Pak. J. Weed Sci. Res., 18(4): 445-459, 2012

EFFECT OF TEMPERATURE, LIGHT, SALINITY, DROUGHT STRESS AND SEEDING DEPTH ON GERMINATION OF *Cucumis melo* var. *agrestis*

Asif Tanveer[1], Muhammad Salman Arshad[1], Muhammad Ayub[1], Muhammad Mansoor Javaid[*2] and Muhammad Yaseen[2]

ABSTRACT

For understanding of seed germination, the ecology of weeds can assist in predicting their potential distribution and in developing their effective management strategies. In this experiment, the effects of various environmental factors on seed germination of Cucumis melo var. (agrestis) were investigated under laboratory and greenhouse conditions during 2009, in the department of Agronomy, University of Agriculture, Faisalabad, Pakistan. The treatments comprised of different temperature regimes (25, 30, 35, 40 and 45°C); salinity levels (0, 25, 50, 75, 100, 125 and 150 mM of NaCl); osmotic stress (0, -0.2, -0.4 and -0.6 MPa) and seed sowing soil depths (0, 1, 2, 4 and 6 cm). Results revealed non-significant effects of temperatures on germination and germination time whereas significant effects on seed germination index (8.39) at 25°C. Seed germination at 25 mM to 100 mM salinity was statistically similar to control treatments; whereas, the 150 mM salinity showed maximum reduction in seed germination and seed germination time, and minimum in seed germination index. The -0.4 MPa osmotic potential had reduced the seed germination of C. melo up to 25% and seed germination of C. melo was completely inhibited at -0.8 Mpa osmotic potential. Osmotic stress at -0.6 MP showed maximum reduction in seed germination and minimum in seed germination time and the germination index. Seedling emergence was 57.50 to 62.50% at seeding depths of 0 to 1cm but decreased as the soil depth increased. Maximum MGT and GI was recorded when seeds were planted at 1.0 cm soil depth. Below and above this depth, the seeds showed decrease in emergence. Seed germination of C. melo was delayed in respect of time to start germination and time to 50% germination (except in drought osmotic stress and soil sowing depth) with increased temperature, salinity, osmotic stress and sowing depth.

Keywords: *Cucumis melo*, emergence, germination, light, osmotic stress, salinity, temperature.

INTRODUCTION

Cucumis melo L. probably originated in East African countries (e.g. Sudan, Ethiopia, Eritrea, Somalia, Uganda and Tanzania) where its wild populations are still present. *Cucumis melo* was domesticated

[1]Department of Agronomy, University of Agriculture Faisalabad, 38040, Pakistan
[2]Department of Agronomy, University College of Agriculture, University of Sargodha
Corresponding author's email: mmansoorjavaid@gmail.com

in the eastern Mediterranean region and West Asia ca. 4000 years ago and subsequently spread into whole Asia. During the long spread of cultivation many types developed with many fruit shapes.

Cucumis melo belongs to cucurbitaceae family. It is a branched prostrate annual and/or perennial herb mostly infesting pearl millet, sorghum, maize, cotton and range lands. Its seed emergence is one of the most critical phases in plant development at which the weed can compete for an ecological niche (Forcella *et al.*, 2000) and is mediated by various environmental factors such as temperature, light, soil pH, osmotic and salt stress (Rao *et al*., 2008; Chauhan and Johnson, 2009; Kegode *et al*., 2010). Temperature and light are considered to be the most important environmental factors regulating seed germination, species distribution and ecological interaction (Chauhan and Johnson, 2008). Temperature is major determinant of seed germination when other factors (soil moisture, soil salinity and acidity) are not limiting (Martinkova and Honek, 1997). Temperature is variable for species within genera (Van-Assche *et al*., 2003) and may also differ between genotype within species (Debeaujon *et al*., 2000). Many plants require light for germination, some are insensitive to light and others are inhibited by light (Bewley and Black, 1994). Moisture stress may also delay, reduce or prevent seed germination and growth of plants (Norsworthy and Oliveira, 2006). Soil salinity may affect seed germination as it reduces the moisture absorbtion of seeds and by facilitating the entry of ions in higher amounts that effect seed health. The level of salinity at which seed germination is reduced varies with species, genotype, environmental conditions, osmotic potentials and specific ions (Ungar, 1991; Gomez *et al*., 2008). Increasing salinity delayed the beginning and ending of germination and reduced final germination percentage of *Limonium emarginatum* and inhibiting germination completely above 2% salinity (Gomez *et al*., 2008). Germination and seedling growth decline with drought stress that is perhaps one of the important abiotic stresses that limits number of seedlings and seedling growth (Kaya *et al*., 2006). Seed burial depth affects the germination and seedling emergence by influencing the availability of moisture, temperature and light exposure (Chachalis and Reddy, 2000). Weed seedling emergence has been reported from a wide range (0-15cm) of soil depths (Balyan and Bhan, 1986). Biological and ecological information specifically germination ecology of a specific weed is necessary to optimize weed control and maximize the efficiency of management tactics (Bhowmik, 1997). In Pakistan, most soils are saline with limited water availability and the average summer temperature range from 30-45°C. Seedbed for summer crop is prepared with conventional cultivator which goes up to a depth of 10 cm. So, in order to understand the expansion of the geographic range

of *C. melo* in Pakistan, we need to learn how their seeds respond to varied climatic factors. To date, no research on seed germination ecology of *C. melo* has been conducted. The objectives of this study are to determine the effects of different temperature regimes, light, soil salinity and osmotic stress, and burial depth in soil on seed germination, seedling emergence and growth performance of *C. melo*.

