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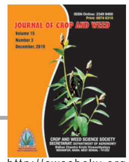

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Germination ecology of *Coronopus didymus* in western region of Haryana

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ABSTRACT

Coronopus didymus (lesser swinecress) is an invasive weed throughout the globe. The experiments were conducted in order to ascertain the effects of different environmental factors on C. didymus germination and emergence process. Its highest germination (53%) was obtained at 15/10^{O}C (day/night). But it decreased with increasing temperature, and failed to germinate at 45/35^{O}C. Germination decreased considerably from 40 to 8% (0 to -0.8 MPa) and inhibited completely at -1.0 and -1.2 MPa osmotic potential. There was 50% reduction in maximum germination as salinity increased from 0 to 50 mM NaCl. It could prefer acidic conditions rather than basic conditions. It was non-photoblastic in nature, as dark and light period had no significant effect on its germination. The optimal seeding depth for maximum emergence was 0.5 cm (>80%), but its emergence decreased as seeding depth increased further. Mulching showed inhibitory action on its emergence. Continuous flooding for different durations significantly increased seedling emergence of C. didymus over no-flooding condition. As after 32 days of continuous flooding, its emergence was 100%. The information obtained from this study would help in predicting potentials and requirements of ecological environments of this weed species and in developing effective and sustainable weed management measures against this weed.

***Keywords*:** Drought, flooding, light, mulching, salinity, seeding depth

Coronopus didymus (lesser swinecress) is a foul-smelling dicotyledonous invasive weed in multiple parts of the globe. It is a major weed of the Brassicaceae (Cruciferae) family. It is annual or biennial self-pollinating herb which is known to form a disk-like mat of prostrate shoots. The weed produces approximately 1,600 seeds per plant that can go up to 18,000 in some cases (Salisbury, 1961). This is highly competitive weed in cropping areas, as well as wide spread in fallow regions and in overgrazed pasture.

In India, it is a principal weed of berseem and lucerne, and also found in the fields of carrot, potato, wheat, mustard, pea, chickpea, fenugreek, oat *etc*. (Degra *et al.*, 2011; Devi *et al.*, 2018). It requires shady, cool and moist habitat for its best growth. Being amply available in crop fields like lucerne and berseem, it is one of major weeds affecting the productivity and fodder quality of berseem and lucerne in the Indo-Gangetic plains and central India. The weed parts have some important chemicals like glucosinolate and glucotropaeolin which are enzymatically converted into benzyl cyanide, benzyl isothio-cyanate, benzylmethyl sulfide and benzyl thicyanate during cutting and crushing (Walker and Gray, 1970). The benzyl methyl sulfide imparts the burnt and unclean flavor to milk when ingested by dairy animals (Park *et al.,* 1969). Cruciferous weeds including *C. didymus* are considered as a potential source of *Xanthomonas campestris*, which causes black rot of crucifers (Schaad and Dianese, 1981).

Germination is one of the most important stages for successful establishment of the weed. Germination process is the result of complex interactions between several seed characteristics like seed vigour and longevity, and environmental conditions like light, temperature, moisture, gases and imposed mechanical thrust. Thorough knowledge about its germination ecology has helped us to choose the most suitable weed management practices (Chauhan *et al.*, 2006). The germination and emergence of weeds are significantly altered by an exposure to varying environments and prevailing agronomic management. The information is necessary to take steps towards prevention of its additional introduction and invasion to a new geographical area, as this weed has a great potential to pose serious biotic threat to economy and ecological diversity in agriculture and non-agriculture areas.

A good understanding of germination and emergence of *C. didymus* can help to foresee its potential spread into new areas and develop sustainable weed management strategies. To date, there is a little information about germination and seedling emergence of *C. didymus*, especially under Indian conditions. Additionally, this knowledge can help us to explain, why *C. didymus* has effectively invaded the production areas in the country. Keeping these points in mind, the present study was conducted to evaluate the seed

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germination in response to temperature, drought, salinity, pH and light, and also to investigate the effect of seeding depth, mulching and flooding on seedling emergence of *C. didymus*.

