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Article

GERMINATION ECOLOGY OF *Lathyrus aphaca*, A PROBLEMATIC WEED OF WHEAT CROP UNDER SEMI-ARID CONDITIONS OF PAKISTAN

*Ecologia da Germinação de **Lathyrus aphaca**, Uma Planta Daninha Problemática para a Cultura do Trigo em Condições Semiáridas no Paquistão*

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ABSTRACT - *Lathyrus aphaca* is an aggressive dicotyledonous weed. The effect of different agroecological components/factors on the germination ecology of this weed was explored under a glasshouse and laboratory condition in 2014. The germination response of *L. aphaca* was lower at high temperature while maximum seed germination was found at 15/12 °C (day/night). Light significantly stimulated *L. aphaca* germination; nevertheless, substantial germination occurred under dark conditions. More than 86-90% of *L. aphaca* seeds germinated at pH level of 6.2-7.5. A significant quantity of seed germinated at 250 mM NaCl. There was no germination at -1 MPa. When the temperature was lower than 20/15 °C (day/night) initiation time of germination and germination index (GI) decreased but time to 50% germination (T_{50}) and mean germination time (MGT) increased. Darkness resulted in increased time to start germination, T_{50}, MGT and decreased GI in *L. aphaca* when compared with the 10 and 12 h photoperiods. The pH of 6 and above 7 enhanced germination time, T_{50}, MGT but decreased GI. Salt stress above 100 mM increased time to germination, T_{50}, MGT but reduced GI. Osmotic potential above -0.4 MPa increased initial germination time, T_{50} and MGT as well as decreased germination index (GI) of *L. aphaca*. Increased seed depth in soil lowered germination percentage and GI but enhanced initial germination time, T_{50}, MGT. It was concluded that *L. aphaca* can grow over a wide range of agroecological/environmental conditions. These results may aid the development of agronomic tools and strategies for weed management in arable crops for yield enhancement.

Keywords: osmotic stress, weed seeds, salt stress, temperature, pH, light.

*RESUMO - **Lathyrus aphaca** é uma planta daninha dicotiledônea agressiva. O efeito de diferentes componentes e fatores agroecológicos na ecologia da germinação dessa planta daninha foi investigado sob condições de estufa e laboratório em 2014. Foi observada menor resposta germinativa de **L. aphaca** em condições de alta temperatura, ao passo que a germinação máxima ocorreu a 15/12 °C (dia/noite). A luz exerceu estímulo significativo para a germinação de L. aphaca; no entanto, observou-se uma quantidade considerável de germinação em condições de pouca luz. Mais de 86-90% das sementes de **L. aphaca** germinaram em nível de pH entre 6,2 e 7,5. Uma quantidade significativa de sementes germinou a NaCl 250 mM. Não ocorreu germinação a -1 MPa. Quando a temperatura foi inferior a 20/15 °C (dia/noite), houve diminuição do tempo para início da germinação e do índice de germinação (IG), mas aumento do tempo para 50% de*

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germinação (T_{50}) e do tempo médio de germinação (TMG). A escuridão resultou em aumento do tempo para início da germinação, T_{50} e TMG, mas levou à diminuição do IG em ***L. aphaca****, em comparação com os fotoperíodos de 10 e 12 horas. O pH de 6 e acima de 7 aumentou o tempo de germinação, T_{50} e TMG, porém diminuiu o IG. O estresse salino acima de 100 mM aumentou o tempo para germinação, T_{50} e TMG; no entanto, reduziu o IG. O potencial osmótico acima de -0,4 MPa aumentou o tempo inicial de germinação, T_{50} e TMG, assim como diminuiu o índice de germinação (IG) de* ***L. aphaca****. O aumento da profundidade das sementes no solo reduziu o percentual de germinação e o IG, mas aumentou o tempo inicial de germinação, T_{50} e TMG. Concluiu-se que a espécie* ***L. aphaca*** *tem capacidade de crescimento em uma grande variedade de condições agroecológicas/ambientais. Esses resultados podem auxiliar no desenvolvimento de ferramentas e estratégias agronômicas para o manejo de plantas daninhas em culturas agrícolas visando a melhoria do rendimento.*

Palavras-chave: estresse osmótico, sementes de plantas daninhas, estresse salino, temperatura, pH, luz.