MATERIALS AND METHODS

Seed germination test

Experiments were conducted at the Department of Agronomy, University of Agriculture Faisalabad, Pakistan under laboratory and greenhouse conditions during 2009. Mature fruits of *C. melo* were collected from several farmers field culivated with cotton at District Layyah (30º N, 70° E), Punjab, Pakistan during 2009. Seeds were removed from the fruits by cutting them into two parts. The seeds were cleaned and dried for seven days at room temperature (25ºC) and then stored in paper bags until used in the experiments.

Seed germination was determined by placing 20 seeds evenly in a 9 cm diameter Petri plates containing filter paper Whatman No. 10. The control treatment was moistened with 5 mL distilled water and the other treatments solution. Seeds of *C. melo* were surface sterilized by soaking in 10% sodium hypochlorite (NaOCl) for 5 min followed by five rinses with distilled water before the trail conduction. All Petri palates were sealed with Para film to minimize evaporation. All the experiments (except temperatures one) were conducted under 35 (min) and 38°C (max) temperatures and at 10 h photoperiod. The germinated seeds (i.e., with radicle at least 2 mm long) were counted and removed daily for a period of three week. For the seed burial depth experiment, the seeds of *C. melo* were placed in 10 cm diameter plastic pots at different soil depths.

Temperature regimes setting

Seeds of *C. melo* were incubated at temperature of 25 to 45 °C with an interval of 5°C for 3 weeks period. These temperatures were maintained constant.

Adjustment of salt stress

Seeds of *C. melo* was incubated in sodium chloride (NaCl) solution of 0, 25, 50, 75, 100, 125, 150, mM to examine the effect of salt stress on germination.

Osmotic stress setting

Cucumis melo seeds were germinated in aqueous solution with osmotic potential of 0, -0.2, -0.4, -0.4, -0.6, and -0.8 MPa. Osmotic potentials were prepared by using Polyethylene glycol[1] (PEG 6000) in distilled water. The following equation (Michel and Kaufmann, 1973)

was used for calculation of water potential from known concentration of PEG 6000.

$$\text{Water potential} = -(1.18 \times 10^{-2})\,C - (1.18 \times 10^{-4})\,C^2 + (2.67 \times 10^{-4})\,18CT + (8.39 \times 10^{-7})\,C^2T$$

Where C is the concentration of PEG (g kg^{-1} distilled water) and T is temperature (°C)

Setting the burial depth on seedling emergence

The effect of seed burial depth on seedling emergence was studied in green house. Twenty seeds of *C. melo* were placed on the soil surface or covered with soil (30% clay, 30% silt and 40% sand) to depth of 1, 2, 4, 6 and 8 cm in 15 cm diameter plastic pots. Pots were left opened and watered as needed to maintained adequate soil moisture. Seedlings were considered emerged when a cotyledon was visible at the soil surface.

The time taken by 50% seed germination or emergence (T_{50} or E_{50}) was calculated according to the formula of Coolbear *et al*. (1984).

$$T_{50} \text{or } E_{50} = t_i + \frac{\left(\frac{N}{2} - n_i\right)(t_j - t_i)}{(n_j - n_i)}$$

Where N is the final number of germinated or emerged seeds and nj and ni are the cumulative number of seeds germinated by adjacent counts at times tj (day) and ti, (day) respectively, when ni < N/2 < nj.

Mean germination or emergence time (MGT or MET) was calculated according to the equation of Ellis and Roberts (1981).

$$MGT \text{ or } MET = \frac{\sum Dn}{\sum n} T_{50} \text{or } E_{50} = t_i + \frac{\left(\frac{N}{2} - n_i\right)(t_j - t_i)}{(n_j - n_i)}$$

Where n is the number of seeds that had germinated on day D and D is the number of days counted from the beginning of germination.