MATERIALS AND METHODS

To study the effect of temperature, drought, salinity, pH and light on seed germination and of seeding depth, mulching and flooding on seedling emergence of *C. didymus*, experiments were carried out under laboratory and screen house, respectively, at CCS Haryana Agricultural University, Hisar, Haryana during *rabi* seasons of 2015-18. Seeds of *C. didymus* were collected from Research Farm of CCSHAU, Hisar for three consecutive years *i. e.* at the end of *rabi* season of 2014-16. Seeds of mature plants were harvested, cleaned, sieved and, then stored in small paper bags at room temperature until their use in experimental trials.

In laboratory experiments, ten seeds of *C. didymus* were placed uniformly in each Petri dish (90 mm diameter) with double layered filter paper (Whatman No. 1). Initially, 7 ml of de-ionized water or a treatment solution (for pH, salinity and drought experiments) was used to moisten the filter paper. After that, the Petri dishes were incubated at 30/20^{o}C (except for the temperature experiment) and 12-hour light and dark period (except for light experiment). When required, 1-2 ml distilled water was added to maintain an adequate moisture level in filter paper. Germination was observed daily (except in the light experiment), and radical protrusion was the criterion for germination of a seed. Germination percentage was determined on the basis of the number of viable seeds.

In screen house experiments, plastic pots (15 cm top diameter with 10 kg soil capacity) were used to study the effect of seeding depth and flooding, whereas, to study effect of mulching on seedling emergence, large sized plastic pots (30 cm diameter with 15 kg soil capacity) were used. For filling the pots, field soil (collected from fields where herbicides were not used for the last 4-5 years), dunal sand and vermicompost were used in the ratio of 3:1:1. The texture of soil was sandy loam, having 0.6 % organic carbon, 320 kg ha^{-1} available nitrogen (N), 17 kg available P_2O_5 ha^{-1} and 307 kg available K_2O ha^{-1} and pH of 7.0. For each treatment, ten seeds of *C. didymus* were sown uniformly in plastic pots at 0.5-1 cm depth, unless otherwise specified. The seedlings were considered to be emerged with appearance of cotyledons above the soil surface.

Each experiment was conducted in completely randomized design (CRD) with four replications and repeated over time. Germination percentage (G%) was calculated by dividing the sum of germinated seeds (SG) to the total number of seeds (TS) placed into each Petri dish:

G (%) = (SG/TS) ×100

Further, the experimental data were analyzed by using SPSS v. 17.0. Standard error of means was calculated, and regression trends were plotted in graphs.

To test the effect of temperature on seed germination of *C. didymus*, Petri dishes were placed in growth cabinets already set to 15/10, 20/10, 25/15, 30/20, 35/25, 40/30 and 45/35^{o}C (day/night), and to see the effects of drought on seed germination of *C. didymus*, polyethylene glycol 8000 (PEG 8000) was dissolved into distilled water to make aqueous solutions of -0.1, -0.2, -0.4, -0.8, -1.0 and -1.2 MPa at 30/20^{o}C (day/night) with control (distilled water only). The aqueous solutions of respective osmotic potentials were prepared by dissolving 85.4, 127.8, 188.2, 274, 308.5 and 339.75 g of PEG 8000 powder in 1,000 ml of distilled water (Michel and Kaufmann, 1973). The effect of salinity on *C. didymus* seed germination was examined by using sodium chloride (NaCl) solutions of 25, 50, 75, 100 and 125 millimole (mM) at 30/20^{o}C (day/night) along with control (distilled water only).

Formula used was X mM NaCl = (Molecular weight of NaCl × X × 10^{-3})/ litre of water

where, X = concentration of salt in mM, Molecular weight of NaCl = 58.45 g

Seed germination was investigated under a range of pH 5.0, 7.0, 9.0 and 11.0 at 30/20^{o}C (day/night). Potassium hydroxide pellets and citric acid were used for preparing different pH solutions. The seeds of *C. didymus* were exposed to light for 0 (dark), 0.5, 1, 2, 4, 8 and 16 hours and after treatment, Petri dishes were wrapped in double layers of aluminum foil to ensure no light penetration, and Petri dishes were kept in growth cabinet which was already set at 30/20°C (day/night). Petri dishes were kept in germinators undisturbed and then unwrapped in dim light to observe germination and to study the effect of seeding depth on seedling emergence, its seeds were placed at a depth of 0 (surface), 0.5, 1.0, 2.0, 4.0 and 8.0 cm in plastic pots.

