

Impact of abiotic factors on emergence of *Avena fatua* seeds

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Many annual and perennial weeds compete with crops, leading to yield reductions, but objectionable weeds are particularly significant in seed production. Objectionable weeds closely resemble the seed crop in either plant or seed appearance, making them difficult and costly to remove once they become mixed with the crop. Various objectionable weeds have been identified in different field crops, including *Phalaris minor* and *Convolvulus arvensis* in wheat, wild oat (*Avena fatua*) in oat, wild rice (*Oryza sativa*) in rice, *Argemone mexicana* in mustard, wild sunflower (*Helianthus spp.*) in sunflower, *Cichorium intybus* in berseem, wild safflower (*Carthamus oxyacantha*) in safflower, and *Cuscuta spp.* in lucerne. According to the Indian Minimum Seed Certification Standards, there is a maximum allowable limit for objectionable weed seeds/plants, with *Avena fatua* seeds not exceeding 2 per kilogram in foundation seeds and 5 per kilogram in certified seeds (Anonymous, 2013).

Different weeds have distinct ecological requirements and thrive in various environments. Since weeds are part of a dynamic agricultural ecosystem, understanding weed ecology is crucial for sustainable weed management. The germination of weed seeds is influenced by factors such as temperature, light, moisture, and the pH of the growing medium, with water and temperature being key determinants. Most seeds germinate best at temperatures between 15 and 30°C. By studying weed ecology, we can understand the conditions necessary for their growth and development. This knowledge will aid in developing effective cultural management practices for problematic

weeds, either by inhibiting their germination or by promoting it when weed seedlings can be easily controlled (Opena *et al.*, 2014).

Weed seeds have the potential to grow into plants that compete with crops for essential resources such as sunlight, water, and nutrients, ultimately reducing crop yields. Their presence can significantly impact both the quality and quantity of the seed harvest, highlighting the importance of effective weed management to ensure optimal seed production. Light plays a critical role in regulating dormancy termination and subsequent germination in many weed species. In natural environments, the light conditions, detected primarily by phytochrome family photoreceptors, provide crucial signals for initiating germination under suitable environmental conditions. The spectral composition and intensity of light allow weed seeds to assess their depth in the soil, the presence of a leaf canopy, and the occurrence of soil cultivation. Seed germination is strongly influenced by light and fluctuating temperature conditions, which are key environmental factors (Baskin and Baskin, 1988; Vandellook *et al.*, 2008). Phytochromes in imbibed seeds help assess the level of competition in their environment (Shinomura, 1997). Temperature also plays a vital role in breaking dormancy by affecting seed physiology, influencing both the rate and percentage of germination across different species (Presotto *et al.*, 2014). Seeds buried deeper in the soil often face reduced success in emergence and establishment, mainly due to the greater energy required to reach the soil surface. The depth of emergence can be



influenced by seed size, with larger seeds having greater energy reserves, allowing them to emerge from deeper soil layers compared to smaller seeds. Seed dormancy is an inherent trait that prevents germination, even under favorable environmental conditions (Batlla and Benech-Arnold, 2007; Fennor and Thompson, 2005). Considering these factors, the present study was designed to investigate the effects of temperature, light and burial depth on the emergence of objectionable weed *A. fatua* seeds.

Fresh seeds of *A. fatua* were collected from research farms, and the study was conducted in the laboratories of the Department of Seed Science and Technology, Chaudhary Charan Singh Haryana Agricultural University, Hisar, during 2023-24. Following observations were recorded:

Germination (%): The germination test was carried out using the top of paper (TP) method, where three replications of fresh objectionable weeds were subjected to alternating temperatures of 15/20, 20/25 and 25/30°C in the germinator. A 16/8 hour light/dark cycle was maintained, with the lower temperature for sixteen hours and the higher temperature for eight hours. A 20-watt cool white fluorescent bulb provided the necessary light. The germination test was conducted in transparent petri dishes for treatments under light. Seeds were observed daily after the emergence of both radicle and plumule until maximum germination was achieved. The germination was calculated using following formula suggested by Weise and Binning (1987):

$$\text{Germination (\%)} = \left[\frac{\text{Number of normal seedlings}}{\text{Total number of seedlings per replicate}} \times 100 \right]$$

Radicle emergence (%): The radicle emergence test was performed using the top of paper method. Weed seeds, in three replications, were randomly placed on petri dishes having adequately moistened Whatman No.1 filter paper. The petri dishes were then placed in a controlled germinator set to alternate temperatures of 15/20°C, 20/25°C, and 25/30°C. Seeds with radicles at least 2 mm in length were counted and recorded at 24-hour intervals, starting from the onset of radicle emergence until maximum emergence was observed.