The germination/emergence index (GI or EI) was calculated as described by the Association of Official Seed Analysis (1983).

$$GI \text{ or } EI = \frac{No\ of\ germinated \text{ or } emerged\ seedlings}{Days\ of\ first\ count} + \cdots\cdots + \frac{No\ of\ gerimnated \text{ or } emerged\ seedlings}{Days\ of\ final\ count}$$

Statistical analysis

A completely randomized design with four replications was used in all experiments. Data were subjected to analysis of variance (ANOVA) using SAS (2002) computer software package. The model structure of ANOVA was

$$Y_{ij} = \mu + T_{i} + \epsilon_{ij}$$

Where Y_{ij} is the observed response variable, μ is an overall mean, T_i is the explanatory variable and ϵ_{ij} is the error. The significant difference among treatment means were identified by using Fisher, LSD at P<0.05 (Steel *et al*., 1997). A square-root arcsine transformation was used to stabilize the variances for percentage data before analysis (Bartlett, 1947). Nonlinear regression analysis was used to determine how NaCl, osmotic stress or burial depth affected percentage germination or emergence. Germination (%) values at different concentrations of NaCl and osmotic potential were fitted to a functional three-parameter logistic model using Sigma Plot 2008 (version 11.0). The model fitted was $G\ (\%) = G_{max}/[1+(x/x_{50})^{Grate}]$, where G is the total germination (%) at concentration x, G_{max} is the maximum germination (%), x_{50} is the NaCl concentration or osmotic potential for 50% inhibition of the maximum germination and G_{rate} indicates the slope. A three parameter logistic model $[E\ (\%) = E_{max}/[1+(x/x_{50})^{E}_{rate}]$ was fitted to the *C. melo* seedling emergence (%) obtained at different burial depth of 0 to 8 cm, and where E is the total seedlings emerged (%) at burial depth x, E_{max} is the maximum seedlings emerged (%), x_{50} is the burial depth for 50% inhibition of seedlings emerged and E_{rate} indicates the slope.

Sources of materials

[1]Polyethylene glycol (PEG) 6000, Panreac Quimica SA E-08110 Montcada i Reixac (Barcelona) Espana.

RESULTS AND DISCUSSION

Effect of temperatures

Temperatures had non-significant effect on seed germination, seed germination initiation and mean seed germination time of *C. melo.* (Table-1 and Figure 1). Time to 50% seed germination of *C. melo* was slightly increased with increased in temperature having maximum at 45°C and minimum at 25°C. Maximum seed germination index (8.39) of *C. melo* was at 25°C and statistically at par with those at 30, 35 and 40°C, while 45°C temperature resulted in minimum seed germination index of *C. melo* (Table-1). Increase in temperature had caused significant reduction in seed germination index. Seed germination of *C. melo* under a wide range of temperature in our study is supported by

the findings of Sobrero *et al*. (1993). They stated that seeds of *Typha subulata* exhibited a high potential for seed germination (88 to 98%) in a wide range (10 to 35°C) of continuous temperatures. Similarly *Portulaca oleracea* L. showed insignificant seed germination at temperatures between 10-40°C (Singh, 2006).

Effect of salt stress

The maximum seed germination (80%) of *C. melo* was obtained in the controlled (distilled water) treatment followed by 25, 50, 75 and 100 mM NaCl solution (Figure 2). The minimum seed germination (15%) was observed at 150 mM NaCl solution. A three parameter logistic model {$G = 76/[1 + (x/123)^{8.22}]$, $R^2 = 0.98$} was fitted to germination (%) of *C. melo* obtained at different concentration levels (Figure 2). The logistic model showed that *C. melo* seed germination had decreased by 50% of the maximum seed germination under NaCl concentration of 123 mM. *Cucumis melo* seed had spent maximum time to start germination and the 50 % germination at 150 mM NaCl and the minimum was found in control treatment (Table-1). Maximum seed germination time (6.02 days) of *C. melo* was recorded at 125 mM NaCl solution which was statistically at par with 100 and 150 mM NaCl solution. Minimum MGT was observed with distilled water treatment which was statistically at par with 25 and 75 mM NaCl solutions. Maximum seed germination index (9.71) was observed with distilled water which was statistically similar with 25 mM and 50 mM NaCl solutions (Table-1). Minimum seed germination index (0.22) was observed with 150 mM NaCl solution. Seed germination index of *C. melo* had decreased with increase in the concentration of NaCl solution.

Similar effects of salt stress on seed germination of *Campsis radicans* was reported by Chachalis and Reddy (2000). Our results are also in line with that of Chauhan *et al*. (2006a) who reported that seed germination of little mallow (*Malva parviflora*) was greater (i.e., 58%) at 0 mM NaCl and less (i.e., 2%) at 160 mM NaCl. Seed germination of *C. melo* up to 150 mM had demonstrated its high genetic potential for salinity tolerance during germination (Pedro *et al*., 2004). Substantial delay in seed germination with an increase in NaCl to 150 mM level is supported by the findings of Al-Khateeb (2006) in *Paniceean turgidum* and Gorai and Neffati (2007) in *Reaumuria vermiculat*.

Effect of osmotic stress

A three parametric logistic model {$G = 68/[1 + (x/-0.35)^{5.5}]$, $R^2 = 0.99$} was fitted to germination (%) of *C. melo* obtained at different osmotic potential (Figure 3). Seed germination had significantly decreased with increase in osmotic potential. There was no significant change in seed germination up to an osmotic potential of -0.2 MPa.