Flooding for 0 (no flooding), 4, 8, 16 and 32 days was maintained continuously by keeping 5-7 cm water layer in the pots. After specified flooding durations, holes were made at the bottom of the pots to drain out the excess water, whereas, different mulching levels (no mulch, 2, 4, 6, 8 and 10 t/ha) were applied to study the effect of mulching on seedling emergence. Chopped paddy straw was used as mulch material.

RESULTS AND DISCUSSION

Laboratory experiment

Effect of temperature

The seeds of *Coronopus didymus* did germinate at a broad range of day/night temperatures from 15/10 to 40/30^{o}C with maximum germination (53%) at lower temperature i.e. 15/10^{o}C (Fig. 1), which could be

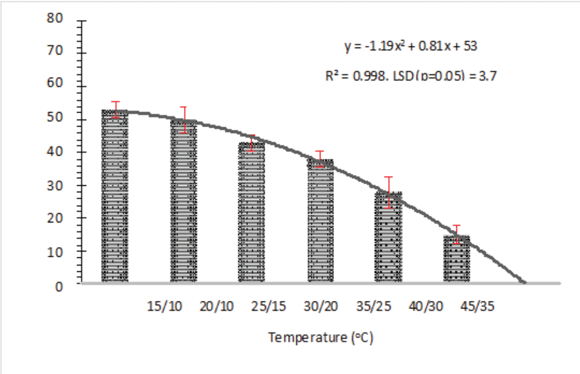


Fig. 1: Effect of alternating temperature (day/night) on seed germination of *C. didymus* at 4 weeks after treatment

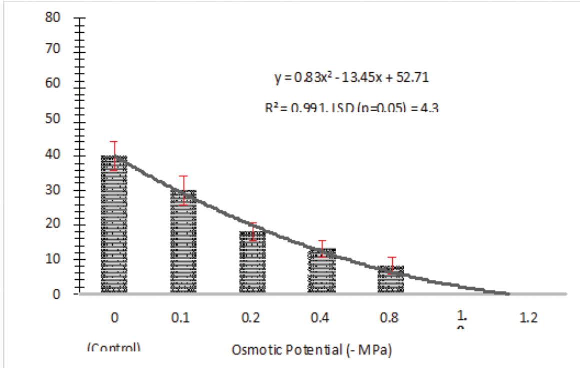


Fig. 2: Effect of drought (osmotic potential) on seed germination of *C. didymus* at 4 weeks after treatment

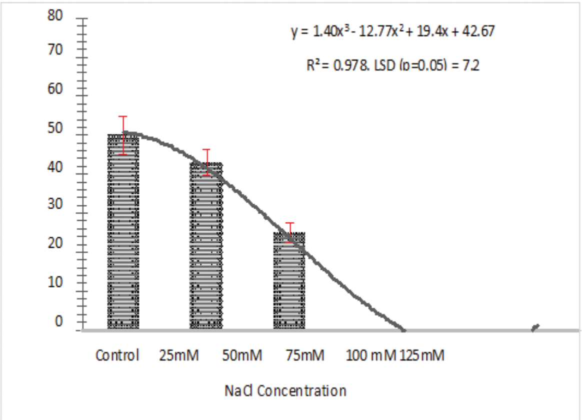


Fig. 3: Effect of salinity on seed germination of C. didymus at 4 week after treatment

