Assiut Journal of Agicultural Science, Vol. 32, No 2, 2001, pp. 173-183

EFFECT OF TEMPERATURE AND WATER POTENTIAL ON GERMINATION OF *SALSOLA VILLOSA* DEL. EX ROEM. ET SCHULT.

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Abstract: *Salsola villosa* is perhaps the most important browse species in Saudi Arabia. It was once a dominant shrub in the northern region. Now it can only be found in protected areas due to heavy grazing. Despite the importance of the species, little is known about its autecology. The objectives of this study were to determine the effects of temperature, water potential and sodium chloride on germination of *S. villosa*. Seeds were germinated at four alternating temperatures (5/20, 10/25, 15/30, and 25/40º C at 12 hours light). Seeds were also germinated in polyethylene glycol (mol. Wt.=8000) solutions mixed to create water potentials of 0, -0.3, -0.6, -0.9, -1.2 and –1.5 MPa and in 0, 0.05, 0.1, 0.15 and 0.2 mol liter^{-1} sodium chloride solutions. Optimum germination was attained at 10/25º C. which corresponds to temperatures prevailing during spring time. Seeds germinated in polyethylene glycol solutions exhibited significantly lower and slower germination than distilled water especially when water potential fell below -0.6 MPa.. Germination was also negatively affected by 0.1 mol liter^{-1} sodium chloride solution or greater. Results indicated that germination is best at temperatures prevailing in spring-time. However, under natural conditions, germination is likely to occur under sub-optimum temperature in winter when soil moisture is available. Germination was also sensitive to both water and salinity stresses.

INTRODUCTION

Salsola villosa Del. ex Roem. et Schult = *S. vermiculata* L., *S. vermiculata* L. subsp. *villosa* (Del.) Eig., *S. vermiculata* var. *villosa* Moq.; a member of the Chenopodiaceae family, is perhaps the most valuable browse species in northern Saudi Arabian rangelands. Recently, it lost its ecological importance and became threatened with extinction because of heavy grazing. Distribution of *S. villosa* is currently limited to protected areas (Heemstra and Al Hassan 1990). Despite the importance of *S. villosa*, there is no available information on its autecology. Also, there is no available information browse production of the species. However, it is inferred from data collected in a protected area, that *S. villosa* produced a dry matter ranging from 255 kg/ha to 2221 kg/ha in two years having an amount of 15 mm and 41 mm rainfall respectively (Mirreh et al. 1991). Under conservative irrigation regime with saline underground-water, cultivated *S. villosa* produced 1074 kg/ha DM of current year growth (Tag El Din 1993). The species is highly preferred by sheep (Mirreh et al. 1991). Mirreh et al. (1990) reported that crude protein in *S. villosa* varied from 7.1% in winter to 16.4 % in spring while total digestible nutrients ranged from 44 % to 49 % in winter and spring respectively.

Successful plant recruitments especially in semiarid and arid regions are controlled by episodic rather than average environmental conditions (Call and Roundy 1991). Therefore, under natural conditions, seeds rely on a highly variable and possibly harsh environment to meet the requirements for germination (Chambers 1989; MacMahon and Schimpt 1981; Meyer and Monsen 1992). Temperature, soil water status and salinity are some of the most important environmental conditions that affect seed germination and hence seedling establishment and survival in arid areas.

Soil water potential consists mainly of matric and osmotic components. High molecular weight polyethylene glycol (PEG) has been used, with certain precautions, to simulate matric potential in germination studies (Kuafman and Ross 1970; McWilliam and Phillips 1971; Shrama 1973; 1976). Sodium chloride is conventionally used to study the effect of salinity (osmotic potential) on germination studies as it easy to handle (Young et al. 1985). Also, sodium chloride is considered one of the dominant salts in soils of Saudi Arabia (Bashour et al. 1983) as well as other arid rangelands.

Successful revegetation requires basic knowledge of germination requirements of species in concern. Therefore the objective of this study was to determine the effect of four alternating temperature regime, water potential and salinity on germination characteristics of *S. villosa* seeds.

MATERIALS AND METHODS

Seeds of *S. villosa* (1997 harvest) were obtained from the Range and Animal Development Research Center, Sakaka, in northern Saudi Arabia. Seeds were stored in a cold room (5±2 C°) for three months before the conduction of experiments. Prior to use, fruiting bracts of seeds were removed to improve germination (Osman and Ghassali 1997, Al-Rowaily 1999). Seeds were germinated on filter papers placed within 10cm diameter plastic dishes. Seeds were treated with benomyl to minimize fungal growth. Four germination dishes (50 seeds per dish) were placed within controlled environment chambers. Chambers were illuminated for 12 hours daily (light intensity averaged 1350 foot candle). Each experiment was replicated four times. Seeds were considered germinated when radicles were ≥5 mm long.