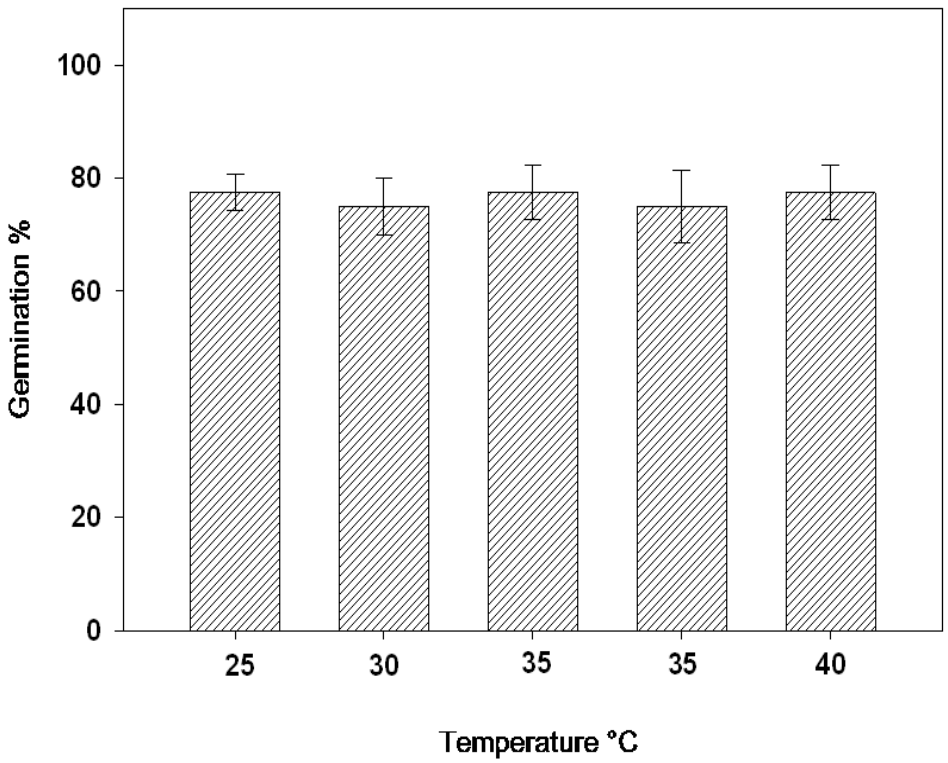

Figure 1. Effect of temperature (°C) on seed germination of *C. melo*. The vertical bars represent ± SE of the data means.

Maximum seed germination (70%) of *C. melo* was attained under the control treatment followed by th drought stress level of -0.2 Mpa (i.e., 65% seed germination). Lowest seed germination (2.5%) was recorded at -0.6 Mpa osmotic stress. Seed germination of *C. melo* was completely inhibited at -0.8 MPA. Model described that osmotic potential for 50% inhibition of the maximum germination was -0.35 MPa (Figure 3). The significantly maximum time to start germination and time to 50 % germination was recorded at -0.4 MPa (Table-1). Maximum germination time (3.22 days) of *C. melo* was recorded with control treatment followed by 2.18 and 2.46 days at -0.2 and -0.6 MPa drought stress levels were statistically at par with one another. Maximum germination time (3.22 days) of *C. melo* was recorded with control treatment followed by 2.18 and 2.46 days at -0.2 and -0.4 osmotic stress levels, respectively. Significantly minimum MGT (0.75days) was recorded at -0.6 MPa (Table-1). Maximum germination index (11.11 days) was recorded in *C. melo* with control treatment while significantly

minimum germination index (0.083 days) was recorded at -0.6 MPa drought stress level followed by -0.4 MPa (1.60 days).