INTRODUCTION

Crow pea (*Lathyrus aphaca* L.) is a trailing or scrambling annual broadleaved (Tiwari et al., 2016) weed with medium height (Marwat et al., 2013). It belongs to the *Fabaceae* family and severely infests wheat (*Triticum aestivum* L.) crops in rain-fed and irrigated areas. It is a problematic weed in the rice-wheat cropping system of Pakistan (Haleemi et al., 1995). Its germination occurs from October-November to April and reaches maturity before wheat crops during early April. It drops its seeds in field before wheat harvest thus increasing the soil weed seed bank and provoking the trouble in subsequent crop of winter season.

Weeds are hidden foe for crop plants and belong to the most ubiquitous pest's class, which significantly decrease the potential yields of agricultural crops (Tanveer et al., 2015). Weeds impose the serious stress on crop plants by occupying space, nutrients, moisture and light (Gupta, 2004); and severity of stress imposed by weeds depends upon types of weeds, germination/emergence time, density and duration of interference (Ali et al., 2015). Various environmental factors such as moisture stress, light, temperature, soil acidity, salinity, pH and depth of seeds burial directly or indirectly affect weeds seeds germination (Mahmood et al., 2016). These environmental factors may influence the seed germination process individually or together with other factors (Koutsovoulou et al., 2014). The intricate seed germination process extremely depends on temperature (Marcos, 2015) because temperature regulates enzyme activity and membrane permeability during seed germination by endorsing or restricting hormonal synthesis (Marcos, 2015). Species in genera and even genotypes of a species may need different ranges of temperature (10-55 °C) for germination (Masin et al., 2010; Gorai et al., 2011). For example; purple nutsedge (*Cyperus rotundus*) often germinates in soils having a high temperature, whereas germination of yellow nutsedge is higher where the soil temperatures frequently fall below freezing (Singh and Singh, 2009). Similarly, *Satureja mutica, Satureja bachtiarica* and *Satureja macrantha* showed 86, 81 and 55% seed germination, respectively, at 20 °C (Ketabi et al., 2016). Tang et al. (2017) reported that triquetrous (*Murdannia triquetra*) seeds exhibited maximum germination (93%) at a temperature regime between 20/10 to 30/20 °C light/dark. Time to start germination declined as temperature regime increased.

Similarly to temperature, light is also a prerequisite to seed germination as some species are sensitive to alteration in light intensity and do not germinate, while others do not require an episode of light during germination (Carta et al., 2014). The germination of some seeds equally continues in light and darkness (Baskin and Baskin, 1996) while some seeds show more rapid germination either under either a light or dark situation (Colbach et al., 2002). Elastic grass (*Eragrostis tenuifolia*) showed 76 and 32% seed germination under light and dark conditions, respectively (Bittencourt et al., 2016). *Salvia hispanica* seed germinated equally in light and darkness (Paiva et al., 2016).

Moisture stress progressively impairs seed germination and all other ongoing processes of plants (Norsworthy and Oliveira, 2006). Capability to germinate and grow in drought stress

may allow weeds to benefit from a situation that limits the growth of other species (Javaid and Tanveer, 2014). Seed germination of green galenia (*Galenia pubescens*) was 45 and 0.0% at -0.2 and -0.4 MPa osmotic potential, respectively (Mahmood et al., 2016) while in bladder ketmia (*Hibiscus tridactylites*), 90% germination occurred at -0.6 MPa (Chauhan, 2016). Similarly, seed germination is impeded and shrunk when salt stress goes above a critical level by diminishing the ease with which seeds imbibe water or facilitate the entry of ions to toxic levels (Ebrahimi and Eslami, 2012). Ground cherry (*Physalis divaricata*) showed no germination at 180 mM NaCl (Nosratti et al., 2016) while seeds of *Hibiscus tridactylites* (15% seeds) germinated at 250 mM NaCl (Chauhan, 2016). Likewise, soil pH affects the competitive ability of plant species; some weed seeds may germinate and grow over a wide range (5 and 10 pH) of pH while other seeds can germinate or grow better in soil having acidic conditions (Fried et al., 2008). Burial depth or location of weed seeds in the soil seedbank significantly affects viability, germination and emergence (Bebawi et al., 2015). Seeds of green galenia (*Galenia pubescens*) and *Asphodelus tenuifolius* exhibited more germination when sown on the soil surface (Tanveer et al., 2014; Mahmood et al., 2016) while *amaranthus* species showed higher germination and emergence at 1 cm depth (Hao et al., 2017). Therefore, it is obvious that seed germination of different weed species or weed species in genera may respond differently to environmental factors.