Germinated seeds were counted daily until germination ceased. Germination rate (GR) was calculated by the equation of Maguire (1962). Percent germination data were arcsine transformed before analysis but presented untansformed in tables.

Effect of temperature, water potentials (PEG and NaCl) on seed germination of *S. villosa* was determined by three different experiments. In one experiment, seeds were germinated at four alternating night and day temperature regime (5/20, 10/25, 15/30, and 25/40ºC) representing the seasonal common temperatures prevailing in some selected meteorological stations in northern Saudi Arabia. Substrata in germination dishes were moistened with 100 ml of distled water.

In a second experiment, seeds of *S. villosa* were germinated at 10/25ºC. Substrata were moistened with 100 ml ployethylene glycol (PEG) 8000 solutions. PEG solutions were prepared according to Michel (1983) to give water potentials of 0, -0.3, -0.6, -0.9, -1.2 and –1.5 MPa. Because the seeds were tested at alternating temperature and osmotic potential of solutions varies with temperature, the solutions were prepared for the mean of the fluctuated temperatures. In the third experiment, seeds were germinated on substrata moistened with 100 ml solutions having 0, 0.05, 0.1, 0.15, 0.20, 0.25 and 0.30 mol liter^{-1} of NaCl. Plastic dishes in both PEG and NaCl experiments were sealed to prevent evaporation. Germination was monitored daily. Radicle and shoot lengths of ten randomly selected seedlings in each dish were measured at the end of both experiments.

RESULTS AND DISCUSSION

Effect of temperature

Significant differences (P<0.01) occurred between different germination temperatures (Fig.1). Highest germination percentage (89.5 %) was observed when seeds were germinated at temperatures of 10/25ºC followed by temperatures of 15/30ºC and 5/20ºC which resulted in 75.5% and 74% respectively and were not significantly different from each other. Lowest germination percentage (4.5%) was observed at alternating temperatures of 25/40ºC. Germination rate also varied significantly (P<0.01) with temperature treatments. Highest germination rates were observed at temperatures of 15/30ºC and 10/25ºC. Lowest germination rate occurred under 25/40ºC. Considering both germination parameters, temperatures of 15/30ºC may reduce total germination but may not affect the rate of germination. Optimum germination temperatures are usually defined as those in which maximum total germination occurs at shortest period of time (Mayer and Poljakoff-Mayber 1989). In the present study, optimum germination temperatures are comparable with those prevailing in spring-time (Table 1). However, moisture conditions at this time may not be favorable for germination and seedling establishment. Therefore, germination would be expected to occur in sub-optimal temperatures during winter-time when moisture conditions are more favorable. Cluff and Roundy (1988) reported that in most years and on xeric sites, optimum temperature and moisture conditions would not overlap to result in high germination of desert saltgrass (*Distichlis spicata var. stricta*). Also, Baskin and Baskin (1972) found that early germinating (spring) seedlings of *Leavenworthia stylosa* suffered higher mortality due to summer drought. Similarly, Al-Qarawi et al. (1996) found that *Achillea fragrantissima* germinated best in spring-time. However, early emerged seedlings had better growth and survival than spring-emerging seedlings.