$$\text{Radicle emergence (\%)} = \left[\frac{\text{No. of seeds with 2 mm radicle length}}{\text{Total no. of seeds placed}} \times 100 \right]$$

Seedling length (cm): The length of seedlings (including both root and shoot) from 10 randomly chosen normal

seedlings from three replicates of the standard germination test, was measured in centimetres using a scale. The average length of the 10 seedlings was then calculated for final analysis. In case, the germination percentage was below 10 percent, average seedlings length was calculated accordingly (ISTA, 2019).

Seedling dry weight (mg): During germination test, 10 randomly selected normal seedlings were taken and dried in oven for 24 hours at a temperature of 80±1°C. The average weight of 10 dried seedlings was recorded and expressed in milligrams (mg). In some cases where germination percentage was below 10 percent, then average weight of germinated seedlings was calculated accordingly (ISTA, 2019).

Top of Form

Hard seeds (%): Seeds that remain hard and impermeable to water at the end of test period were considered as hard seeds. The hard seeds were also confirmed by using tetrazolium test (viability test).

Vigour indices: The Vigour Index-I and Vigour Index-II were calculated by following formula suggested by Abdul-Baki and Anderson (1973):

Vigour Index-I = Standard germination (%) × Average seedling length (cm)

Vigour Index-II = Standard germination (%) × Average seedling dry weight (mg)

To assess the effect of burial depth, twenty-five seeds in three replications were sown in plastic pots of (3 feet long and one feet deep)) at various depths *i.e.* 4, 6 and 8 cm in soil. The pots were placed under open environment and following field parameters were recorded:

Speed of emergence: The number of seedlings emerged were counted on each day up to seedling establishment. The speed of emergence was calculated as described by Maguire (1962).

Speed of emergence =

$$\left[\frac{\text{No. of seedlings emerged}}{\text{Day of first count}} + \dots + \frac{\text{No. of seedlings emerged}}{\text{Day of final count}} \right]$$

Field emergence (%): Field emergence was calculated by counting the total number of seedlings after completion of emergence or when there were no further additions to the total number of seedlings.



Statistical Analysis: Statistical analysis of data collected during the study was done by using the factorial complete randomized (CRD) design as described by Panse and Sukhatme (1985). All the values described as mean of the replicates with the evaluation of CD at 5% level of significance using the online statistical tool (OPSTAT) developed by Sheoran (2010).

The results revealed that maximum germination (48.66%) was observed at 15/20°C while minimum germination (27.33%) was observed at alternate temperature of 25/30°C. Under two light regimes more germination (37.89%) was observed under exposure to complete darkness for 24 hours as compared to 16 hours light followed by 8 hours darkness (33.56%). Maximum germination was recorded at 15/20°C (50.66%) in complete darkness while minimum (24.00%) was recorded at 25/30°C under 16 hours light followed by 8 hours darkness. Temperature and light interaction was found non-significant. No hard seeds were found at any temperature and light conditions. Same trend was observed for other seed quality parameters also and maximum seedling length (20.31 cm) was observed at an alternate temperature of 15/20°C whereas minimum seedling length (15.22 cm) was observed at 25/30°C. Between the light regimes, more seedling length (19.06 cm) was observed under exposure to complete darkness for 24 hours as compared to 16 hours light followed by 8 hours darkness (16.70 cm). The maximum seedling length (23.01 cm) was recorded at 15/20°C under complete darkness while minimum (14.64 cm) was recorded at 25/30°C under 16 hours light followed by 8 hours darkness (Table 1). Similarly, maximum seedling dry weight (7.27 mg) was recorded at 15/20°C and minimum seedling dry weight

(6.17 mg) was recorded at 25/30°C. More seedling dry weight (7.06 mg) was recorded under complete darkness over 16 hours light followed by 8 hours darkness (6.35 mg). Maximum Vigour Index-I (992.80) was observed at an alternate temperature of 15/20°C and the temperature that exhibited the minimum vigour index-I (484.40) was 25/30°C. More Vigour Index-I (747.18) was recorded in complete darkness over 16 hours light followed by 8 hours darkness (569.13). Maximum Vigour Index-I (1162.35) was recorded at alternate temperature of 15/20°C under complete darkness. Similarly maximum Vigour Index-II (355.69) was observed at 15/20°C and the temperature that exhibited the minimum Vigour Index-II (169.19) was 25/30°C. More Vigour Index-II (272.74) was recorded under complete darkness over 16 hours light followed by 8 hours darkness (215.67). Maximum Vigour Index-II (396.92) was recorded at alternate temperature of 15/20°C under complete darkness (Table 2).

