with a lower seedling vigor index. Decrease in seedling vigor index I at 35°C was in agreement with results for *Pisum sativum* (Matthews 1973), pigeon peas (Khare & Satpute 1999), and *Lens culinaris* (Khatun, Kabir, & Bhuiyan 2009). The lowest seedling vigor index II was recorded at 15°C, and this might be because of lower germination percentage and seedling dry mass. Harvesting the seed before the attainment of physiological maturity also could decrease viability and vigor potentials because of a large number of immature seeds with a relatively low degree of embryo development and high moisture content as reported in *Lens culinaris* (Khatun, Kabir, & Bhuiyan 2009) and *Pisum sativum* (Matthews 1973).

CONCLUSIONS

Maximum germination percentage and seedling vigor index I and II were recorded at 25°C with day 2–3 and day 6–7 as first and final count day, respectively, in *Ocimum basilicum* cv. CIM-Saumya. These results will be

useful to the Indian basil-producing industry in producing good yield/unit area and to researchers in developing high standards for seed quality.

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