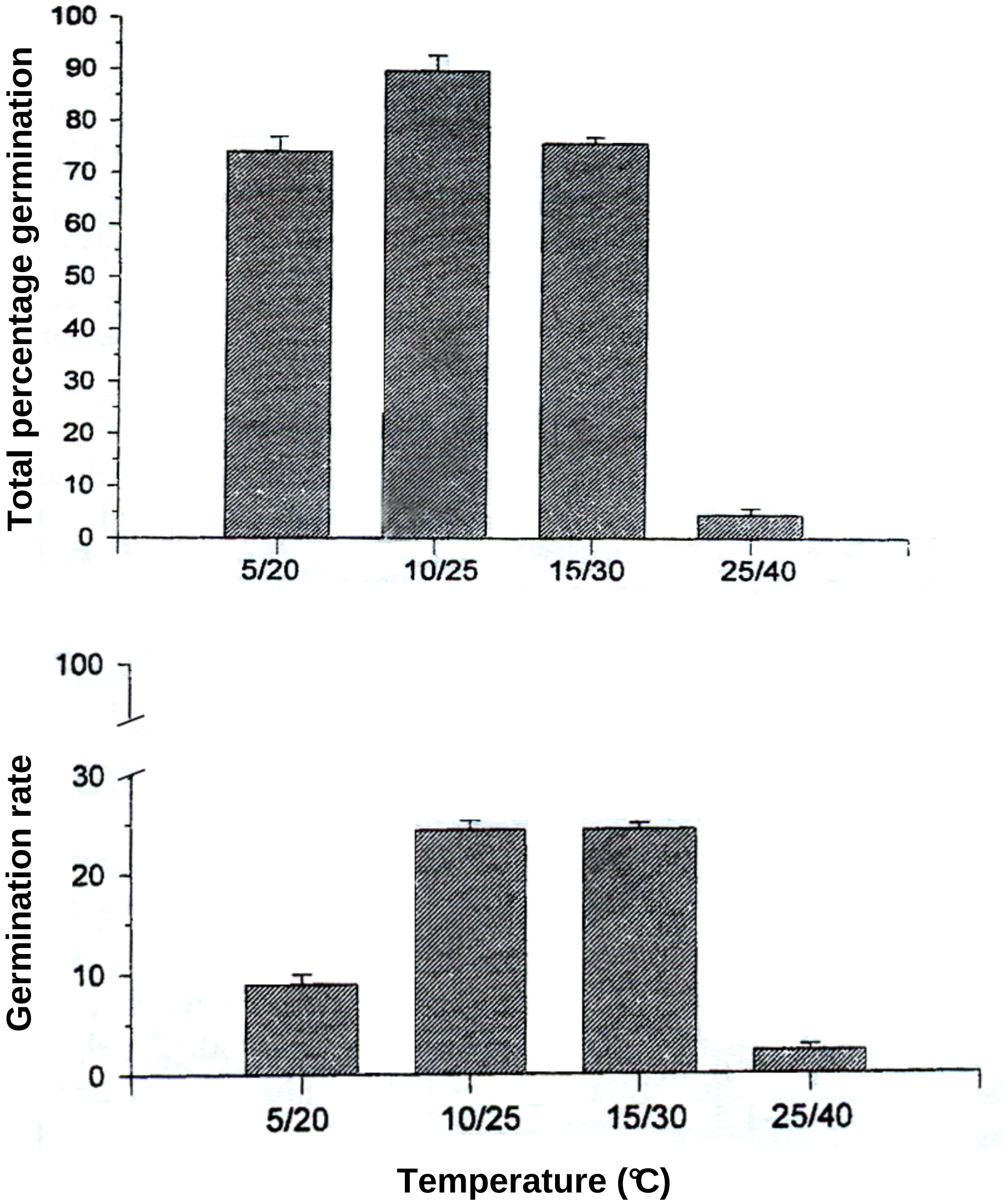

Figure 1. Total percentage germination and germination rate (% day^{-1}) of *Salsola villosa* in response to four different alternating temperatures.

Table 1. Monthly mean maximum and minimum temperature (°C) and rainfall distribution (mm) for Sakaka, in northern Saudi Arabia (29 47 N, 40 05 E).

	Temperature (°C)			Rainfall (mm)
	Minimum	Maximum	Mean	
January	3.0	15.4	8.6	42.6
February	4.7	17.7	11.9	9.3
March	8.4	21.6	15.7	16.6
April	14.2	28.6	22.3	20.7
May	18.8	33.7	27.4	1.1
June	21.9	37.4	31.1	0.0
July	23.5	39.5	33.0	0.0
August	24.0	39.7	33.2	0.2
September	21.2	37.6	30.6	0.0
October	16.4	31.0	24.3	19.9
November	10.2	23.0	17.0	12.1
December	4.9	16.9	11.1	14.6

Several studies indicated that some species of Chenopodiaceae including *Salsola* genera have short-lived seeds under natural conditions (Clor et al. 1976, Sankary and Barbour 1977; Creager 1988; Al-Rowaily 1999). It appears that loss of seed viability with time could be compensated for by germination improvement under warmer temperatures provided that other environmental conditions were not limiting. There is a practical importance for our findings. If supplementary irrigation is available, then sowing seeds in spring would be recommended.