The radicle emergence was started on 4th day. Maximum radicle emergence (46.42%) was observed at alternate temperature of 15/20°C followed by 20/25°C (25.51%) while minimum was recorded at 25/30°C (20.84). More radicle emergence (35.53%) was recorded at dark 24 hours complete darkness. The radicle emergence was completed on 9th day at 15/20°C while at 20/25°C maximum radicle emergence was completed on 12th day under 16 hours light followed by 8 hours darkness and 14th day at complete darkness. At 25/30°C alternate temperature, maximum germination was attained after 12th day under 16 hours light followed by 8 hours darkness and on 9th day under complete darkness. Maximum radicle emergence (58.67%) was recorded on 9th day at 15/20°C

Table 1: Effect of temperature and light/darkness on germination, hard seeds and seedling length of *Avena fatua*

Alternate Temperatures (T)	Germination (%)			Hard seeds (%)			Seedling length (cm)		
	L ₁	L ₂	Mean	L ₁	L ₂	Mean	L ₁	L ₂	Mean
15/20°C	46.66	50.66	48.66	00	00	00	17.84	23.01	20.31
20/25°C	30.00	32.33	31.17	00	00	00	17.61	18.39	18.11
25/30°C	24.00	30.67	27.33	00	00	00	14.64	15.80	15.22
Mean	33.56	37.89		00	00	00	16.70	19.06	
SE±(m)	T=0.75, L=0.61, T x L= (0.65)			T=00, L=,00 T x L=00			T=0.87, L=0.71, T x L=1.23		
C.D. (P=0.05)	T=2.34, L=1.91, T x L=NS			T=00, L=00, T x L=00			T=2.70, L=2.20, T x L=NS		

Where L₁ =16 hours light followed by 8 hours darkness and L₂= exposure to complete darkness for 24 hours



Table 2: Effect of temperature and light/darkness on seedling dry weight and vigour indices of *Avena fatua* seeds

Alternate Temperatures (T)	Seedling dry weight (mg)			Vigour index-I			Vigour index-II		
	L ₁	L ₂	Mean	L ₁	L ₂	Mean	L ₁	L ₂	Mean
15/20°C	6.71	7.83	7.27	823.25	1162.35	992.80	314.45	396.92	355.69
20/25°C	6.36	7.00	6.68	533.82	594.78	564.30	189.17	226.30	207.74
25/30°C	5.98	6.37	6.17	350.33	484.40	417.36	143.39	195.00	169.19
Mean	6.35	7.06		569.13	747.18		215.67	272.74	
SE±(m)	T=0.19, L=0.16, T x L=0.27			T=19.60, L=16.01, T x L=27.73			T=2.86, L=2.33, T x L=4.04		
C.D. (P=0.05)	T=0.60, L=0.49, T x L=NS			T=61.08, L=49.87, T x L=86.37			T=8.91, L=7.27, T x L=12.59		

Where L₁ = 16 hours light followed by 8 hours darkness and L₂ = exposure to complete darkness for 24 hours

in complete darkness (Table 3). Hilton and Bitterli (1983) found that light has inhibitory effect on freshly shed non-dormant seeds of *A. fatua* whereas Adkins (1981) found out that white light promoted the germination of partially-dormant seeds. Light has no effect on germination of *Avena fatua* has also been supported by Atwood (1914) and Alshallash (2018). Khan *et al.* (2016) demonstrated that maximum germination for *Avena fatua* occurs at low temperature (15°C) followed by 25°C and minimum at 40°C. Low temperatures (15°C) during development extend the dormancy period in *A. fatua* seeds, whereas high temperatures (25°C) reduce the seed development time, seed numbers, and seed dry weight (Adkins *et al.*, 1987). The results of the present study are in conformity with Marshall and Jain (1968) who reported that seedling

growth and seedling dry weight was maximum at low temperature 15/20°C and minimum at alternate temperature of 25/30°C. Similar results were found by Sarić-Krsmanović *et al.*, (2015) who confirmed that seedling growth of *Avena fatua* is significantly influenced by temperature, showing higher germination at 15°C and increased germination rates at 26°C/21°C under an alternating day/night photoperiod. Under dark conditions, Gibberellin activity increases resulting in promoting cell elongation. This hormonal effect is more pronounced at lower temperatures, resulting in more seedling length. This reason is also supported by Yamaguchi (2008) who discussed how gibberellins play a crucial role in promoting stem elongation in dark-grown seedlings.

