EVALUATION OF *SALSOLA VERMICULATA* L. FOR RANGE IMPROVEMENT IN HIGHLAND BALOCHISTAN, PAKISTAN

Sarfraz Ahmad[1], Sarwat N. Mirza[1] and Muhammad Islam[1]

Abstract

Water scarcity limits the establishment, growth and production of range plants in Balochistan. *Salsola vermiculata* a Mediterranean perennial shrub was evaluated under natural rainfall regimes to assess its potential of germination and establishment under drill and broadcast seeding treatments for range improvement in highland Balochistan. Seeds of *S.vermiculata* germinated in both treatments with higher germination percentage in drill seeding. Apparently, no differences were observed for seedling survival and seedling establishment between drill and broadcast methods. The seedlings of *S.vermiculata* were able to survive and attain some growth under extreme drought conditions and withstand minimum temperature of -11^{o}C. The initial trial on emergence and survival indicates that *S. vermiculata* possesses characteristics of drought and cold resistance and has adaptability to be grown under arid conditions of highland Balochistan.

Introduction

Rangeland productivity in Balochistan is substantially affected by low and erratic rainfall distribution, inter and intra seasonal variation and over-exploitation of natural resources. Most of the rangelands in Balochistan lies within the arid (100–150 mm annual rainfall) and semi-arid (200–250 mm annual rainfall) climatic zones. These rangelands not only provide feed for livestock/wildlife but also energy material, herb plants, watershed areas, and perform many biological and chemical processes essential for a healthy ecosystem. With an increasing human and livestock population, a rapid decline in rangeland health has been observed in Balochistan (Mirza *et al*., 1995). Many desirable range species are being eliminated from the ecosystem at an alarming rate or are found only in some protected places. Moreover, on many rangelands in Balochistan deterioration has reached a point where succession or natural plant replenishment will not take place within a reasonable time, even with proper grazing management plans. One strategy for reclaiming the range productivity may be the development of improved forage plants with better resistance to drought and adaptability to prevailing conditions (Johnson *et al*., 1981).

Although the native range plants of Balochistan are very well adapted to the prevailing environmental conditions, however, assemblage of a broad base genetic germplasm of range plants from other areas of the world with similar climate, soil and topography may lead to the selection of desirable range plants for re-vegetation (Johnson, 1994). Plant improvement for arid and semi-arid rangelands should include a wide diversity of species, characterization of the environment, selection criteria, development of screening techniques and incorporating screening techniques in plant improvement program (Johnson, 1980).

S. vermiculata is a Mediterranean arid zone fodder shrub, has wide distribution and can grow on rocky sites, rough slopes and foothills (Sankary and Barbour, 1972).

[1] Senior Scientific Officers, Arid Zone Research Center, Brewery Road Quetta

S. vermiculata is a medium sized xerophalophytic shrub, common on dry gypsosaline land throughout West Asia and North Africa. This species is saline and drought tolerant, a good pasture species across seasons and is palatable to goats, sheep and camels. This species received some attention as a potential species for re-vegetating highland ranges via direct seeding (Sankary, 1986) and has the capability of self-regeneration if rainfall reaches about 200 mm/year (Murad, 2000). *S. vermiculata* start growth in early spring (depends on rainfall) and provides a considerable amount of palatable forage for small ruminants.

Previous efforts made at Arid Zone Research Centre (AZRC) focused on identifying fast growing *Atriplex* species (*A. canescens* and *A. lentiformis*) for re-vegetating the depleted ranges by planting in winter rainy season (Aro *et al*., 1992, Thomson *et al*., 1997). However, the seedlings of these species have to be grown under nursery conditions before planting out in the field. Therefore, efforts have also been diverted to identify range species which can be established by direct sowing and have the potential of self-regeneration. The present study was conducted to evaluate *S. vermiculata* for seed germination, emergence, and seedling establishment under rainfed conditions in highland Balochistan.

Material and Methods

The experiment was conducted at Arid Zone Research Center (AZRC), Quetta during 1999 and 2000. The study site has altitude of 1690 m, latitude 30^o 07' N and longitude 66° 58' E. The site has a continental Mediterranean climate (Kidd *et al*., 1988). Long term average rainfall of 200 mm has been recorded (Samiullah *et al*., 2000). Sowing of *S. vermiculata* seeds was carried out on 1st March, 1999 at AZRC field after clearing the local vegetation. Three replications in RCBD were used for two treatments, viz., broadcast seeding and drill seeding. The plot size was 3×3 m and row to row distance was maintained at 0.5 m with row length of 3 m each. Six hundred utricles (seeds) were used per plot for each treatment. A single row hand drill was used for drill seeding while for broadcast treatment, seeds were broadcast manually and covered with soil by dragging brush over the soil surface. The treatments were applied without providing irrigation to the plots.