In order to manage weed influx efficiently, information on germination biology and ecology of a particular weed is very important for efficient weed control and to enhance the efficacy of management lines (Ebrahimi and Eslami, 2012). In the southern part of rain-fed areas (Agroecological Zone iv) of Pakistan, sandy loam soils have salinity patches with limited rainfall and accessibility of irrigation water. Average temperature between November and December (wheat sowing season) remains in the range from 25 to 15 °C, respectively. For wheat crops, seedbeds are prepared with conventional cultivators whose working depth is 10 cm. To understand the diffusion of *L. aphaca* in a geographic range of Pakistan, we want to observe how its seeds respond to various climatic factors. To date, no study has particularly addressed the germination ecology of the weed *L. aphaca* in Pakistan. The main objective of the present research was to investigate the effects of temperature, light, salinity, pH, osmotic stress and seed burial depth on germination and seedling emergence of *L. aphaca*. The findings of this study would indeed enable us to understand the biology of the weed and thereby develop effective agronomic strategies for to control it for the purpose of crop yield enhancement.

MATERIALS AND METHODS

Seed description and germination tests

Experiments were carried out at the Seed Technology Lab, Department of Agronomy, Gomal University Dera Ismail Khan, Khyber Pakhtunkhwa, Pakistan in 2014. In April 2014, seeds of *L. aphaca* (ten collections were harvested from an area with 100 km diameter) were collected from matured plants from different distantly situated farmers' wheat fields in the District Dera Ismail Khan, Khyber Pakhtunkhwa, Pakistan, and a bulked sample was prepared. Working samples were drawn from this composite sample. The collected seeds were packed in paper bags and the bags were placed in a laboratory at ambient temperature until further use. Analysis of experimental soil is given in Table 1.

To determine seed germination, 25 seeds were placed in a 9 cm diameter petri dish having Whatman No. 10 filter paper, moisturized with five milliliter distilled water or moisturized with a treatment solution. Before the start of each germination experiment, seeds of *L. aphaca* were surface-sterilized by dipping seeds in 10% sodium hypochlorite (NaOCl) solution for five minutes followed by 5 washings with distilled water. To minimize water loss, the petri dishes were wrapped with Parafilm. All the trials (except the temperature trial) were carried out at 20/12 °C (day/night) with a 10 h light period (except study regarding light experiment). Cool white fluorescent bulbs (FL40SBR-A, NEC Lighting Co., Ltd., Japan) were used to generate a photosynthetic photon flux density of 200 µmol m^{-2} s^{-1} for all the trials, except the dark trial in the light experiment. A seed with 2 mm radicle length was considered as germinated (AOSA, 1990), recorded and disposed of daily for a period of three weeks. The Petri dishes possessing darkness treatments were unwrapped in a dark room outfitted with a green safe light.

Table 1- Analysis of experimental soil

Characteristic	Unit	Value
pH		7.1
EC	dS m^{-1}	0.29
Bulk density	g cm^{-3}	1.48
Organic matter	%	1.02
Nitrogen (N)	%	0.049
Phosphorus (P)	ppm	8.3
Potassium (K)	ppm	121
Moisture level	%	19

Effect of temperature

To investigate the effect of temperature on *L. aphaca* seed germination, three temperature treatments (15/10, 20/12 and 25/15 °C day/night) were applied. The variation in temperature treatments reflects the temperature variation from winter to autumn. All the petri dishes containing their respective treatments were kept in germinator cabinets under variable day/night temperatures (15/10, 20/12 and 25/15 °C day/night) with a 10 h photoperiod for three weeks.