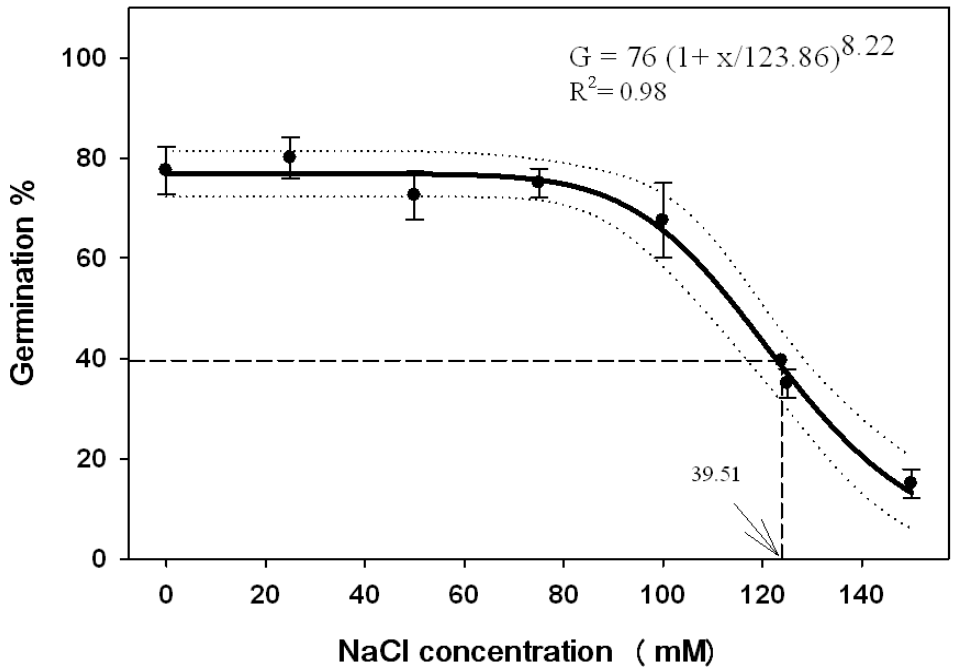

Figure 2. Effect of NaCl concentration (mM) on seed germination of *C. melo.* The bold line represent a three-parameter logistic model fitted to the seed germination of *C. melo* and the dotted lines show confidence intervals (at 95% level). The vertical bars represent ± SE of the data means.

The results suggested that with increase in drought stress level seed germination of *C. melo* had decreased. Decrease in water potential gradient between seed and surrounding media adversely affected seed germination probably due to the conditions with water deficit decreased germination by inadequate water uptake by seeds (Dodd and Donovan, 1999). Similar results were observed by Nandula *et al.* (2009) for *Lolium multiflorim* where seed germination was reduced from 79 to 80% when drought stress was increased from 0 to -0.8 Mpa. Taisan (2010) reported that PEG decreased and delayed seed germination of *Pennisetum divisum* and increase in drought stress from 0 to -0.8 MPa decreased seed germination to 10% only. Chauhan *et al*. (2006b) reported that seed germination of three horn bedstraw (*Galium tricornutum*) decreased linearly as osmotic potential

increased from 0 to -0.8 MPa. Tingle and Chandler (2003) reported that smellmelon (*C. melo* Naud. Var. dudaim) seed germination reduced from 81 to 61%, 48 and 7% with increase in osmotic stress from -0.2 MPa to -0.4 and at -0.6 MPa, respectively. Increase in drought stress from 0 to -08 MPa resulted in gradual decrease in seed germination of *Carthamus oxyacantha* (Tanveer *et al*. 2012).

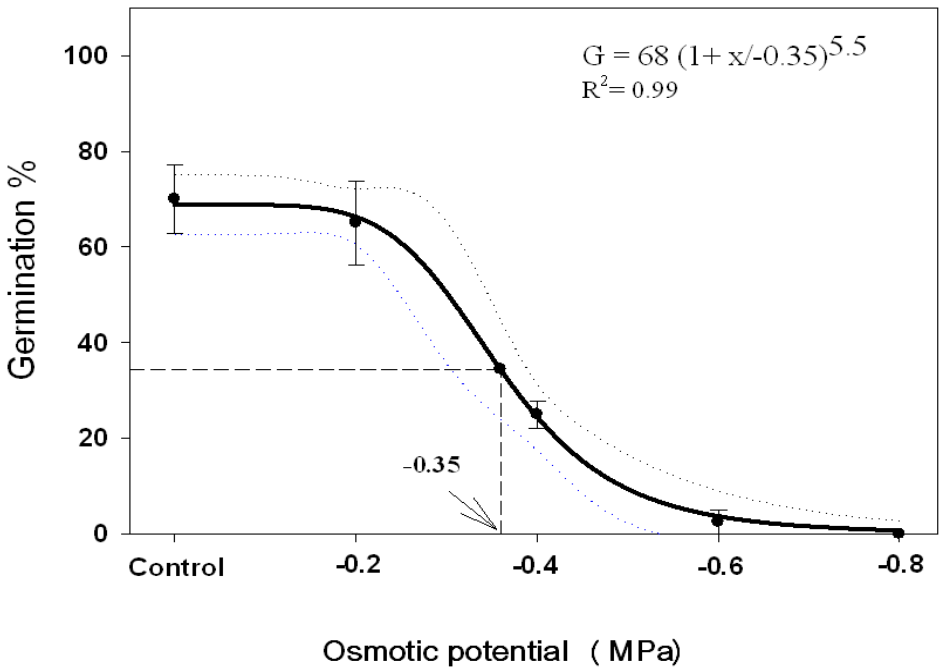

Figure 3. Effect of osmotic potential (MPa) on seed germination of *C. melo.* The bold line represent a three-parameter logistic model fitted to the germination of *C. melo* and dotted lines show 95% confidence intervals. Vertical bars represent ± standard error of the mean.

