THE ASIAN JOURNAL OF HORTICULTURE
Volume **9** | Issue 1 | June, 2014 | 100-105
e ISSN- 0976-724X | Open Access-*www.researchjournal.co.in* |

Research Paper

Article history **:**
Received : 30.10.2013
Revised : 16.04.2014
Accepted : 28.04.2014

Standardization of optimal concentration of PEG 6000 for induction of drought and screening of coriander (*Coriandrum Sativum* L.) genotypes

■ **SUDHEESH KULKARNI, SHIVANAND HONGAL** AND **N. SHOBA**

Members of the Research Forum

Associated Authors:
[1]College of Horticulture, SIRSI (KARNATAKA) INDIA

[2]Department of Horticulture, Tamil Nadu Agricultural University, COIMBATORE (T.N.) INDIA

Author for correspondence :
SUDHEESH KULKARNI
University of Horticultural Sciences, BAGALKOT (KARNATAKA) INDIA
Email : sudheesh.kulkarni@gmail.com

ABSTRACT : Coriander commonly known as "Dhania" (*Coriandrum sativum L.*) belongs to family Apiaceae. Coriander fruits are an important spice of many countries of Europe, Northern Africa, West, Central and South Asia. In India, it is cultivated in 3.40 lakh hectares with an annual production of 2.23 lakh tonnes. It is cultivated in Rajasthan, Gujarat, Madhya Pradesh, Tamil Nadu, U.P., etc. In general, water stress is critical to seed germination and seedling growth phase (Levitt, 1980). The sensitivity of different vegetable crops to different levels of moisture stress as revealed from the seed germination and seedling growth have been well established (Ross and Hegarty, 1979). The present laboratory study involving an array of 50 genotypes have clearly demonstrated that the genotypes are endowed with a wide degree of variation in respect of their sensitivity to induced moisture stress. Among the criteria considered for screening, the variability manifested by the genotypes are of comparatively greater order for germination (27.50 to 0 %) and root length (0.68 to 0.25 cm) as against shoot length (5.47 to 2.00 cm) and vigour index (168.93 to 11.93). The inhibited germination recorded in other genotypes tested at -0.15 MPa osmotic potential may be related to the moisture deficit in the seeds below the threshold level for germination. These results are in conformity with the earlier findings in hot pepper and egg plants.

KEY WORDS : Coriander, PEG 6000, Drought, Screening

HOW TO CITE THIS ARTICLE : Kulkarni, Sudheesh, Hongal, Shivanand and Shoba, N. (2014). Standardization of optimal concentration of PEG 6000 for induction of drought and screening of coriander (*Coriandrum Sativum* L.) genotypes. *Asian J. Hort.*, **9**(1) : 100-105.

Coriander commonly known as "Dhania" (*Coriandrum sativum L.*) belongs to family Apiaceae. Coriander fruits are an important spice of many countries of Europe, Northern Africa, West, Central and South Asia. In India, it is cultivated in 3.40 lakh hectares with an annual production of 2.23 lakh tonnes (Anonymous, 2006). It is cultivated in Rajasthan, Gujarat, Madhya Pradesh, Tamil Nadu and U.P.

Using six different Poly ethylene glycol (PEG) concentrations and 11 sorghum cultivars, Saint-Clair (1976) concluded that increasing concentrations of the osmoticum resulted in poorer germination. The osmotic potential of a colloidal solution can mimic the soil water potential and soil water potential is a most important parameter in controlling seed germination under normal farming conditions. Predicting field emergence using poly ethylene glycol (PEG) as a water stress, Hadas (1977) found good correlation between field emergence and time needed to attain germination in a solution of PEG 6000 (MW) from -0.01 to -1.28 MPa water potential.