Effect of water potential

Significant (P<0.01) differences occurred in all observed germination characteristics in response to decreased matric potential (PEG osmotic solutions) (Table 2). In general, all measured germination characteristics deceased as water potential decreased. A reduction of 92% was observed in percent germination when seeds were exposed to –1.5 MPa compared to the control treatment. A water potential lower than –0.6 MPa may be critical to total germination. Percent germination was reduced by over two folds when water potential fell from –0.6 MPa to –0.9 MPa. Similarly, germination rate decreased from 32 under the control treatment to only 0.5% day^{-1} when seeds were exposed to –1.5 MPa. Radicle length was also reduced dramatically when water potential fell below –0.6 MPa. The magnitude of reduction in radicle length reached 97 % when seeds were exposed to –1.5 MPa as compared to the control treatment. Similarly, shoot length was reduced sharply when water potential fell below –0.6 MPa. No shoot growth was observed when water potential reached –1.5 MPa. These results suggest that germination of *S. villosa* is not likely to occur under low soil moisture levels as low soil moisture availability would not ensure seedling establishment. These results are also in consistency with findings reported for several desert plant species (Sharma 1976; Cluff and Roundy 1988; Fulbright 1988). Further, the results explain the common occurrence of *S. villosa* in wadi beds (Heemstra and AL-Hasan 1994). Supplementary irrigation would assure proper establishment and survival of *S. villosa*. If direct range seeding is desired, then careful selection of low topographic sites and/or use of pitting may improve survival and establishment of the species.

Table 2. Germination characteristics of *Salsola villosa* in response to water potential.

Water Potential (MPa)	Percent Germination	Germination Rate (% day^{-1})	Radicle Length (mm)	Shoot length (mm)
0	85.0	32.46	39.35	28.90
-0.3	71.0	17.38	35.93	21.70
-0.6	59.0	14.18	28.25	19.38
-0.9	26.5	4.79	7.60	6.25
-1.2	8.0	0.70	3.50	1.63
-1.5	6.5	0.48	1.25	0.001
***LSD* 0.05**	8.02	3.27	5.90	3.94

Significant (P<0.01) differences were observed in all measured characteristics of *S. villosa* seed germination in response to osmotic potential (NaCl solutions). Mean comparison of percent germination revealed that reduction in seed germination was significantly different from the control treatment when NaCl concentration reached 0.1 mol. liter^{-1}. Percentage reduction in germination due to the highest NaCl concentration examined (0.3 mol liter^{-1}) was 52% compared to the control treatment.

Differences in GR, followed a similar pattern of total germination percentage. Unger (1978) reported that when seeds are exposed to a saline environment, there is a decrease in rate of germination, delaying completion of germination and creating a water potential below which germination will not occur. Apparently, this was not the case in our study at least for the less concentrated solutions. Although significant, GR differences were not substantial and ranged from 35.2 to 17% day^{-1} for distilled water and the 0.3 mol liter^{-1} NaCl solution respectively. Gradual decrease in radicle and shoot lengths was observed as NaCl concentration increased. The differences in radicle and shoot lengths between the control and the 0.3 mol liter^{-1} treatments were about four and five folds respectively. In general, it is agreed that salinity affects germination by creating a potential sufficiently low to inhibit water uptake and/or by providing conditions for the entry of ions that may be toxic to the embryo (Bewley and Black 1982). In saline seedbeds, however, osmotic potential is not necessarily additive to soil matric potential effect (Roundy 1987). The osmotic potential of a 0.30 mol liter $^{-1}$ solution of NaCl is about –1.5 MPa. Comparing the effect of both types of water potential, the present results indicate *S. villosa* seeds are efficient in osmotically adjusting to NaCl solutions. Ions may enter the seed, lowering its osmotic potential and thus facilitating hydration (Sharma 1973). Therefore, seeds permeable to ions in a saline but saturated seedbed could be well-hydrated even though the soil osmotic potential might be low. Within the tested NaCl solutions, *S. villosa* may germinate in moist saline seedbed especially early in the season before warm days evaporate water and salinity increases beyond the tolerance of the species. In conclusion, optimum temperatures for total germination and speed of *S. villosa* seeds were found to be those of prevailing in spring. However, germination is expected to occur at su-optimum temperatures coinciding with periods when soil moisture is likely to be available in winter. Germination was hindered when matric potential fell below -0.6 Mpa indicating that best revegetation results would be expected at low topographic sites. Alternatively, when supplementary irrigation is available, spring seed sowing is recommended. Results also indicated that seed germination of *S. villosa* is less sensitive to osmotic potential indicating that the seeds of the species are efficient in osmotically adjusting to soluble salts. This suggests the possibility of revegtating moderately salt affected soils. Further work is needed to study the effect of interaction among the three environmental conditions on germination and seedling growth and establishment of *S. villosa*.