Effect of light

To assess the impact of light and dark condition on seed germination, *L. aphaca* seeds were given 0/24, 10/12 and 12/12 h light/dark treatment per 24 h cycle at 20/12 °C (day/night). Treatments with a 24 h dark regime were roofed with a binary layer of aluminum foil to prevent light exposure. Treatments with 10/12 h light/dark were exposed for 10 h to permit light exposure. The source of light was white fluorescent bulbs having photosynthetic photon flux density of 200 µm m^{-2} s^{-1}. For the dark treatment, all the operations, e.g., water addition and daily germination counts, were performed in a dark room where green safe light was present.

Effect of pH

To study the effect of pH on *L. aphaca* seed germination, buffer solutions ranging from pH 6 to 9 were prepared by following the method given by Chachalis and Reddy (2000). A 1N sodium hydroxide (NaOH) solution was mixed with 2 mM of MES (2-(N-morpholino) ethanesulfonic acid) to maintain pH of solution at 6. Again 1N sodium hydroxide with 2 mM of HEPES (N-(2-hydroxymethyl) piperizine-N-(2-ethanesulfonic acid)) was used to maintain the solution pH at 7.0 and 8.0. A 2 mM solution of TRICINE (NTris (hydroxymethyl) methylglycine) was adjusted with 1N sodium hydroxide to prepare buffer pH of 9.0 while deionized water having pH 6.2 was used in the control treatment. All the petri dishes having *L. aphaca* seeds were placed in a seed incubator for three weeks. The experiment was visited daily to record germination count.

Effect of salinity stress

The experiment was comprised of 6 salinity levels (0, 50, 100, 150, 200 and 250 mM) prepared from sodium chloride. For control treatment, distilled water was used. All the petri dishes having *L. aphaca* seeds were kept in a seed incubator for three weeks. The experiment was visited daily to record germination count.

Osmotic stress

To investigate the effect of osmotic stress on *L. aphaca* seed germination, 6 osmotic stress levels (0 -0.2, -0.4, -0.6, -0.8 and -1.0 MPa by adding 0, 135, 180 and 225 g L^{-1} PEG) were created by using PEG 6000 (Polyethylene glycol) following the Michel and Kaufman (1973) equation:

Water potential = - (1.18×10^{-2}) C – (1.18×10^{-4}) C^2 + (2.67×10^{-4}) 18CT + (8.39×10^{-7}) C^2T

where C is concentration of PEG 6000 (g kg^{-1} distilled water) and T is temperature in °C.

After preparation of the solutions, their osmotic potential was checked by an osmometer {(vapour pressure type) model 5520; Wescor, Logan, UT, USA}. All the petri dishes having *L. aphaca* seeds were kept in a sseed incubator for three weeks. The experiment was visited daily to record germination count.

Effect of burial depth on seedling emergence

To examine the germination response of *L. aphaca* seeds against different seeding depths, an experiment was carried out in a greenhouse. The experiment was comprised of 7 seeding depths viz. 0 (Surface placement), 2, 4, 6, 8, 10 and 12 cm. Sand (1/2 kg per pot) was used to fill plastic pots with a diameter of 25 cm. Each pot had 25 seeds of *L. aphaca* which were sown by following the per treatment requirement (0, 2 to 6 cm burial depths). Greenhouse temperature was 23 ± 2 °C at day time but 15 ± 2 °C at night. Seedling emergence was recorded daily for three weeks. Germination percentage was calculated with the following formula:

$$\text{Germination \%} = \frac{\text{Germinated seeds}}{\text{Total seeds sown}} \times 100$$

Time taken for 50% emergence (T_{50}) was calculated by following the formulae of Coolbear et al. (1984):

$$T_{50} = \frac{ti + \left[\left(\frac{N}{2} - ni\right)(ti - tj)\right]}{ni - nj}$$

where *N* represents total final quantity of germinated/emerged seeds and *ni*, *nj* are the number of cumulative seeds that emerged by adjacent count at time *ti* and *tj* when *ni*<*N*/2 <*nj*.

Mean germination/emergence time (MGT or MET) was measured by following Ellis and Roberts (1981):

$$\frac{\text{MGT}}{\text{MET}} = \frac{\sum Dn}{\sum n}$$

where *n* is the number of seeds which were germinated on day *D*; and *D* is the number of days counted from the start of germination.