Effect of burial depth on seedling emergence

A three parametric model {$E = 56/[1 + (x/6.1)^{3.51}]$, $R^2 = 0.74$} was fitted to seedling emergence of *C. melo* at different burial depth (Figure 4). Seed placed at soil surface or buried up to a depth of 1 cm showed similar emergence. After this depth, emergence steadily decreased with increase in burial depth. According to fitted model, depth for 50% inhibition of the maximum emergence was 4.8 cm (Figure 4). Minimum emergence was observed at 2 and 6 cm which was statistically at par with that of 4 cm sowing depth. Seeds of *C melo* sown at 6cm depth took maximum time to start emergence, time

to 50 % emergence and were at par with that of 4 cm depth (Table-1). Minimum mean emergence time (2.34 days) of *C. melo* was attained at 2 cm sowing depth while maximum mean emergence time (7.87 days) was attained at 0 cm which was statistically similar with 7.21days at 1 cm sowing depth. Significantly maximum emergence index of *C. melo* (10 days) was attained at 1 cm sowing depth while minimum emergence index (1.96 days) was attained at 6 cm sowing depth. Generally emergence index decrease with increase in sowing depth (Table-1).

These results are in line with those of Singh and Achhireddy (1984) who reported decreased emergence due to increased planting depth in milkweedvine (*Morrenia odorata* Lindl.). Our findings are also supported by Mohler and Galford (1997), who recorded that seedling emergence decreased with increasing sowing depth.

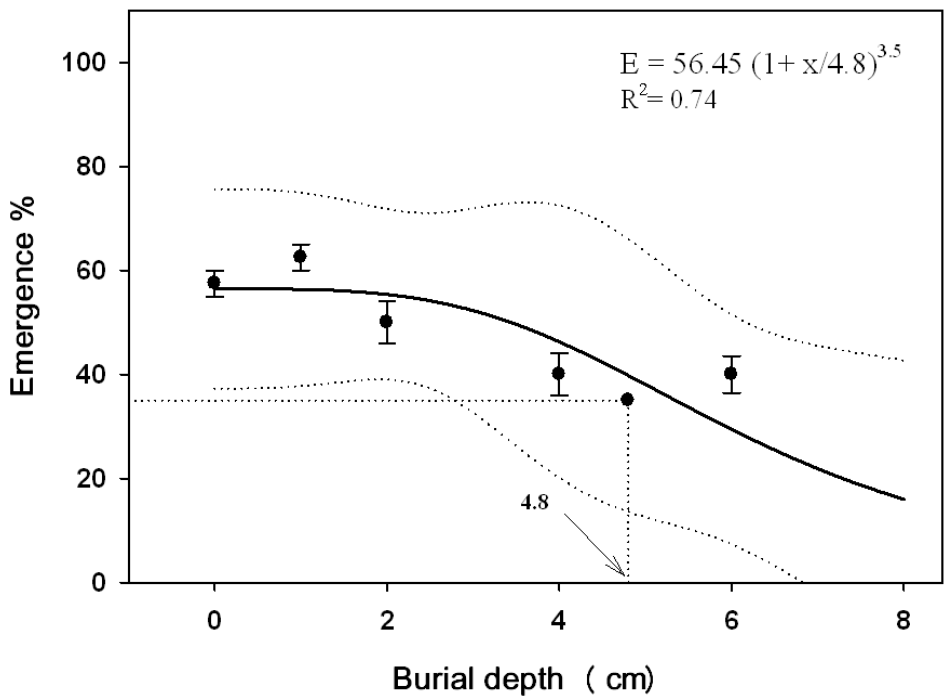

Figure 4. Effect of burial depth (cm) on seed germination of *C. melo.* The bold line represent a three-parameter logistic model fitted to the germination of *C. melo* and dotted lines show 95% confidence intervals. Vertical bars represent ± standard error of the mean.

Table-1. Effect of temperature, salinity, osmotic stress and seeding depth on different seed germination traits of *Cucumis melo.*

Treatments	Time to seed germination initiation (days)	T_{50} or E_{50} (days)	MGT or MET (days)	GI or EI
Temperature (°C)				
25	1	1.40 c	2.64	8.39 a
30	1	1.73 bc	3.10	8.13 ab
35	2	1.86 bc	3.54	7.48 ab
40	2	2.10 b	3.89	6.89 ab
45	2	5.44 a	3.22	5.03 b
LSD	NS	0.511	NS	3.252
NaCl concentration (mM)				
0 (Control)	2.00 c	1.36 c	2.08 c	9.71 a
25	2.25 c	1.56 bc	3.36 bc	9.27 a
50	2.25 c	1.70 bc	4.58 ab	7.24 ab
75	3.00 bc	1.70 bc	3.22 bc	5.52 bc
100	3.00 bc	2.32 b	5.54 a	5.00 c
125	3.50 b	4.50 a	6.02 a	2.92 c
150	5.50 a	5.00 a	5.34 a	0.22 d
LSD	1.088	0.847	1.508	2.648
Osmotic potential (MPa)				
0 (Control)	1.00 b	0.98 ab	3.22 a	11.12 a
-0.2	1.00 b	1.42 ab	2.18 a	6.75 b
-0.4	1.00 b	1.75 a	2.47 a	1.61 c
-0.6	1.75 a	0.63 b	0.75 b	0.08 c
-0.8	NG	NG	NG	NG
LSD	0.738	0.863	1.085	1.903
Burial depth (cm)				
0	1.25 b	5.38 a	7.21 a	6.83 b
1	1.00 b	5.13 a	7.87 a	10.50 a
2	1.00 b	0.81 c	2.35 c	4.82 c
4	2.75 a	2.60 b	4.45 b	3.85 c
6	3.25 a	3.29 b	4.45 b	1.97 d
LSD	0.584	1.085	1.349	1.028