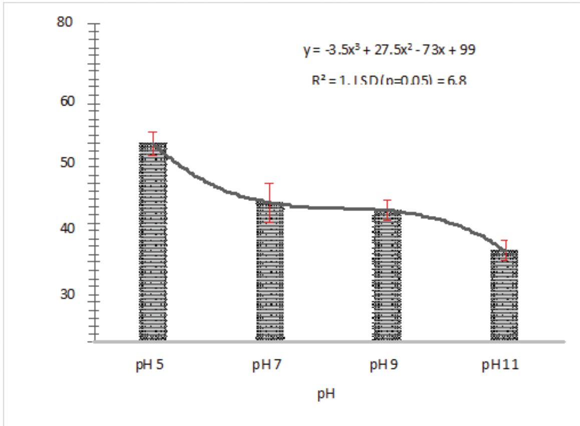
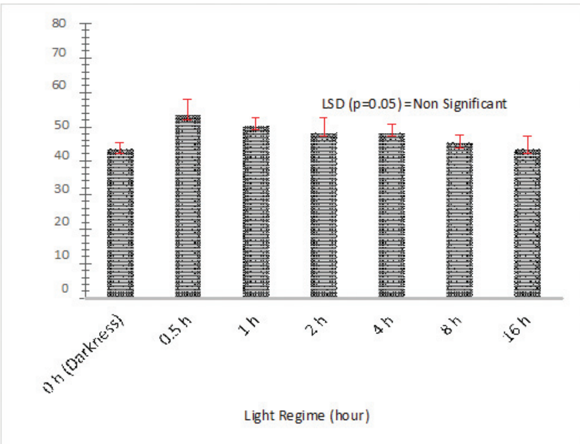


Fig. 4: Effect of pH on seed germination of *C. didymus* at 4 weeks after treatment



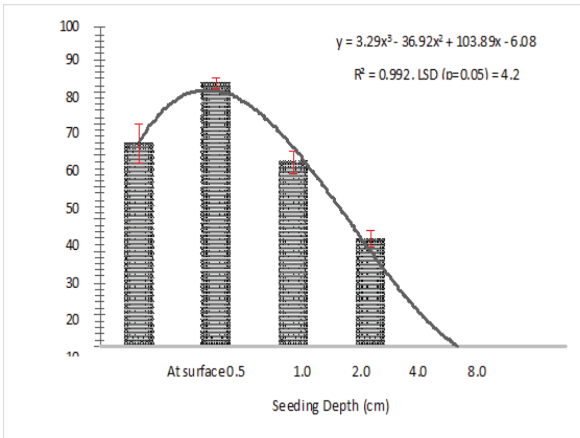


Fig. 5: Effect of light on seed germination of C. didymus at 4 weeks after treatment

Fig. 6: Effect of seeding depth on seedling emergence of *C. didymus* at 4 weeks after sowing

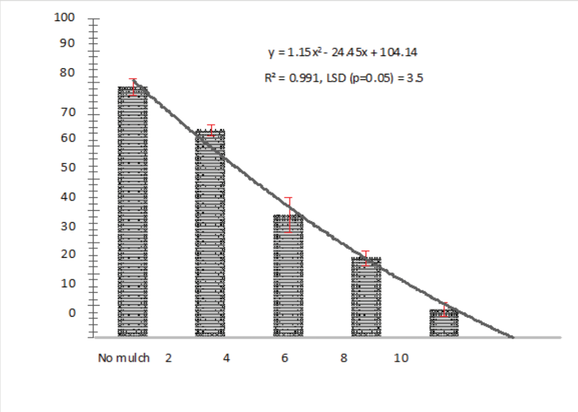


Fig. 7: Effect of mulching on seedling emergence of C. didymus at 4 weeks after sowin

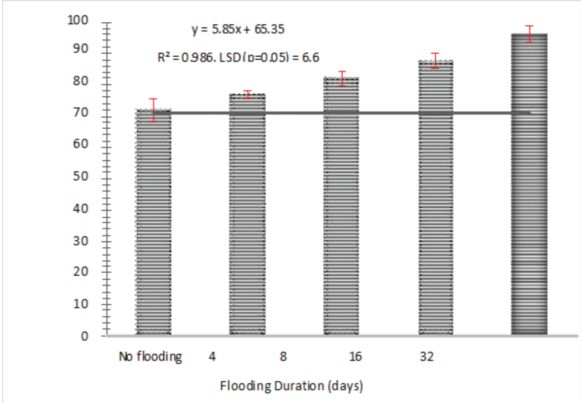


Fig. 8: Effect of flooding on seedling emergence of *C. didymus* at 4 weeks after drainage