Jayawardhana *et al.* (1989) concluded that PEG solutions inhibit germination of sorghum seeds. Germination was decreased significantly at the lowest potential of -1.0 MPa. Polyethylene glycol was a satisfactory osmoticum for studying the direct effect of water potential on germination. Sorghum seed germinability under moisture stress imposed by PEG 6000 at -0.2 to -1.0 MPa was studied by Dighe and Rajurkar (1981). Their results pointed out that germination energy declined with increases in osmotic concentrations, where germination energy is defined as the cumulative germination counts divided by the time interval.

Working with sorghum and other annual crops, Dart *et al*. (1992) used PEG 6000 and found that sorghum is more resistant to water potential and temperature increases than soybean and sunflower. The maximum germination of sorghum

seed occurred in a range of 27 to 37º C at -1.2 MPa after 3 days. Germination under drastic conditions of water stress was inhibited, but was restored with an increase of water availability (Silva Ligia *et al.,* 2001).

The seeds germinated well until -0.3 MPa water potential. Germination percentage reduced from -0.5 MPa while the speed of germination was reduced from -0.3 MPa. The limit of tolerance to water stress in PEG-6000 of *C. quercifolius* seeds was between -0.7 and -0.9 MPa (Viégas *et al*., 2005).

Leila Radhouane (2007) reported that mean germination per cent of pearl millet [*Pennisetum glaucum* (L.) R. Br] for all provenances of Tunisia decreased about 73 per cent in -2.0 MPa compared to control (0 MPa) treatment. Decreases in the external osmotic potential induced decreased shoot growth while a slight increase in root length associate with the -1.0 MPa treatments was observed for some ecotypes. This reflects an adaptive response involving an increase in root length to reach deeper water in the soil.

RESEARCH METHODS

The present investigation on standardization of optimal concentration of PEG 6000 for induction of drought was carried out at Department of Spices and Plantation Crops laboratory, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore (T.N.) during the year 2006-2008.

Laboratory screening for drought tolerance of coriander:

Standardization of optimal concentration of PEG 6000 for induction of drought:

Poly ethylene glycol (PEG) with a molecular weight of 6000 of analytical grade was used to induce stress conditions. Different concentrations of PEG 6000 were prepared as per the Michel and Kaufmann (1973) in order to fix the optimal concentration.

Treatment details:

T_1: Control (Distilled water)

T_2: 5% PEG 6000 (-0.05 MPa)

T_3:10% PEG 6000 (-0.15 MPa)

T_4: 15% PEG 6000 (-0.30 MPa)

T_5: 20% PEG 6000 (-0.49 MPa).

Table A : Accessions used for screening under laboratory conditions

CO 3	CS – 97	CS – 138	CS – 177	CS – 208
CO (CR) 4	CS – 103	CS – 143	CS – 178	CS – 210
CS – 18	CS – 113	CS – 150	CS – 183	CS – 213
CS –31	CS – 118	CS – 153	CS – 184	CS – 220
CS – 33	CS – 121	CS – 154	CS – 185	CS – 221
CS – 37	CS – 122	CS – 161	CS – 188	CS – 222
CS-73	CS – 126	CS – 164	CS – 195	CS – 224
CS – 78	CS – 127	CS – 168	CS – 196	CS – 225
CS – 79	CS – 131	CS – 169	CS – 201	CS – 233
CS – 90	CS – 134	CS – 173	CS – 202	CS – 267

Coriander genotypes for screening:

Seeds of the following fifty accessions of coriander available at Department of Spices and Plantation Crops, Horticulture College and Research Institute, T.N.A.U., Coimbatore were utilized for the study. The screening in the laboratory was made based on the germination percentage and vigour index.

The coriander variety CO (CR) 4 of coriander was employed for fixing the concentration of PEG 6000 for screening for drought tolerance.

Number of replications: 4

Design: CRD.

For fixing concentration, seeds of ruling variety CO (CR) 4 were taken and they were lightly pressed to separate inter mericarps and soaked in water for 16 hours (Padmapriya *et al.*, 2007). Twenty seeds were counted for each treatment and placed in separate Petri dishes. All the Petri dishes were kept uniformly in a germination chamber. One mL solution of PEG 6000 from each of the five concentrations was added to the Petri dishes separately at regular intervals of 24 hours.