Emergence was recorded on March 20, 1999. Survival data were recorded on monthly basis up to the end of August, 1999. Plant development (plant height, crown cover, crown volume) of the surviving seedlings was recorded in September, 1999. Plant height was recorded in cm from the base of the plant to its maximum twigs. Crown cover was calculated by taking the two diameter measurements on the crown spread of the *S. vermiculata* plants. The first measurement was taken to the maximum value of the diameter (D1). The second reading was taken perpendicular to the first one, giving the maximum value in this direction (D2). Crown cover (CC) was then calculated with the formula CC = 1/4 * D1D2 (Thalen, 1979). Crown volume (CV) was determined from the crown cover and plant height (h) by using the formula CV= 1/6 * D1D2 h. (Thalen, 1979).

Overwinter survival (over winter surviving seedlings/first year surviving seedlings * 100) and second year's seedling development (plant height, crown cover & crown volume) was recorded at the end of September, 2000. Due to very low emergence and survival rate and non-normality of the data only means and standard errors for different parameters were calculated.

Results and Discussion

Total rainfall during 1999 (165.9 mm) and 2000 (37.5 mm at the end of September 2000) was well below the long term average rainfall (200 mm) of the study site (Table 1). The region was experienced one of the worst drought of its history during the last three to four years continuously. Comparatively, the 1999 season was better in terms of total rainfall and its distribution. During 2000, drought was more prevalent throughout the year and resulted in greater drought stress on plants. Maximum mean daily temperatures of 1999 and 2000 were 37 and 36°C, respectively. Absolute minimum temperature (–11^{o}C) was recorded in January, 2000 which resulted some seedling mortality.

Rain showers of (25.2 mm) in early March, 1999 promoted the emergence of *S. vermiculata* seeds. An emergence of 13% and 5% was recorded in drill and broadcast treatments, respectively (Table 2). Emergence percentage in both treatments was very low. However, drill seeding treatment had a better emergence rate than the broadcast treatment (Table 2). At the end of the first growing season, 64% and 84% seedlings were surviving in drill and broadcast sowing methods, respectively. Maximum seedlings mortality was observed during June and July due to high temperatures and severe drought conditions. Apparently there was no differences for plant development characteristics (plant height, crown cover, crown volume) between drill and broadcast seeding methods (Table 2). From April, 1999 to July, 1999, no rainfall was received and plant growth was badly affected by the non-availability of soil moisture. However, the surviving seedlings attained a maximum mean height of 13 cm during the first growing season with crown cover of 57 cm^2 and crown volume of 614 cm^3 in drill treatment (Table 2).

Over-winter survival of the seedlings was 72% in drill treatment and 81% in broadcast treatment (Table 2). Most of the seedlings were capable to endure the absolute minimum temperature of –11^{o}C and survived over the second year. Plant development during the second growing season was badly affected due to prolonged drought stress from April to the end of the experiment (end of September 2000). However, the second year's surviving seedlings were more vigorous than the first year's growing season (Table 2). Average plant height during second year was recorded 26 cm and 23 cm in drill and broadcast treatment, respectively. Crown cover ranged from 417 cm^2 in drill to 483 cm^2 in broadcast treatment, whereas crown volume was recorded 7694 cm^3 and 9506 cm^3 in drill and broadcast treatment, respectively (Table 2).

Emergence percentages in both treatments were low. This low percentage value may be either related with low rainfall distribution during the emergence period or low seed viability. Seeds of *S. vermiculata* start to loose viability within a few months if stored at room temperature (Sankary and Barbour, 1972). It appears from the results that if enough moisture is available, the seeds of *S. vermiculata* are able to germinate at average minimum and maximum temperatures of (7 and 19^{o}C). Sankary and Barbour (1972) reported that the optimal germination temperature of *S. vermiculata* (12–18^{o}C).

However, germination can occur over a wide range of temperatures (3–33^{o}C) and is insensitive to light and temperature (Sankary and Barbour, 1972).