Germination index (GI) was measured according to AOSA (1990):

$$\text{GI} = \frac{\text{Number of germinated seeds}}{\text{Days of first count}} + \cdots + \frac{\text{Number of germinated seeds}}{\text{Days of final count}}$$

Statistical analysis

A completely randomized design with four replicates was laid out in all experiments. All the collected data were analyzed using Fisher's analysis of variance techniques (Steel et al., 1997). To test the mean difference among treatments, the least significant difference (LSD) test was used at 5% probability level.

RESULTS AND DISCUSSION

Effect of temperature

Temperature regimes did not influence time to start germination; however, they progressively affected seed germination percentage, time to 50% germination, mean germination time and germination index (Table 2). Seeds placed at 15/10 °C (day/night) showed maximum germination percentage, took less time for T_{50} and MGT, which was statistically similar to 20/12 °C (day/night) while seeds kept at 25/15 °C (day/night) showed minimum seed germination percentage,

Table 2 - Effect of environmental factors on germination or emergence parameters of *Lathyrus aphaca*

Treatment		Time to start germination (days) ± sd(df)	Germination (%) ± sd(df)	T_{50} (days) ± sd(df)	MGT (days) ± sd(df)	Germination index ± sd(df)
Temperature	15/10 °C	5.2 ± 0.25(2)	91.6 a ± 3.33(2)	6.7 b ± 0.24(2)	10.2 b ± 0.10(2)	11.3 a ± 0.10(2)
	20/12 °C	5.2 ± 0.25(2)	88.3 a ± 3.33(2)	6.9 b ± 0.14(2)	10.3 b ± 0.06(2)	10.7 b ± 0.51(2)
	25/15 °C	5.1 ± 0.18(2)	81.6 b ± 3.33(2)	8.2 a ± 0.13(2)	10.7 a ± 0.06(2)	10.3 b ± 0.35(2)
LSD		Non-significant	5.30	0.28	0.11	0.58
Light	0/24 h	5.7 a ± 0.50(2)	83.3 b ± 3.85(2)	8.1 a ± 0.25(2)	11.6 a ± 0.36(2)	9.22 b ± 0.38(2)
	10/12 h	5.0 b ± 0.0(2)	91.6 a ± 3.34(2)	7.2 b ± 0.44(2)	10.3 b ± 0.63(2)	10.2 a ± 0.44(2)
	12/12 h	5.0 b ± 0.0(2)	90.0 a ± 3.85(2)	7.1 b ± 0.37(2)	10.4 b ± 0.53(2)	10.0 a ± 0.47(2)
LSD at 5%		0.46	5.86	0.57	0.82	0.69
pH	6	5.0 c ± 0.0(7)	83.3 bc ± 1.92(7)	7.1 d ± 0.04(7)	10.3 d ± 0.04(7)	9.2 bc ± 0.23(7)
	6.2	5.0 c ± 0.0(7)	91.6 a ± 1.67(7)	6.6 e ± 0.11(7)	9.85 e ± 0.11(7)	9.9 a ± 0.10(7)
	6.5	5.0 c ± 0.0(7)	88.3 ab ± 1.67(7)	6.7 e ± 0.17(7)	9.92 e ± 0.17(7)	9.7 ab ± 0.10(7)
	7	5.0 c ± 0.0(7)	90.0 a ± 1.92(7)	6.7 e ± 0.13(7)	9.92 e ± 0.13(7)	9.8 a ± 0.12(7)
	7.5	5.0 c ± 0.0(7)	86.7 ab ± 0.01(7)	7.4 c ± 0.12(7)	10.6 c ± 0.12(7)	9.6 ab ± 0.0(7)
	8	5.5 b ± 0.29(7)	80.0 c ± 2.72(7)	7.9 b ± 0.02(7)	11.1 b ± 0.02(7)	8.8 cd ± 0.31(7)
	8.5	6.0 a ± 0.0(7)	78.3 cd ± 1.67(7)	8.2 b ± 0.10(7)	11.4 b ± 0.10(7)	8.6 de ± 0.18(7)
	9	6.0 a ± 0.0(7)	73.3 d ± 2.72(7)	8.6 a ± 0.17(7)	11.8 a ± 0.17(7)	8.1 e ± 0.29(7)
LSD at 5%		0.29	5.69	0.34	0.34	0.55
NaCl	0 mM	5.0 c ± 0.0(5)	91.6 a ± 1.67(5)	6.7 e ± 0.02(5)	10.0 e ± 0.03(5)	10.0 a ± 0.05(5)
	50 mM	5.0 c ± 0.0(5)	88.3 ab ± 1.67(5)	6.8 e ± 0.04(5)	10.1 e ± 0.06(5)	8.5 b ± 0.18(5)
	100 mM	5.0 c ± 0.0(5)	85.0 bc ± 1.67(5)	7.1 d ± 0.03(5)	10.6 d ± 0.04(5)	7.1 c ± 0.13(5)
	150 mM	5.2 c ± 0.25(5)	80.0 c ± 2.72(5)	7.7 c ± 0.14(5)	11.5 c ± 0.21(5)	4.4 d ± 0.18(5)
	200 mM	6.2 b ± 0.25(5)	61.6 d ± 1.67(5)	8.4 b ± 0.11(5)	12.6 b ± 0.17(5)	3.3 e ± 0.15(5)
	250 mM	7.0 a ± 0.41(5)	41.6 e ± 1.67(5)	9.2 a ± 0.12(5)	13.7 a ± 0.18(5)	2.0 f ± 0.10(5)
LSD at 5%		0.65	5.60	0.27	0.40	0.41