Laboratory screening of accessions for drought tolerance:

PEG 6000 at a concentration of -0.15 MPa as arrived in the standardization studies was employed for screening the accessions.

For preliminary screening 50 genotypes were taken and they were lightly pressed to separate inter mericarps and soaked in water for 16 hours (Padmapriya *et al.*, 2007). Twenty seeds of the each accession were counted placed in separate Petri dishes. All the Petri dishes were kept uniformly in a germination chamber. One mL solution of PEG 6000 (-0.15 MPa) was added to the Petri dishes separately at regular intervals of 24 hours. The Petri dishes were kept uniformly in a germination chamber.

Number of genotypes: 50

Replication: 2

Design : CRD.

Observations recorded:

Germination percentage:

The number of seedlings emerged were counted fifteen days after sowing in each of the accession tested and the mean was expressed in percentage. Germination percentage was calculated as below:

$$\text{Germination percentage} = \frac{\text{No. of seeds germinated}}{\text{No. of seeds sown}} \times 100$$

Height of the seedling:

The height of the seedling was measured from the collar region to the top in each of the accessions and the mean value was expressed in centimeter (cm).

Root length:

Root length was measured from the collar region to the tip of the primary root in each of the accessions and the mean was expressed in centimeter (cm).

Vigour index (%):

The vigour index was worked out as per the method of Abdul-Baki and Anderson (1970).

VI=Germination percentage x (Shoot length+Root length)

RESEARCH FINDINGS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarised under following heads:

Fixing the optimal concentration of PEG for screening the genotypes:

The data related to fixing concentration for screening the coriander genotypes is furnished in Table 1.

Germination percentage:

The treatments exhibited a wide degree of variation for germination from 0 to 73.50 per cent. The germination percentage of CO (CR) 4 was significantly on the higher side in T_1 (73.50 %), followed by T_2 and T_3 with a germination of 57.00 and 17.50 per cent, respectively. No germination was recorded in T_4 and T_5 *i.e.,* 0 per cent.

Shoot length:

The shoot length of the CO (CR) 4 under different treatments ranged from 4.62 to 7.35 cm. The shoot length was significantly higher in T_1 (7.35 cm) followed by T_2 (5.63 cm) and the lowest shoot length was recorded in T_3 (4.62 cm).

Root length:

The root length of the seedlings of CO (CR) 4 showed significant deviation ranging from 0.67 to 4.71cm. The root length was significantly on the higher side in T_1 (4.71 cm), followed by T_2 (1.33 cm). The lowest root length (0.67 cm) was recorded in T_3.

Vigour index:

Vigour index of CO (CR) 4 significantly differed and ranged from 92.13 to 883.04. High vigour index was noticed in the T_1 (883.04), whereas the treatment T_3 recorded low vigour index of 92.13.

Laboratory screening of coriander genotypes for drought tolerance:

The data on the laboratory screening of coriander genotypes for drought tolerance is presented in Table 2.

Germination percentage:

The genotypes exhibited a wide degree of variation from 0 to 27.50 per cent. The germination was significantly on the higher side in CS 127 (27.50 %) and was at par with CS 161 (25.00 %) and CS 18 (22.50 %) and followed by CS 202, CS 208 and CO (CR) 4 with a germination of 17.50, 17.50 and 15.00 per cent, respectively. Out of 50 genotypes, 27 genotypes failed to germinate.

Shoot length:

The shoot length of the genotypes ranged from 2.00 to 5.47 cm. The shoot length was significantly higher in CS 127 (5.47 cm) and was at par with CS 161, CS 202, CS 208 and CS 18 with a shoot length of 4.83, 4.67, 4.66 and 4.35 cm, respectively. In CO (CR) 4 shoot length of 4.25 cm was recorded. The lowest shoot length was recorded in CS 134 (2.00 cm).

