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Germination of *Salsoa vermiculata* seeds as affected by temperature and storage duration

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Abstract. *Salsola vermiculata* L. Syn. *Caroxylon villosum* (Delile) Akhani & Roalson (*Chenopodiaceae*) is a perennial small woody species widely distributed in arid zones of Middle East and North Africa (MENA) region. It is one of the promising pastoral species for the rehabilitation of arid rangelands in Mororcco. The objectives of this study were to determine the effects of temperature and duration of seed storage on the germination of *Caroxylon villosum* (*Salsola vermiculata* var villosa). Experiments were conducted in the laboratory of the Experimental station of Errachidia (Morocco). Seeds were germinated at six alternating temperatures (10 – 0, 5 – 15, 10–20, 15–25, 20–30 and 25 – 40 °C) with 14-8 h photoperiod and six cardinal temperatures (5, 15, 20, 25, 30 and 40 °C). Three storage durations of seeds under ambient conditions (seed of the same year of production, 2 years storage and 4 years storage) were tested. Germination percentage and germination rate were high for several regime of temperature except for higher temperatures. In addition, germination decreases significantly with the duration of seed storage.

Keywords. *Caroxylon villosum* – Rehabilitation – Temperature – Storage duration – Arid pastures.

Résumé. Salsola vermiculata L. *(Chenopodiaceae) est un ligneux bas largement répandue dans les zones arides dans le Moyen-Orient et l'Afrique du Nord (MENA). C'est l'une des espèces pastorales prometteuses pour la réhabilitation des pâturages arides du Maroc. Les objectifs de cette étude étaient de déterminer les effets de la température et la durée de stockage des graines sur la germination de* Caroxylon villosum (Salsola vermiculata *var villosa). Les essais ont été menés dans une enceinte de germination au laboratoire de la station expérimentale d'Errachidia (Maroc). Les graines ont été germées à six températures alternes (10 à 0, 5 à 15, 10 à 20, 15 à 25, 20 à 30 et 25 à 40 ° C) avec une photopériode de 14 à 8 h et six températures cardinales (5, 15, 20 25, 30 et 40 ° C). Trois durées de stockage des graines dans les conditions ambiantes ont été testées (semences de la même année de production, 2 ans de stockage et 4 ans de stockage). Le pourcentage de germination et le taux de germination étaient très élevés pour plusieurs régimes de température, sauf pour les températures plus élevées. En outre, elle a diminué très significativement avec la durée de stockage des graines.*

Mots-clés. *Caroxylon villosum – Réhabilitation – Température – Durée de stockage – Pâturages arides.*

I – Introduction

Salsola vermiculata L. (Mediterranean saltwort, shrubby Russian thistle, sisallo, rama), a perennial shrub of the family Amaranthaceae. It is a Saharo-Sindien and Mediterranean species with a large geographical repartition. It is one of the most valuable dominant browse in arid zones of North Africa, South Europe, and Southwest Asia (Creager, 1988; Neffati *et al*., 1993;). Many varieties were describe for this species like the one used in this study: *Salsola vermiculata* var. villosa (Delile) Moq. (1840) under the actual name *Caroxylon villosum* (Delile) Akhani & Roalson (according the Geneva plant database).

Salsola vermiculata L. s.l. is also one of the most promising species for rangeland rehabilitation as it contributes to revegetation of degraded rangelands thanks to their potential selfreseeding and can be established from direct seeding (Osman and Ghassali, 1997). It was considered convenient for that purpose and it has been also reported as valuable and palatable forage for goats, sheep

and camels in arid regions (Osman *et al*., 2006). Moreover, its integration in dry areas could not only reduce feed gaps but also stop desertification processes. The crude protein in *C. villosum* varied from 7.1% in winter to 16.4 % in spring while Digestability ranged from 44 % to 49 % in winter and spring, respectively (Assaeed, 2001).

Successful rangeland rehabilitation requires basic knowledge of germination requirements of the potential species to be utilized. Therefore, the objective of this study was to determine the effect of six alternating temperatures regime, six cardinal temperatures and three seed storage duration on germination characteristics of *C. villosa* seeds.

II – Materials and methods

1. Seed origin, collection and storage

Seedling of *C. villosum* (2010 harvest) were obtained at first from the regional center of Oujda in the Oriental part of Morocco, which received the seeds from the International Center for Agricultural Research in the Dry Areas (ICARDA). The original site of collection was located in northern Saudi Arabia. We started to harvest the seeds one year after its plantation in the Experimental Station of Errachidia (Centre-East of Morocco), then we harvested these seeds two years and four years later. They were stored at the temperature of laboratory conditions.