Means sharing the same letter case in a column do not differ significantly at probability level of 5%. T_{50}: time to obtain 50% germination or emergence; MGT: mean germination time; GI: germination index.

and gained more time for T_{50} and MGT. Similarly, seeds kept at 15/10 °C (day/night) exhibited higher germination index while lower germination index was noted at 25/15 °C (day/night), which was statistically equal to 20/12 °C (Table 2).

Our findings showed that 25/15 °C (day/night) temperature negatively affected *L. aphaca* germination and there will be less *L. aphaca* population in wheat if crop is sown during the first week of November because temperature is about 25 °C. However, as temperature decreases in the last week of November and December (20 to 13 °C), *L. aphaca* germination in wheat may swell. Previous studies showed that temperature affected germination of various weeds species (Guma et al., 2010). Benvenuti et al. (2004) reported that *Leplochloa chinensis* showed higher germination at 25 °C while *Cuscuta campestris* had maximum germination at 30 °C and reduced germination at 10 °C (Benvenuti et al., 2005). Nogueira et al. (2014) reported that *Dalbergia cearensis* Ducke took minimum time to start germinate at 30 °C but maximum germination occurred at 20 °C.

Effect of light

Light greatly affected the start of germination, germination percentage, T_{50}, MGT and GI of *L. aphaca* seeds (Table 2). Seeds that faced continuous dark condition (0/24 h light/dark) took more time to germinate as compared to seeds kept under 10/12 or 12/12 h light/dark. Early germination started in seeds which received 10/12 and 12/12 h light/dark. Higher germination percentage and GI while lower T_{50} and MGT were found under photoperiod of 10 h; however, it

was also statistically equal to 12 h photoperiod. Whereas seeds kept under complete darkness exhibited minimum germination percentage and GI. While time taken for 50% germination and mean germination time was higher (Table 2). Our results suggest that germination of *L. aphaca* seeds is lower under dense crop canopy or under shade conditions. If a wheat crop stand is good and it has a suitable plant population, germination of *L. aphaca* seeds is low as compared to sparse wheat crops. Similarly to our results, Tang et al. (2017) reported that germination of triquetrous (*Murdannia triquetra*) seeds was affected by light. Likewise, Chauhan (2016) reported that bladder ketmia (*Hibiscus tridactylites*) seeds germinated equally in the presence or absence of light. Nosratti et al. (2016) reported that light had stimulatory effects on seed germination of annual ground cherry (*Physalis divaricata*).