The means followed by different letters are significantly different at $P < 0.05$.
T_{50} or E_{50} = time to obtain 50% seed germination,
MGT or MET = mean seed germination or emergence time,
GI or EI =germination or emergence index
NG = No (seed) germination.

Seeds germinated well at 1 cm sowing depth because of sufficient moisture and less energy required by seeds to come out on the surface, while at 0 cm depth germination was less because less moisture was available for seeds to germinate. Ghorbani *et al*. (1999), and Penny and Neal (2003) reported maximum emergence of hairy nightshade and mulberry weed seed with planting depths of 2 cm or less and on the soil surface, respectively. Hussain *et al*. (1993) stated that seed germination of *Zizyphus nummulara* got delayed and decreased with increased sowing depth.

CONCLUSION

This study concludes that *C. melo* is capable of emerging in a range of environmental conditions. *Cucumis melo* germinated at constant temperature between 25 and 40 °C. Similarly, *C. melo* is capable of germinate under considerable saline conditions. *Cucumis melo* seed was sensitive to osmotic potential and its spread could be restricted to moist soils. This study will be helpful in predicting suitable environment for germination of this weed and then it would be lot more easier to control it from spreading into new areas.

REFERENCES CITED

Al-Khateeb, S.A. 2006. Effect of salinity and temperature on germination, growth and ion relations of *Panicum turgidum* Forssk. J. Biores. Technol. 97: 292-298.

Anonymous. 2007. Economic Survey Govt. of Pakistan 2007-2008. Finance Division, Economic Advisory Wing, Islamabad, Pakistan.

Association of official seed analysis. 1990. Rules for testing seeds. J. Seed Sci. Technol. 12: 1-112.

Balyan, R.S. and V.M. Bhan. 1986. Germination of horse purslane (*Trianthema portulacastrum*) in relation to temperature, storage conditions, and seedling depths. Weed Sci. 34: 513-515.

Bartlett, M.S. 1947. The use of transformations. Biometrics 3: 3952.

Bewley, J.D. and M. Black. 1994. Seeds. Physiology of development and germination. pp 445. New York: Plenum Press, New York.

Bhowmik, P.C. 1997. Weed biology: importance to weed management. Weed Sci. 45: 349–356.

Chachalis, D. and K.N. Reddy. 2000. Factors affecting *Campsis radicans* seed germination and seedling emergence. Weed Sci. 48: 212-216.

Chauhan, B.S., G. Gill and C. Preston. 2006a. Factors affecting seed germination of annual sowthistle (*Sonchus oleraceus*) in southern Australia. Weed Sci. 54: 854-860.

Chauhan, B.S., G. Gill and C. Preston. 2006b. Seed germination and seedling emergence of threehorn bedstraw (*Galium tricornutum*). Weed Sci. 54: 867-872.

Chauhan, B.S. and D.E. Johnson. 2008. Germination ecology of goosegrass (*Eleusine indica*): an important grass weed of rainfed rice. Weed Sci. 56: 699-706.

Chauhan, B.S. and D.E. Johnson. 2009. Germination ecology of spiny (*Amaranthus spinosus*) and slender amaranth (*A. Viridis*): Troublesome weeds of direct-seeded rice. Weed Sci. 57: 379-385.

Coolbear, P., A. Francis and D. Grierson. 1984. The effect of low temperature pre–sowing treatment on the germination performance and membrane integrity of artificially aged tomato seeds. J. Exp. Bot. 35: 1609-1617.

Debeaujon, I., K.M. Leon-Kloosterziel and M. Koornneef. 2000. Influence of the testa on seed dormancy, germination, and longevity in *Arabidopsis*. Plant Physiol. 122: 403–413.

Dodd, G.L. and L.A. Donovan. 1999. Water potential and ionic effects on germination and seedling growth of two cold desert shrubs. Amer. J. Bot. 86: 1146-1153.

Ellis, R.A. and E.H. Roberts. 1981. The quantification of aging and survival in orthodox seeds. Seed Sci. Technol. 9: 373-409.

Forcella, F., R.L. Benech-Arnold, R. Sanchez and C.M. Ghersa. 2000. Modeling seedling emergence. Field Crops Res. 67: 123–139.

Ghorbani, R., W. Seel and C. Leifert. 1999. Effects of environmental factors on germination and emergence of *Amaranthus retroflexus*. Weed Sci. 47: 505-510.