2. Germination experiments

Seeds were germinated on filter papers placed within 15 cm diameter plastic dishes. Four Petri dishes per treatment (50 seeds per dish) were placed within controlled environment chambers (incubator permitting to fix the temperature, photoperiod and intensity of light). Chambers were illuminated for 14 hours daily. Each experiment was replicated four times. Seeds were considered germinated when radicles were >1 mm long. Germinated seeds were counted daily until germination ceased (on average 30 days). Petri dishes were moistened with the same quantity of water every two to three days according to the dryness of the filter paper (its dryness differ according to temperature). Effect of temperature on germination seeds of *C. villosum* was determined by incubating them at twelve temperature regimes (Table 1).

Table 1. Treatments used in this study

Code	Cardinal temperature °C	Code	Alternate temperature °C
C1	40 ° – (<1 year)	A1	40/25 ° – (<1 year)
C2	30 ° – (<1 year)	A2	30/20 ° – (<1 year)
C3	25 ° – (<1 year)	A3	25/15 ° – (<1 year)
C4	20 ° – (<1 year)	A4	20/10 ° – (<1 year)
C5	15 ° – (<1 year)	A5	15/5 ° – (<1 year)
C6	5 ° – (<1 year)	A6	10/0 ° – (<1 year)
C5B	15 ° – 2 years	A5C	15/5 ° – 2 years
C5D	15 ° – 4years	A5D	15/5 ° – 4 years °

3. Germination indices

Germination was monitored daily. Counting number of germinating seeds began from the first day and was done till the end of the experiment (30 days). Nine germination indices were calculated to describe the process of germination: germinability (G%) or final germination percentage (FGP); mean germination time (MGT); coefficient of variation of the germination time (CVt); mean germi-

nation rate (MGR); germination rate index (GRI); coefficient of velocity of germination (CVG) (Speed of germination); mean daily germination (MDG) (number of seeds per day); germination value (GV); U: uncertainty of germination and Synchrony of germination (Z). Time, rate, homogeneity, and synchrony are aspects that can be measured, informing the dynamics of the germination process. Uncertainty measurement is an adaptation of the Shannon index and measures the degree of uncertainty associated to the distribution of the relative frequency of germination (Ranal and Santana 2006). Low values indicate more synchronized germination. According to Ranal and Santana (2006), the synchrony of germination of one seed with another assumed Z=1 when the germination of all seeds occur at the same time and Z=0 when at least two seeds can germinate, one at each time, in fact it is a degree of germination overlapping. All the germination parameters were calculated according to formulas given by Ranal and Santana (2006).

4. Data analysis

All data were submitted to one-way analysis of variance (ANOVA) and the averages of treatments were compared according to the method of Newman and Keuls to determine the significance of seed germination percentage under each treatment. SPSS program for windows Version 18.0 was used to perform these analysis. Excel 2007 software was used to transform data and to calculate different indices based on the work of Ranal *et al*. (2009).

III – Results and discussion

1. Effect of temperature

The statistical analysis of variance showed a significant effect of the alternating/ cardinal temperature regimes and storage duration of seeds on almost all parameters of germination (Table 2).

Table 2. Germination characteristics of *C. villosum* in response to different temperature combine to the storage duration

Temperatures	G (%)	MGT (day)	CVT (%)	MGR (day^{-1})	U (bit)	Z (unit less)	GRI (day)	CVG (%)	GV %day^{-2})	MDG (%)
A1	2.0^{a}	1.5^{a}	0.0^{a}	0.38^{ab}	0.00^{a}	0.00^{a}	1.0^{a}	37.5^{ab}	0.1^{a}	0.1^{a}
A2	**87.5^{d}**	3.1b^{c}	24.5^{b}	0.32^{ab}	1.37^{c}	0.49^{d}	29.5^{cd}	31.9^{ab}	70.0^{ef}	2.9^{d}
A3	**98.0^{d}**	3.8^{c}	47.9^{ef}	0.26^{ab}	2.39^{e}	0.22^{b}	31.4^{cd}	26.4^{ab}	62.5^{de}	**3.3^{d}**
A4	**96.0^{d}**	3.1^{bc}	42.6^{cdef}	0.32^{ab}	1.70^{cd}	0.38^{cd}	34.3^{de}	32.1^{ab}	**83.3^{f}**	**3.2^{d}**
A5	**98.0^{d}**	3.8^{c}	40.9^{cdef}	0.27^{ab}	1.93^{d}	0.34^{c}	29.9^{cd}	26.5^{ab}	70.2^{ef}	**3.3^{d}**
A6	**96.5^{d}**	**6.2^{d}**	**52.7^{f}**	0.16^{a}	**3.04^{f}**	0.13^{b}	19.3^{b}	16.1^{a}	35.0^{c}	**3.2^{d}**
C1	1.5^{a}	1.5^{a}	0.0^{a}	0.38^{ab}	0.00^{a}	0.00^{a}	0.8^{a}	37.5^{ab}	0.1^{a}	0.1^{a}
C2	37.5^{b}	2.4^{b}	33.6^{bcde}	**0.42^{b}**	1.03^{b}	**0.61^{e}**	16.8^{b}	**41.9^{b}**	18.2^{b}	1.3^{b}
C3	73.5^{c}	2.8^{b}	27.5^{bc}	0.36^{ab}	1.41^{c}	0.43^{cd}	28.6^{c}	36.3^{ab}	52.3^{d}	2.5^{c}
C4	**93.5^{d}**	2.8^{b}	44.8^{def}	0.36^{ab}	1.67^{cd}	0.41^{cd}	**38.2^{e}**	36.2^{ab}	**85.7^{f}**	**3.1^{d}**
C5	**98.0^{d}**	2.9^{bc}	30.6^{bcd}	0.34^{ab}	1.65^{cd}	0.33^{c}	**36.6^{e}**	34.2^{ab}	**79.7^{f}**	**3.3^{d}**
C6	**92.5^{d}**	7.0^{e}	40.7^{cdef}	0.14^{a}	**3.26^{f}**	0.12^{b}	16.1^{b}	14.3^{a}	26.6^{bc}	**3.1^{d}**