explained with the fact that it was a winter weed species. Its germination gradually decreased with increasing temperature, while, at 45/35^{O}C, it failed to germinate. The germination percentage as a function of temperature was found to follow the equation ($y = -1.19x^2 + 0.81x + 53$, $R^2 = 0.998$, where y is germination percentage and x is temperature. Optimum temperature range for *C. didymus* seed germination was observed between 15 to 30^{O}C as each plants species has cardinal temperatures for its germination and growth (Ghaderi-Far *et al.*, 2010). These results were consistent with the results of Tanveer *et al.* (2014) on *Asphodelus tenuifolius* where maximum germination (80%) of this weed was recorded at 15^{O}C and its germination decreased with increasing temperature.

Effect of drought

Under drought or moisture stress condition, the seed germination of *C. didymus* was the highest in control (no moisture stress condition) *i.e.* 40% (Fig. 2). As the exposure of seeds to osmotic potential increased from -0.1 to -0.8 MPa, the germination percentage decreased dramatically from 25-80% over control. Its germination was completely inhibited at -1.0 and -1.2 MPa osmotic potential. This indicated that *C. didymus* was sensitive to moisture stress, due to which its spread might be restricted to moist soil. Likewise, *Eclipta alba* might be sensitive to moisture stress (Dhawan, 2007). The germination percentage of *C. didymus* was found to be varying with potential according to relation ($y = 0.83x^2 - 13.45x + 52.71$, $R^2 = 0.991$), where y is germination percentage and x is osmotic potential.

Effect of salinity

For salinity treatments, it was found to germinate up to 50 mM NaCl concentration in solution. With further increase in NaCl concentration in solution from 75 to 125 mM, the weed failed to germinate completely. Maximum germination (50%) was obtained in control treatment. In 25 and 50 mM NaCl concentration solution, the reduction in germination over maximum was about 14 and 50% respectively. These results showed that *C. didymus* was sensitive to salinity (Fig. 3). Its germination percentage varied with salinity, according to equation ($y = 1.40x^3 - 12.77x^2 + 19.4x + 42.67$, $R^2 = 0.978$) where y is germination percentage and x is NaCl concentration. High salt concentration might decrease the osmotic potential of the solution to such an extent that it might reduce or prevent the uptake of water which was necessary for activation of enzymes and mobilization of nutrient in seed. These results were in close conformity with findings of Camlica and Yaldiz (2017) on *Ocimum basilicum*.

Effect of pH

Significantly higher germination of *C. didymus* was observed at pH 5 (50%), followed by pH 7 (35%), pH 9 (33%) and pH 11 (25%). The results indicated that it could germinate in a wide range of pH *i.e* 5 to 11, but this weed might prefer acidic pH 5 (Fig. 4). The results were similar to the results reported by Burke *et al.* (2003), who found that crowfoot grass (*Dactyloctenium aegyptium*) germination was higher at lower pH of 4-5, As pH of substrate solution was increased, its germination decreased considerably. The variation in germination percentage of *C. didymus* with pH could be reported by the equation ($y = -3.5x^3 + 27.5x^2 - 73x + 99$, $R^2 = 1$), where y is germination percentage and x is pH value.

Effect of light

Light did not show any significant effect on germination of *C. didymus* with respect to variations in light and dark period exposure (Fig. 5). These results indicated that light was not a prerequisite for germination of this *rabi* season weed. Therefore, it might be considered that this weed would be non-photoblastic in nature. These results were similar to the findings of Kumari (2010) on *M. denticulata, V. sativa, L. aphaca* and *C. arvensis*, whose germination was also not influenced by different light periods.