Gomez, S.R., E.M. Naranjo, O. Garzon, J.M. Castillo, T. Luqueand and M.E. Figueroa. 2008. Effects of salinity on germination and seedling establishment of endangered *Limonium emarginatum* (Wild) O. Kuntze. J. Coastal Res. 24(1): 201-205.

Gorai, M. and M. Neffati. 2007. Germination responses of *Reaumuria vermiculata* to salinity and temperature. Ann.Appl. Biol. 151(1): 53-59.

Hussain, F., S. Shoukot, I. Illahi and M.Z. Qureshi. 1993. Germination promotion of *Zizyphus nummularia*. Hamdard Medic. 34: 46-56.

Kaya, M. D., G. Okcu and M. Atak. 2006. Seed treatments to overcome salt and drought stress during germination in sunflower (*Helianthus annuus* L.). Eur. J. Agron. 24: 291-295.

Kegode, G.O., G. Nazre and M.J. Christoffers. 2010. Germination ecology of biennial wormwood (*Artemisia biennis*) and lanceleaf sage (*Salvia reflexa*) seeds. Weed Sci. 58: 61-66.

Kpoghomou, B.K., V.T. Sapra and C.A. Beyl. 2008. Screening for drought tolerance: soybean germination and its relationship to seedling responses. J. Agron. Crop Sci. 164(3): 153-159.

Martinkova, Z. and A. Honek. 1997. Geographic variation in the rate of seed dormancy termination in barnyard grass, *Echinochloa crus-galli*. Ochrana Rostlin, 33: 26-32.

Michel, B.E. and M.R. Kaufmann. 1973. The osmotic potential of polyethylene glycol 6000. Plant Physiol. 51: 914-916.

Mohler, C.L. and A.E. Galford. 1997. Weed seedlings emergence and seed survival: separating the effects of seed position and soil modification by tillage. Weed Res. 37: 147-155.

Nandula, V. K., D. H. Poston and K. N. Reddy. 2009. Seed germination difference between glyphosate resistant and susceptible Italian ryegrass population. Weed Technol. 31(2): 123-133.

Norsworthy, J. K. and M. J. Oliveira. 2006. Sicklepod (*Senna obtusiflia*) germination as affected by environmental factors and seedling depth. Weed Sci. 54: 903-909.

Parsons, W. and E. Cuthbertson. 2001. *Noxious weeds of australia*. . p 540 Csiro.

Pedro, Z.J., S. Maria, P. M. Teresa, A. Asuncion and B. M. Angeles. 2004. Polyamines and ethylene changes during germination of different plant species under salinity. Plant Sci. 167(4): 781-788.

Penny, G. M. and J. C. Neal. 2003. Light, temperature, seed burial and mulch effects on mulberry weed (*Fatoua villosa*) seed germination. Weed Technol. 17(2): 213-218.

Rao, N., L. Dong, J. Li and H. Zhang. 2008. Influence of environmental factors on seed germination and seedling emergence of american sloughgrass (*Bechmannia syzigachne*). Weed Sci. 56: 529-533.

[SAS] Statistical Analysis Systems. 2002. *SAS Procedures Guide*, Version 9.Cary, NC: Statistical Analysis Systems Institute.

Singh, K.P. 2006. Effect of temperature and light on seed germination of two ecotypes of *Portulaca oleracea* L. New Phytology 72: 289-295.

Singh, M. and N. R. Achhireddy 1984. Germination and ecology of milkweedvine (*Morrenia odorata* Lindl.). Weed Sci. 32:781-785.

Sobrero, M. T., O. A Fernandez, and M. R. Sabbatino. 1993. Seed germination of *Typha subulata* in relation to weed management. J. Aquatic Plant Manag. 31: 98-100.

Steel, R.G.D., Torrie J.H. and D.A. Dickey. 1997. Principles and Procedures of Statistics: A Biometrical Approach. 3rd ed. pp.1 72-177. McGraw Hill Book Co., Inc., Singapore,

Taisan, W. A. 2010. Competitive effects of drought and salt stress on germination and seedling growth of *Pennisetum divisum* (Gmel) Henr. Amer. J. App. Sci. 7(5): 640-646.

Tanveer, A., M. Z, Farid, M. Tahir, M. M. Javaid and A. Khaliq. 2012. Environmental factors affecting the germination and seedling emergence of *Carthamus oxyacantha* M. Bieb. (Wild Safflower). Pak. J. Weed Sci. Res. 18(2): 221-235.

Tingle, C. H. and J. M. Chandler. 2003. Influence of environmental factors on smellmelon (*Cucumis melo* var. dudaim Naud.) germination, emergence and vegetative growth. Weed Sci. 51: 56-59.

Ungar, I. 1991. Ecophysiology of vascular halophytes. Boca Raton, FL: CRC Press. 209.

Van-Assche, J.A., D.M.V. Nerum and P. Darius. 2003. The comparativegermination ecology of nine *Rumex* species. Plant Ecol. 159: 131–142.