The probability of occurrence of monthly late winter and early spring rains (the optimal time for emergence of range species) in Balochistan is around 41 and 39 %, respectively (Kidd *et al*., 1988). These rains may be utilized for the establishment of *S. vermiculata* plantation. The early germination/emergence of *S. vermiculata* in the spring season under comparatively low temperature may allow the plants of early root initiation and seedling establishment. The ability of seedlings to germinate and emerge early in the growing season is an important criterion for selecting plants for rangelands improvement in arid and semiarid areas (Johnson, 1994).

Drill seeding gave higher emergence percentage than the broadcast method. Numerous rangeland seeding trials confirmed the better germination/emergence and seedling establishment of drilling than broadcast methods due to less seed predation, more uniform seed distribution, seed coverage, better moisture and temperature conditions which help the seeds to carry out metabolic processes rapidly without interruption (Nelson *et al*., 1970; Keller, 1979). However, Sankary and Barbour (1972) reported that the germination of *S. vermiculat*a usually occurs on the soil surface and heavy seed cover (1 cm or more) retard establishment.

The seedlings of *S. vermiculata* faced extreme drought conditions and survived four months after emergence without any further rainfall and first year's survival rate was comparatively better than the newly recruited range perennial grasses (Ahmad *et al*., 2000). Although not quantified, it seems that *S. vermiculat*a possess some drought resistance mechanisms. Plants adapted to drought may involve a wide variety of morphological and physiological mechanisms (Turner and Kramer, 1980). Broadly, the drought stress mechanisms in range plants have been classified into escape, maintenance of high water potential under stress and tolerance of low tissue water potential (Asay and Johnson, 1983).

At the end of the first growing season, surviving seedlings of *S. vermiculata* attained comparatively better height, crown cover, and crown volume than the local range species (Personal communication). Few plants also produced seeds in both treatments. Winter damage is another important environmental factor in highland Balochistan that affect the seedling establishment. The ability of *S. vermiculata* to withstand winter temperature is very good and 72% and 81% in drill and broadcast treatment respectively, of the first year survived seedling overcome the winter temperatures of –11^{o}C and 36 days below 0^{o}C during the months of December and January, 2000.

Like the first year of experiment, the second year was also extremely dry and plants survived under meager 37.5 mm of total rainfall up to the end of the experiment. The extreme drought conditions hinder the plant growth and development however, at the end of the experiment the surviving plants of *S. vermiculat*a attained a mean maximum crown cover (483 cm^2) and crown volume of (9506 cm^3) in broadcast treatment. The plant development in broadcast treatment was comparatively better than the drill treatment due to low plant density and more open spaces. Moreover, most of the second year's plants produced and dispersed seeds.

The preliminarily data on emergence and survival indicate that *S. vermiculata* has a good potential of drought resistance and has adaptability in highland Balochistan. However, further studies are required to investigate its re-generation potential, forage production, forage quality, grazing behavior, competition with local vegetation and performance over a wide range of climatic conditions in Balochistan.

Table 1. Rainfall (mm), mean maximum and minimum temperatures (^oC) during the experiment at AZRC Quetta.

Months	Temperature					
	1999 season			2000 season		
	Rainfall	Max.	Min.	Rainfall	Max.	Min.
January	50.7	11.87	–0.14	13.4	12.69	–1.13
February	66.2	14.68	4.22	16.5	12.9	6.0
March	27.6	19.52	7.35	7.6	18.7	11.1
April	0.0	26.91	12.28	0.0	24.8	16.6
May	0.0	30.4	21.0	0.0	35.71	18.98
June	0.0	35.68	19.97	0.0	34.05	19.81
July	0.0	37.25	21.76	0.0	36.60	21.05
August	6.6	35.05	19.80	0.0	35.77	20.41
September	14.8	33.36	17.66	0.0	34.26	17.74
October	0.0	26.95	11.12*			
November	0.0	21.10	7.54			
December	0.0	16.35	0.53			

* Experiment was completed at the end of September 2000.

Table 2. Percent (mean ± SE) emergence, plant survival at the end of first growing season, plant development (height, crown cover, crown volume) of the surviving seedlings, percent over-winter survival and plant development of the surviving seedlings at the end of the second growing season.