Screen house experiment

Effect of seeding depth

The seedling emergence of *C. didymus* firstly increased with an increase in seeding depth from zero (surface) to favorable depth, and then decreased remarkably. Maximum seedling emergence (83%) was observed when its seeds were placed at 0.5 cm deep in soil (Fig. 6), and its emergence decreased significantly with an increase in seeding depth up to 2 cm. It failed to emerge at seeding depth beyond 2 cm. This might be related to carbohydrate reserves and size of respective weed seed (Baskin and Baskin, 1988). Emergence of *C. didymus* was reduced by deeper seed burial, suggesting that seeds burial with tillage might reduce the impact of this species on crop/fodder yield. Similar results were earlier reported by Chauhan *et al.* (2006) on *B. tournefortii* as this weed emergence was also influenced by different seeding depth. The variation in emergence percentage of *C. didymus* with seeding depth could be modelled by equation ($y = 3.29x^3 - 36.92x^2 + 103 - 6.08$, $R^2 = 0.992$), where y is emergence percentage and x is seed seeding depth.

Effect of mulching

The seedling emergence of *C. didymus* decreased dramatically with increasing rice straw mulching level from zero (no mulch) to 10 t ha^{-1} (Fig. 7). Significantly higher emergence (79%) was recorded under no mulch/mulch-free condition. More than 60% seedling emerged at 2 t ha^{-1}, whereas only less than 10% seedlings emerged when 8 t ha^{-1}of mulching was applied on soil surface. However, mulch application at 10 t/ha had complete inhibitory effect on its emergence. The impact of mulch on weed emergence, however, was dependent on quantity, position relative to weed seeds (below or above), and allelopathic potential of mulch residue with the weed species (Chauhan *et al.*, 2006).

Emergence suppression of weed by mulch could be credited to various physicochemical factors (like lower soil temperature, shading and physical obstruction as provided by mulch itself). Mulch materials could block the access of sunlight to weeds, and thus, weed would not have enough energy to emerge out through the mulch again (Blum *et al.*, 1997). The variation in emergence percentage with mulching could be modelled by equation ($y = 1.15x^2 - 24.45x + 104.14$, $R^2 = 0.991$), where y is emergence percentage and x is mulching levels.

Effect of flooding

Seedling emergence of *C. didymus* took place only when flooded water was drained out from pots. Flooding for different periods favored the seedling emergence that increased with increase in flooding duration from zero to 32 days (Fig. 8). Maximum seedling emergence (95%) was recorded after continuous flooding for 32 days, and minimum emergence (about 70%) was noted under normal (no flooding) condition. Flooding for 32 days increased 33% emergence as compared to non-flooding condition. Flooding could change the chemical properties of soil and density of microbes like fungi *etc*., which might act by breaking dormancy of seeds, either by decomposition of hard seed coat or by other molecular processes (Sperber *et al.*, 2017). During flooding situation, activities of anaerobic microbes (mostly of gram positive bacteria) increased, while, after drainage of flooded water, activity of aerobic microbes (fungi *etc.*) increased in the soil (due to high moist condition), and these microbes like fungi possibly affected the germination and emergence of *C. didymus*. Flooding did not emerge to be a practical option for *C. didymus* control in rotation, because its seeds could germinate even after 1 month of flooding (Fig. 8). Likewise, the germination rates of *Brassica tournefortii* was not affected by flooding (Bangle *et al.*, 2008). The variation in emergence percentage with flooding duration could be modelled by equation ($y = 5.85x + 65.35$, $R^2 = 0.986$), where y is emergence percentage and x is flooding duration.

CONCLUSION

The present study suggested that the thriving invasion of *Coronopus didymus* in an area could be explained, by the ability of the weed seeds to germinate and to emerge under different ecological conditions. As the optimum temperature range for germination of this weed was 15-30^{O}C, it was found to be sensitive to drought and salinity stresses. The optimum pH for its germination was acidic. It was found to be non-photoblastic in nature, as dark and light period had no effect on its germination. The optimal seeding depth for higher emergence of *C. didymus* was 0.5 cm, and its emergence decreased with increasing burial depth. The application of rice straw mulching decreased the emergence of this weed. Continuous flooding for different periods significantly increased its emergence. These findings might lead to a good understanding of the requirements of *C. didymus* germination and emergence with regard to its sustainable management.

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