Table 3. Germination characteristics of *Salsola villosa* in response to concentration of sodium chloride.

NaCl solution (mol. 1^{-1})	Percent Germination	Germination Rate (% day^{-1})	Radicle Length (mm)	Shoot length (mm)
0	88.0	35.20	39.35	28.90
0.05	82.5	33.00	33.95	22.75
0.10	75.0	30.00	26.50	16.15
0.15	59.5	23.80	22.88	13.58
0.20	56.0	22.40	23.85	14.45
0.25	49.0	19.60	14.9	8.8
0.30	42.5	17.00	10.3	5.7
LSD $_{0.05}$	7.48	2.99	3.73	3.39

REFERENCES

Al-Qarawi, A.A., A.M. Assaeed and A.A. Al-Doss. 1996. Effect of time of sowing on emergence and seedling growth of *Achillea fragrantissima*. Egypt. J. Appl. Sci. 11: 168-175.

Al-Rowaily, S.L. 1999. Influence of storage and scarification on germination of three native rangeland shrubs. Saudi Boil. Soc. pp. 194. 19th annual meeting abstracts. p. 223.

Bashour, I.I., A.S. Al-Mashhady, J.D. Prasad, T. Miller and M. Mazroa. 1983. Morphology and composition of some soils under cultivation in Saudi Arabia. Geoderma 29: 327-340.

Baskin and Baskin 1972. Influence of germination date on survival and seed production in a natural population of *Leavenworthia stylosa*. Amer. Midl. Nat. 88:318-323.

Bewley, J.D. and M. Black. 1982. Physiology and biochemistry of seeds in relation to germination. Vol. 2. Viability, dormancy and environmental control. Springer-Verlag. New York.

Call, C.A. and B.A. Roundy. 1991. Perspectives in revegetation of arid and semiarid rangelands. J. Range Manage. 44:543-549.

Chambers, J.C. 1989. Seed viability of alpine species: variability within and among years. J. Range Manage. 42: 304-308.

Clor, M.A., T.A. Al-Ani and F. Charchafchi. 1976. Germinability and seedling vigor of *Haloxylon salicornicum* as affected by storage and seed size. J. Range Manage. 29: 60-62.

Cluff, G.J. and B. Roundy. 1988. Germination responses of desert saltgrass to temperature and osmotic potential. J. Range Manage. 41: 150-153.

Creager, R.A. 1988. The biology of Mediterranean saltwort, *Salsola vermiculata*. Weed Tech. 2:369-374.

Fulbrught, T. 1988. Effect of temperature, water potential and sodium chloride on Indiangrass germination. J. Range Manage. 41: 207-209.

Heemstra, H.H. and H.O. Al-Hassan. 1990. Range monitoring in northern Saudi Arabia. Range and Animal Development Research Center, Al-Jouf, Saudi Arabia.

Heemstra, H.H. and H.O. Al-Hassan and F.S. Al-Minwer. 1990. Plants of northern Saudi Arabia. Ministry of Agriculture and water, Riyadh. 357 p.

Kaufmann, M.R. and K.J. Ross. 1970. Water potential, temperature and kinetin effects effects on seed germination in soil and solute systems. Am. J. Bot. 57: 413-419.

MacMahon, J.A. and D.J. Schimpf. 1981. Water as a factor in the biology of North American plants. p. 114-171. In: D.D. Evans and J.L. Thames (eds.). Water in desert ecosystems. USIBP Synthesis series II. Dowden, Hutchinson and Ross, Inc. Stroudsberg, Pa.

Maguire, J.D. 1962. Speed of germination- Aid in selection and evaluation for seedling emergence and vigor. Crop Sci. 25: 215-220.

Mayer, A.M. and A. Poljakoff-Mayber. 1989. The germination of seeds. 4th edition. Pergaman Press, Oxford. 270p.

McWilliam, J.R. and P.J. Phillips. 1971. Effect of osmotic and matric potentials on the availability of water for seed germination. Aust. J. Biol. Sci. 24: 423-431.

Meyer, S.E. and S.B. Monsen. 1992. Big sagebrush germination patterns: subspecies and population differences. J. Range Manage. 45: 87-93.

Michel, B.E. 1983. Evaluation of the water potentials of polyethylene glycol 8000 both in the presence and absence of other solutes. Plant Physiol. 72: 66-70.