	Drill sowing	Broadcast sowing
Emergence (%)	13.0 ± 1.3	5.0 ± 2.4
First year survival (%)	64.0 ± 3.5	84.0 ± 6.8
First year plant height (cm)	13.0 ± 0.7	8.0 ± 0.8
First year crown cover (cm^2)	57.0 ± 12.2	45.0 ± 26.3
First year crown volume (cm^3)	614.0 ± 23.5	405.0 ± 296.9
Over-winter survival (%)	72.0 ± 5.5	81.0 ± 9.0
Second year plant height (cm)	26.0 ± 1.5	23.0 ± 2.1
Second year crown cover (cm^2)	417.0 ± 17.9	483.0 ± 64.5
Second year crown volume (cm^3)	7694.0 ± 402.7	9506.0 ± 1536.3

References

Ahmad, S., C. A. Call., E. W. Schupp and S. N. Mirza, 2000. Regeneration ecology of *Chrysopogon aucheri* and *Cymbopogon jwarancusa* in upland Balochistan. III. Effects of precipitation and seedbed micro-habitat on seedling recruitment. Pak. Jour. Biol. Sci. 3 (12): 2041-2047.

Aro, S. R., M. I. Sultani., M. Asghar and J.D.H. Keatinge, 1992. Introduction of Fourwing Saltbush (*Atriplex canescens*) into degraded rangelands in upland Balochistan. Proceedings of the XVI International Grassland Congress, Nice. PP 1501-1502.

Asay, K. H. and D. A. Johnson, 1983. Breeding for drought resistance in range plants. Iowa State Jour. Res. 57 (4): 441- 455.

Johnson, D. A., 1980. Improvement of perennial herbaceous plants for drought stressed western rangelands. PP (419- 433). In: Adaptation of plants to water and high temperature stress. Turner, N. C. and Kramer, P. J. (eds.). Wiley Interscience, New York.

Johnson, D. A., M. D. Rumbaugh and K. H. Asay, 1981. Plant improvement for semiarid rangelands: possibilities for drought resistance and nitrogen fixation. Plant Soil, 58: 279 - 303.

Johnson, D. A., 1994. Possible germplasm evaluation procedures for water-limiting overgrazed environment in Patagonia. Proceedings of the international workshop on plant genetic resources, desertification and sustainability. Argentina, 7-11 Nov.

Keller, W., 1979. Species and methods for seeding in the sagebrush ecosystem. PP 129-163. In the sagebrush ecosystem: A symposium, Utah State University, Logan, Utah.

Kidd, C. H. R., D. J. Rees., J. D. H. Keatinge., F. Rehman., A. Samiullah and S. H. Raza, 1988. Meteorological data analysis of Balochistan. ICARDA Research Report No. 19. Arid Zone Research Institute, Quetta, Pakistan.

Murad, N., 2000. A study on the Syrian steppe and forage shrubs. pp 109-121. In : Gintzburger G., M. Bounejmate and A. Nefzaoui (eds.). 2000. Fodder shrub development in arid and semi-arid zones. Proceedings of the workshop on native and exotic fodder shrubs in arid and semi-arid zones, 27 Oct-2 Nov 1996, Hammamet, Tunisia, ICARDA, Aleppo, Syria. Vol vii 290 pp.

Mirza, S. N., G. Akbar and I. Begum, 1995. Land degradation and its control in highland Balochistan. Progressive Farming, 15 (2): 46 - 51.

Nelson, J. R., A. M. Wilson and C. J. Goebel, 1970. Factors influencing broadcast seeding in bunchgrass range. Jour. Range Manag. 23:163 - 170.

Samiullah, A., A. Jalil., Z. Ali and I. Begum. 2000. Agronomy at Arid Zone Research Center (1995-99): Rational and Results. AZRC Research Report No. 22.

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

Sankary, M. N., 1986. Species distribution and growth on salt-affected land in Syria. Reclamation and Reveg. Res. 5 (1-3):125 - 142.

Thalen, D. C. P., 1979. Ecology and utilization of desert shrub rangelands in Iraq. Dr. W. Junk B.V Publishers-The Hague.

Thomson, E. F., S. N. Mirza., S. Rafique., J. Afzal., I. Rasool., Atiq-ur-Rehman., M. Ershad., A. Hussain., G. Akbar and A. S. Alvi, 1997. Utilization of fourwing saltbush for the arid rangelands of highland Balochistan, Pakistan. In: N. Haddad, R. Tutwiler and E. Thomson (eds.). Proceedings of regional symposium on integrated crop-livestock systems in the dry areas of West Asia and North Africa held at Amman, Jordan from 6-10 November. ICARDA, Aleppo, Syria. 572 p.

Turner, N. C. and P. J. Kramer (eds.), 1980. Adaptation of plants to water and high temperature stress. John Willey and Sons, New York.