Root length:

The root length of the seedlings among the genotypes showed significant deviation ranging from 0.25 to 0.68 cm. The root length was significantly at the higher side in CS 127 (0.68 cm) and was at par with CS 161 (0.64 cm), CS 202 (0.62 cm), CS 18 (0.61 cm) and CS 208 (0.61 cm), respectively. The lowest root length was recorded in CS 154 (0.25 cm) but genotype CO (CR) 4 recorded root length of 0.53 cm.

Table 1: Effect of PEG 6000 on germination, shoot length, root length and vigour index of coriander cv. CO (CR) 4

Treatments	Germination percentage	Shoot length (cm)	Root length (cm)	Vigour index
T_1: Control (distilled water)	73.50 (8.63)	7.35 (2.89)	4.71 (2.39)	883.04 (8.63)
T_2: 5% PEG 6000 (-0.05 MPa)	57.00 (7.62)	5.63 (2.57)	1.33 (1.52)	396.67 (7.62)
T_3: 10% PEG 6000 (-0.15 MPa)	17.50 (4.30)	4.62 (2.37)	0.67 (1.29)	92.13 (4.30)
T_4: 15% PEG 6000 (-0.30 MPa)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T_5: 20% PEG 6000 (-0.49 MPa)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
Mean	29.60 (4.50)	3.52 (1.44)	1.34 (1.97)	274.37 (12.24)
S.E.$\pm$	0.2180	0.0611	0.0640	0.7548
C.D. (P=0.05)	0.4647**	0.1302**	0.1364**	1.6089**

** indicates significance of value at P=0.01, (Values in the parenthesis are square root transformed)

Table 2 : Effect of PEG 6000 on germination, shoot length, root length and vigour index of coriander genotypes

Genotypes	Germination percentage	Shoot length (cm)	Root length (cm)	Vigour index
CO 3	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CO (CR) 4	15.00 (4.00)	4.25 (2.29)	0.53 (1.23)	71.63 (8.52)
CS 18	22.50 (4.85)	4.35 (2.31)	0.61 (1.27)	112.88 (10.67)
CS 31	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 33	5.00 (2.45)	2.95 (1.99)	0.35 (1.16)	16.50 (4.18)
CS 37	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 73	5.00 (2.45)	3.95 (2.22)	0.30 (1.14)	21.23 (4.71)
CS 78	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 79	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 90	5.00 (2.45)	3.60 (2.14)	0.41 (1.19)	20.03 (4.59)
CS 97	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 103	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 113	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 118	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 121	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 122	5.00 (2.45)	2.45 (1.86)	0.31 (1.14)	13.78 (3.84)
CS 126	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 127	27.50 (5.34)	5.47 (2.54)	0.68 (1.29)	168.93 (13.04)
CS 131	10.00 (3.32)	2.39 (1.84)	0.38 (1.17)	27.53 (5.34)
CS 134	5.00 (2.45)	2.00 (1.73)	0.39 (1.18)	11.93 (3.60)
CS 138	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 143	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 150	5.00 (2.45)	2.10 (1.76)	0.44 (1.20)	12.70 (3.70)
CS 153	5.00 (2.45)	3.25 (2.06)	0.33 (1.15)	17.88 (4.34)
CS 154	5.00 (2.45)	3.96 (2.23)	0.25 (1.12)	21.00 (4.69)
CS 161	25.00 (5.10)	4.83 (2.41)	0.64 (1.28)	138.90 (11.83)
CS 164	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 168	5.00 (2.45)	2.90 (1.97)	0.35 (1.16)	16.23 (4.15)
CS 169	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 173	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 177	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 178	7.50 (2.92)	3.26 (2.06)	0.26 (1.12)	26.60 (5.25)
CS 183	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 184	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 185	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 188	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 195	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 196	10.00 (3.32)	3.64 (2.15)	0.32 (1.15)	39.55 (6.37)
CS 201	5.00 (2.45)	2.45 (1.86)	0.32 (1.15)	13.83 (3.85)
CS 202	17.50 (4.30)	4.67 (2.38)	0.62 (1.27)	90.23 (9.66)
CS 208	17.50 (4.30)	4.66 (2.38)	0.61 (1.27)	92.13 (9.65)
CS 210	5.00 (2.45)	3.85 (2.20)	0.48 (1.22)	21.65 (4.76)
CS 213	10.00 (3.32)	3.20 (2.05)	0.32 (1.15)	36.78 (6.15)
CS 220	7.50 (2.92)	3.95 (2.22)	0.38 (1.17)	32.50 (5.79)
CS 221	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 222	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 224	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 225	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 233	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CS 267	5.00 (2.45)	2.95 (1.99)	0.33 (1.15)	16.38 (4.17)
Mean	4.60 (2.37)	1.63 (1.62)	0.19 (1.09)	20.98 (4.69)
S.E.+	0.2907	0.1171	0.0210	0.7431
C.D. (P=0.05)	0.5839**	0.2352**	0.0421**	1.4928**