Effect of pH

Germination of *L. aphaca* seeds and the respective attributes were significantly affected by pH. Minimum time to start germination, time taken for 50% germination and mean germination time were noted at pH levels of 6.0-7.5 (Table 2). Higher germination percentage and GI were found at pH level of 6.2 (distilled water) however; it was also statistically equal to pH levels of 6.5, 7.0 and 7.5. Further increase in pH levels also increased germination time but reduced germination percentage. More time to start germination and lower germination percentage were recorded at pH level of 8.5 to 9. Similarly, seed sown at pH level of 9 took more time for 50% germination and mean germination, followed by 8 and 8.5 pH levels. Likewise, minimum germination index was recorded at pH level of 9, which was statistically equal to 8.5 pH level (Table 2). Our findings showed that *L. aphaca* may develop at various pH ranges under different soil conditions. This etiquette of weeds is extremely supportive for its successful incursion. Watanabe et al. (2002) reported such type of actions for problematic weeds species. Seed germination/emergence of several weeds species continued without any effect of pH (4.0 to 9.0 pH) in different experiments (Thomas et al., 2006; Chachalis et al., 2008; Wang et al., 2009). Tanveer et al. (2014) stated that there was no difference in germination percentage in wild onion (*Asphodelus tenuifolius*) seeds at pH levels of 6.0-7.5. Approximately 92% germination was recorded in *Hyparrhenia hirta* at 7.00 pH level, but at pH levels of 5.0 or 9.0, seed germination was reduced (10%) in (Chejara et al., 2008).

Effect of salinity stress

The results showed that the *L. aphaca* seeds acquired minimum time for germination initiation at salinity levels of 0 to150 mM and then increased by increasing the salinity level (Table 2). Maximum germination percentage, less time taken for 50% germination and mean germination time were noted at 0 mM NaCl level (control); however, it was statistically similarly to 50 mM NaCl level (Table 2). Maximum time to start germination, time taken for 50% germination and mean germination time were found at the 250 mM NaCl level, followed by the 200 mM salinity level. Similarly, lower germination percentage and germination index were also noted at 250 mM NaCl level, followed by the 200 mM NaCl level, while seeds sown at the 0 mM NaCl level showed higher germination index, followed by the 50 mM NaCl level (Table 2). Our findings suggest that *L. aphaca* is less sensitive to salt stress, and some seeds of *L. aphaca* were able to grow at higher salinity stress (250 mM), which permits *L. aphaca* to extend in salt areas around the country. Similarly, seeds of *L. aphaca*, *Hibiscus tridactylites* (Chauhan, 2016), *Brassica tournefortii* (Chauhan et al., 2006) and *Mimosa invisa* (Chauhan and Johnson, 2008) showed germination at an incredibly high salinity level.

Osmotic stress

Osmotic potential progressively affected *L. aphaca* seed germination. Minimum time to start germination was recorded at 0 to -0.4 MPa and further increase in osmotic stress also increased time to start germination, T_{50} and MGT (Table 3). Minimum time to T_{50} and MGT was found at 0 MPa; however, it was statistically similar to -0.2 and -0.4 MPa. Likewise, higher germination percentage was recorded at 0 MPa, followed by -0.2 MPa. At -0.8 MPa, 11.6% of the seeds were

Table 3 - Effect of environmental factors on germination or emergence parameters of *Lathyrus aphaca*

Treatment		Time to start germination (days) ± sd(df)	Germination (%) ± sd(df)	T_{50} (days) ± sd(df)	MGT (days) ± sd(df)	GI ± sd(df)
Osmotic potential	0 MPa	5.0 c ± 0.0(5)	91.6 a ± 0.67(5)	6.1 c ± 0.0(5)	10.0 c ± 0.0(5)	10.0 a ± 0.19(5)
	-0.2 MPa	5.0 c ± 0.0(5)	86.7 b ± 0.0(5)	6.3 c ± 0.02(5)	10.3 c ± 0.0(5)	9.5 b ± 0.02(5)
	-0.4 MPa	5.0 c ± 0.0(5)	65.0 c ± 0.67(5)	6.3 c ± 0.03(5)	10.4 c ± 0.01(5)	7.1 c ± 0.18(5)
	-0.6 MPa	6.2 b ± 0.25(5)	45.0 d ± 0.67(5)	7.6 b ± 0.31(5)	12.5 b ± 0.26(5)	5.0 d ± 0.10(5)
	-0.8 MPa	7.5 a ± 0.29(5)	11.6 e ± 0.67(5)	9.9 a ± 0.03(5)	13.9 a ± 0.30(5)	2.1 e ± 0.0(5)
	-1 MPa	NG	NG	NG	NG	NG
LSD at 5%		0.51	4.48	0.41	0.53	0.38
Seed burial depth	0 cm	10.0 e ± 0.0(6)	63.3 c ± 1.92(6)	13.5 e ± 0.33(6)	19.2 e ± 0.57(6)	6.9 c ± 0.20(6)
	2 cm	9.0 f ± 0.0(6)	91.6 a ± 1.67(6)	10.9 f ± 0.31(6)	15.5 f ± 1.15(6)	10.1 a ± 0.20(6)
	4 cm	12.5 d ± 0.29(6)	81.6 b ± 1.67(6)	15.4 d ± 0.22(6)	21.8 d ± 1.72(6)	8.9 b ± 0.17(6)
	6 cm	20.2 c ± 0.25(6)	28.3 d ± 1.67(6)	22.9 c ± 0.54(6)	32.5 c ± 2.30(6)	3.1 d ± 0.20(6)
	8 cm	25.0 b ± 0.0(6)	18.3 e ± 1.67(6)	26.8 b ± 0.10(6)	38.0 b ± 2.87(6)	2.0 e ± 0.18(6)
	10 cm	27.5 a ± 0.65(6)	8.3 f ± 1.67(6)	29.2 a ± 0.11(6)	41.4 a ± 3.44(6)	0.9 f ± 0.20(6)
	12 cm	no germination	no germination	no germination	no germination	no germination