Numbers with different letters (a to d) are significantly different by Newman & Keuls test at $p < 0.05$.

For the same storage duration of seeds (fresh seeds <1year), generally alternating temperatures regimes were better than some cardinal temperatures. The test of Newman & Keuls (SNK) defined four groups of cardinals temperatures and only two groups of alternating temperatures for the germinability parameter. Highest germination percentage (98 %) was observed when seeds were ger-

minated at cardinal temperatures (C5=15°C) and alternating temperature A3 (15/25°C) and A5 (5/15°C). Lowest germination percentage always for fresh seeds was observed for higher temperature (A1= 25/40°C, C1=40°C and C2=30). Furthermore, SNK test distinguished many groups for other parameters of germination ($p<0.01$).

2. Effect of storage duration under ambient temperature

Regarding the duration of storage, it affects significantly all parameters of germination. Most important is that the germination faculty is reduced to the half after two years and almost all seeds lost their germination faculty after four years of storage (Table 3).

Table 3. Total percentage germination of the fresh harvested *C. villosum* in response to the duration of storage

Temperatures	G (%)	MGT (day)	CVT (%)	MGR (day^{-1})	U (bit)	Z	GRI (day)	CVG (%)	GV $\%day^{-2}$)	MDG (%)
A5	**98.00^{d}**	3.79^{b}	40.91^{b}	0.27^{c}	1.93^{bc}	0.34^{d}	29.89^{c}	26.50^{c}	70.19^{c}	0.31
A5B	43.50^{c}	4.05^{b}	41.36^{b}	0.25^{c}	2.29^{c}	0.23^{c}	12.29^{b}	25.16^{c}	10.98^{b}	0.74^{c}
A5D	9.00^{b}	5.49^{c}	33.90^{b}	0.19^{b}	1.69^{b}	0.11^{b}	1.75^{a}	18.86^{b}	0.39^{a}	5.75^{d}
C5	**98.00^{d}**	2.93^{b}	30.60^{b}	0.34^{d}	1.65^{b}	0.33^{d}	36.58^{d}	34.18^{d}	79.65^{c}	0.31
C5B	36.00^{c}	4.02^{b}	35.27^{b}	0.26^{c}	2.04^{bc}	0.27^{cd}	10.34^{b}	26.25^{c}	8.48^{b}	0.85^{c}

Numbers with different letters (a to d) are significantly different by Newman & Keuls test at $p < 0.05$.

The two most important results are:

First we should use fresh seeds for *C. villosum* and they should not be stored over two years at the temperature of laboratory conditions because the faculty of germination is halved. Several studies indicated that some species of Amaranthaceae including Salsola genera have shortlived seeds under natural conditions (Sankary and Barbour 1977; Creager 1988; Al-Rowaily 1999). Loss of seed viability with time could be compensated by the remarkable ability of plant to produce a huge amount of seeds.

The second most important result is the ability to use seeds several times during the year because the fresh seeds germinate very well at several alternating temperature, of course only the summer period should be avoided as the increase of temperature decreases the germinability, which is in concordance with the results obtained by Guma *et al*. (2010) and Neffati *et al*. (1993). These last authors stated that optimum germination is between 5 and 25 °C. Also Sankary and Babour (1972) reported that the optimum temperature of germination of this species is between 12 and 18 °C.

IV – Conclusion

Caroxylon villosum showed excellent germinability and it is promising pastoral species for the rehabilitation by reseeding of arid lands in the Centre-East of Morocco under the condition of using fresh seeds. Nevertheless, more research in the field on its establishment and behavior towards browsing should be done.

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