** - Significant at 1% level of significance, (Values in the parenthesis are square root transformed)

Vigour index:

Vigour index significantly differed among the genotypes. Vigour index ranged from 11.93 to 168.93. High vigour index was noticed in the CS 127 (168.93) and CS 161 (138.90) and were closely followed by CS 18, CS 202 and CS 208 with vigour index of 119.28, 92.23 and 92.13, respectively. Genotype CO (CR) 4 recorded vigour index of 71.63. The lowest vigour index of 11.93 was recorded by genotype CS 134.

Effect of PEG on germination percentage and vigour index:

The artificial induction of drought was done using poly ethylene glycol (PEG) as has been followed earlier in hot pepper and egg plant (Krishnasamy and Irulappan, 1994). The artificial induction of drought using poly ethylene glycol however is dependent on the concentration and varies with the crop and genotype. Under such circumstances, the study involved in itself a preliminary standardization of the concentration of PEG 6000. Based on the results attained for germination percentage and vigour index, a concentration of -0.15 MPa has been fixed as optimum for coriander for further studies involving screening for drought tolerance under laboratory condition.

Under laboratory studies, the criteria considered for screening are limited to germination and seedling morphology as followed in hot pepper and egg plants (Krishnasamy and Irulappan, 1994).

In general, water stress is critical to seed germination and seedling growth phase (Levitt, 1980). The sensitivity of different vegetable crops to different levels of moisture stress as revealed from the seed germination and seedling growth have been well established (Ross and Hegarty, 1979). The present laboratory study involving an array of 50 genotypes have clearly demonstrated that the genotypes are endowed with a wide degree of variation in respect of their sensitivity to induced moisture stress. Among the criteria considered for screening, the variability manifested by the genotypes were of comparatively greater order for germination (27.50 to 0 %) and root length (0.68 to 0.25 cm) as against shoot length (5.47 to 2.00 cm) and vigour index (168.93 to 11.93).

Though study has brought out that the scope for selection is very high on variation registered in the population in respect of the sensitivity of genotypes from among the 50 genotypes tested based on the higher values obtained in respect of germination, root length, shoot length and vigour index which were later subjected to a critical performance study under field conditions. Such differential sensitivity of genotypes to moisture stress has been reported in many crops (Singh and Afria, 1985; Singh, 1990).

In giant foxtail seed, either a brief exposure to -0.3 MPa PEG solution, a slow hydration in humid air or drying after partial hydration has been reported to improve germination in a similar fashion (Taylorson, 1986). Certain physiological and biochemical changes are reported to occur during osmo-conditioning that allow seeds to develop a higher germination potential (radical thrust) or the ability to remove the seed coat restraint (Khan, 1993). This might be the basis for an improvement in the rate of germination and emergence recorded in the present experiments.