Mirreh, M.M., M.S. Al-Daraan, A. Narciso. 1990. Chemical content and nutritional adequacy of native shrubs in the widyan of northern Saudi Arabia. Range and Animal Development Research Center, Sakaka, Saudi Arabia. Unpublished report. 25p.

Mirreh, M.M., A.A. Al-Rawaf and M.M. Al-Rowaili. 1991. Effect of year to year variability on the performance of Naimi sheep grazing good condition range of wadi Tamriat in northern Saudi Arabia. Range and Animal Development Research Center, Sakaka, Saudi Arabia. Unpublished report. 32p.

Osman, A.E. and F. Ghassali. 1997. Effects of storage conditions and presence of fruiting bracts on the germination of *Atriplex halimus* and *Salsola vermiculata*. Expl. Agric. 33:149-155.

Roundy, B.A. 1987. Seedbed salinity and the establishment of range plants. p. 68-81. In: G. W. Frasier and R. A. Evans (eds.). Proc. of symposium-seedbed ecology of rangeland plants. USDA, Agr. Res. Serv.; Nat. Tech. Inform. Serv., 5285 Port Royal Rd., Springfield, Va 22161.

Sankary, M.N. and M.G. Barbour. 1972. Autecology of *Salsola vermiculata* var. *villosa* from Syria. Flora 161: 421-439.

Sharma, M.L. 1973. Simulation of drought and its effect on germination of five pasture species. Agron. J. 65: 423-431.

Sharma, M.L. 1976. Interaction of water potential and temperature effects on germination of three semi-arid plant species. Agron. J. 68: 390-394.

Tag El Din, S.S. 1993. Effect of grazing season on the productivity parameters of five range shrubs. Arab Gulf J. Scient. Res. 11: 209-219.

Unger, P.W. 1978. Straw mulch effects on soil temperature and sorgham germination and growth. Agron. J. 70: 858-864.

Young, J.A., R.A. Evans, B.A. Roundy and G.J. Cluff. 1983. Moisture stress and seed germination. USDA Agr. Res. Serv. ARM-W-36. Oakland, Ca.

تأثير درجة الحرارة والجهد المائي في إنبات بذور الروثة

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ص. ب ٢٤٦٠ الرياض ١١٤٥١ المملكة العربية السعودية

تعد الروثة *Salsola villosa* من أهم النباتات الشجيرية في مراعي المملكة العربية السعودية. وقد كان هذا النبات سائداً في المنطقة الشمالية من المملكة. غير أنه لا يوجد اليوم إلا في المواقع الرعوية المحمية من الرعي. ورغم أهمية هذا النبات ، إلا أنه لا تتوفر إلا معلومات محدودة عن بيئته الذاتية. أجريت هذه الدراسة للتعرف على تأثير درجة الحرارة والجهد المائي في إنبات الروثة. نبتت بذور الروثة تحت أربع درجات من الحرارة المتبادلة (٢٠/٥ ، ٢٥/١٠ ، ٣٠/١٥ ، ٢٥ / ٤٠°م تحت فترات من الإضاءة طولها ١٢ ساعة). كما نبتت البذور في ماء مقطر ومحاليل من مادة بولي إثيلين جلايكول (الوزن الجزيئي ٨٠٠٠) جهزت لتحدث جهداً مائياً مماثلاً لصفر ، - ٠٫٣ ، - ٠٫٦ ، - ٠٫٩ ، - ٠٫١٫٢ ، - ١٫٥ ميجا باسكال. ونبتت البذور أيضاً تحت تركيز صفر ، ٠٫٠٥ ، ٠٫١ ، ٠٫١٥ ، ٠٫٢ ، ٠٫٢٥ ، ٠٫٣ مول/لتر من كلوريد الصوديوم. أظهرت النتائج أن أفضل درجة حرارة للإنبات كانت عند ٢٥/١٠°م كما تبين أن الإنبات في محاليل البولي إثيلين كان منخفضاً وبطيئاً خاصة عند انخفاض الجهد المائي إلى - ٠٫٦ ميجا باسكال أو أقل من ذلك.وتأثر الإنبات سلباً أيضاً عند تركيز ٠٫١ مول/ لتر أو أعلى من كلوريد الصوديوم. ويستنتج من هذه الدراسة أنه بالنظر إلى ندرة تزامن موسم الأمطار مع درجات الحرارة المثلى للإنبات في بيئة الروثة الطبيعية، فإن فإن الإنبات قد يحدث في درجات حرارة أدنى من المثلى في فصل الشتاء. كما يستنتج أيضاً أن إنبات البذور قد يتأثر بكل من الإجهادين المائي والملحي.