Means sharing the same letter case in a column do not differ significantly at probability level of 5%. T_{50}: time to obtain 50% germination or emergence; MGT: mean germination time; GI: germination index.

able to complete their germination while there was no germination at -1 MPa. Higher germination index was also noted at 0 MPa, followed by -0.2 MPa while lower GI (2.1) was recorded at -0.8 MPa (Table 3). Our outcomes revealed that moisture availability is very essential for *L. aphaca* germination, and moisture stress can adversely reduce *L. aphaca* germination. There was a similar response of *Hibiscus trionum* (venice mallow seeds) (Chachalis et al., 2008), *Synedrella nodiflora* (Chauhan and Johnson, 2008) and *Ipomoea purpurea* (morning glory) (Singh et al., 2012), i.e. the seeds of these weed species were susceptible to different drought stress levels.

Effect of seed burial depth on germination and emergence of *L. aphaca*

Seed burial depth greatly affected *L. aphaca* germination. Less time to start germination, time taken to T_{50}, MGT, higher germination percentage and GI were noted when *L. aphaca* seeds were sown at 2 cm depth. More time to start germination, T_{50} and MGT were recorded when seed planting depth was more than 2 cm, and there was no germination at 12 cm depth (Table 3). Seeds sown at 0 cm depth showed lower germination percentage as compared to 2 cm depth but significantly higher than 6, 8 and 10 cm depths. Similarly, more time to 50% germination, mean germination time and lower germination index were recorded when seeds had been sown at 10 cm depth, followed by 8 and 6 cm depth (Table 3). Our results are supported by the findings of Baskin and Baskin (1998) and Thomas et al. (2006), who reported that some weeds species may emerge from 8 cm seeding depth. In contrast, seedling emergence of various weeds species were negatively influenced by increasing seed burial depth (Chauhan and Johnson, 2008). Bittencourt et al. (2016) reported that maximum seed germination (more than 70%) of elastic grass (*Eragrostis tenuifolia*) occurred at 0 cm (soil surface) and there was no germination at 3 cm seeding depth.

The outcomes of our laboratory experiments showed that *L. aphaca* can tolerate wide range of various environmental or ecological features, which is a bonus point of *L. aphaca* against its management. It also germinates under dark conditions but light further improves its germination. At 15/10 °C (day/night) temperature, germination of *L. aphaca* was maximum; however, at 20/12 and 25/15 °C (day/night) temperature, considerable *L. aphaca* germination was noted. Significant germination of *L. aphaca* happened at all levels of pH ranging from 6.00 to 9.00, and Pakistani soils has such similar pH level. Greater moisture stress progressively lowered *L. aphaca* germination. *L. aphaca* is less sensitive to salinity and some of its seeds were able to

germinate even at high salinity stress. Seeds of *L. aphaca* showed more emergence when planted at 2 cm depth, but a substantial amount of seeds showed emergence at 0, 6 and 10 cm burial depths. However, they did not germinate at 12 cm depth. This fact (12 cm depth) hints that for successful management of *L. aphaca* in wheat, seed burial depth at 12 cm or beneath is useful.

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