Table 3: Effect of temperature and light/darkness on radicle emergence (%) of *Avena fatua* seeds

Temperature (T)	15/20°C		20/25°C		25/30°C		Mean
Duration (D) ↓ Light (L) →	L ₁	L ₂	L ₁	L ₂	L ₁	L ₂	
4 th day	4.00	2.67	0.00	6.67	1.33	4.67	3.22
5 th day	34.67	34.67	2.67	11.33	5.33	7.33	16.00
6 th day	42.67	42.67	9.33	18.33	8.00	17.33	23.06
7 th day	45.33	46.67	13.33	27.67	10.67	26.00	28.28
8 th day	49.33	54.67	18.67	34.67	12.00	30.00	33.22
9 th day	52.00	58.67	22.67	36.67	18.67	34.33	37.17
10 th day	52.00	58.67	25.33	38.67	21.33	34.33	38.39
11 th day	52.00	58.67	29.33	40.67	22.00	34.33	39.50
12 th day	52.00	58.67	30.67	43.33	22.67	34.33	40.28
13 th day	52.00	58.67	30.67	44.00	22.67	34.33	40.39
14 th day	52.00	58.67	30.67	46.00	22.67	34.33	40.72
Mean	44.36	48.49	19.39	31.64	15.21	26.48	
SE±(m)	T=0.28, L=0.23, D=0.54 T x L=0.40, T x D=0.94, L x D=0.77, T x L x D=1.33						
C.D. (P=0.05)	T=0.79, L=0.65, D=1.52 T x L=1.12, T x D=2.63, L x D=2.15, T x L x D=NS						
Mean	15/20°C =46.42, 20/25°C =25.51, 25/30°C =20.84, L ₁ = 26.63, L ₂ =35.53						

Where L₁ =16 hours light followed by 8 hours darkness and L₂ = exposure to complete darkness for 24 hours



Field emergence (%) was reduced as the burial depth increased and maximum field emergence is recorded at 4 cm (33.67%), followed by 6 cm (31.00%) and minimum at 8 cm (29.33%). Speed of emergence also reduced as the depth increased and maximum speed of emergence was observed at 4 cm (4.94) and minimum (3.62) 8 cm (Table 4). Similar results were reported by Baye *et al.*, (2020) in faba bean (*Vicia faba L.*) Similarly, Singh *et al.* (2012) reported that with each increase in seeding depth, the germination was delayed, taking longer for seedlings to emerge. Likewise, Umeoka and Ogbonnaya (2016) stated that telfairia seeds sown at depths of 3 cm and 6 cm germinated faster than seeds sown at depths 9 cm and 12 cm. The delay in germination with increased sowing depth may also be due to soil compaction at greater

depths, which requires the coleoptile to expend more energy to break through and emerge. In line with this, Yagmur and Kaydan (2009) found that the coleoptile (a leaf sheath that surrounds and protects the first true leaf as it grows from the seed towards the surface) lengthens with increased sowing depth. They also reported that when the coleoptile length is shorter than planting depth, emergence becomes difficult. Deep sowing also causes elongation of the stem between the seed and the secondary roots, which severely depletes the food reserves of the grain and may prevent the seedling from emerging. Increased hypocotyl or epicotyl length, as observed in deep-sown seedlings, reduces the likelihood of overcoming soil strength and makes the seedlings more susceptible to pathogen attacks (Yu *et al.*, 1990).

Table 4: Effect of burial depth on field emergence and speed of emergence of *Avena fatua* seeds

Burial depth (cm)	Field emergence (%)	Speed of emergence
4	33.67	4.94
6	31.00	4.38
8	29.33	3.62
SE±(m)	1.04	0.22
C.D. (P=0.05)	NS	0.78

Conclusion

Alternate temperature of 15/20°C is optimum for germination of *A. fatua* seeds. The germination decreased as the temperature increased. No effect of light was observed on germination and more germination was recorded in the seeds exposed to complete darkness for 24 hours. Field emergence (%) and speed of emergence were reduced as the burial depth increased from 4 cm to 8 cm. This information can be used for the management of objectionable weed *A. fatua* in oat crop during seed production.

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Author contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Conflict of interest

No

Declaration

The authors declare no conflict of interest.

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