The inhibited germination recorded in other genotypes tested at -0.15 MPa osmotic potential may be related to the moisture deficit in the seeds below the threshold level for germination. These results are in conformity with the earlier findings in hot pepper and egg plants (Krishnasamy and Irulappan, 1994).

REFERENCES

Abdul – Baki, A.A. and Anderson, J.D. (1970). Viability and leaching of sugars from germinating barley. *Crop Sci.*, **10**(1): 31-34.

Anonymous (2006). Area, production and yield of coriander in India. Spices Board, Ministry of Commerce & Industry and Ministry of Agriculture, Govt. of India.

Dart, I.K., Schafer, B.M. and So, H.B. (1992). The effect of temperature and water potential on germination and subsequent shoot growth of sorghum and other summer crops. AIAS. *Occasional Publications*, **268** : 243-259.

Dighe, R.S. and Rajurkar, B.S. (1981). Seed germinability in some cereals under moisture stress. *Punjabrao Krishi Vidyapeeth Res. J.*, **1** : 108-110.

Hadas, A. (1977). A simple laboratory approach to test and estimate seed germination performance under field conditions. *Agron. J.*, **69** : 582-587.

Jayawardhana, P.M., Ferraris, R. and So, H.B. (1989). Effect of water potential and temperature on germination and emergence of sorghum in different media. AIAS Occasional Publications vol.43.

Khan, A.A. (1993). Preplanting physiological seed conditioning. *Hort. Rev.*, **20** : 131-181.

Krishnasamy, V. and Irulappan, I. (1994). Germination response to water stress in the seeds of hot pepper and egg plant genotypes. *Seed Res.*, **13** : 1-9.

Leila Radhouane (2007). Response of Tunisian autochthonous pearl millet (*Pennisetum glaucum* (L.) R. Br.) to drought stress induced by polyethylene glycol (PEG) 6000. *African J. Biotechnol*, **6** (9): 1102-1105.

Levitt, J. (1980). Plant responses to environmental stress. 2nd (ed.) Acad. Press, New York, USA.

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

Padmapriya, S., Chezhiyan, N., Vadivel, E., Rajamani, K., Sathiyamurthy, V.A. and Kumanan, K. (2007). Evaluation of Coriander (*Coriandrum sativum* L.) germplasm for germination and vigour index through leaching method. Production, development, quality and export of seed spices. S.K. Malhotra and B.B. Vashishtha (Eds.). NRCSS, Ajmeer, pp. 365-369.

Ross, H.A. and Hegarty, T.W. (1979). Sensitivity of seed germination and seedling radicle growth to moisture stress in some vegetable crop species. *Ann. Bot.*, **43** : 241-243.

Saint-Clair, P.M. (1976). Germination of *Sorghum bicolor* (L.) Moench under PEG-induced stress. *Canadian J. Plant Sci.*, **56** : 21-24.

Silva Lígia, M. De. M., Ivor B. de Aguiar and Teresinha de J.D. Rodrigues (2001). Seed germination of *Bowdichia virgilioides* Kunth, under water stress. *Revista Brasileira de Engenharia Agrícola e Ambiental*, **5**(1): 115-118.

Singh, A.K. (1990). Genetic variability, correlation and path co-efficient studies in tomato (*Lycopersicon esculentum* Mill.) under cold arid region of Ladakh. *Prog. Hort.*, **37**(2): 437-443.

Singh, T.N. and Afria, D. (1985). Stress metabolism III. Variations in response to water deficit in the barley palnt. *Aus. J. Boil. Sci.*, **26**: 65-76.

Taylorson, J. (1986). Preplanting physiological seed conditioning. *Hort. Rev.*, **13** : 131-181.

Viégas, R.A., De, L.M., Silva, M., I.B. De. Aguiar and D.L. de. Morais (2005). Water stress and osmotic conditioning on physiological quality of *Cnidoscolus quercifolius* Pax & K. Hoffam seeds. *Revista Brasileira de Engenharia Agrícola e Ambiental*, **9**(1) : 66-72.