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Preliminary Studies of Germination Requirements of Shadscale Atriplex Confertifolia Torr. and Ferm. Wats

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PRELIMINARY STUDIES OF GERMINATION REQUIREMENTS OF SHADSCALE (ATRIPLEX CONFERTIFOLIA (TORR. AND FREM.) WATS)

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CHAPTER I

INTRODUCTION

Shadscale (Atriplex confertilolia (Torr. and Frem.) Wats.) is an important component of the salt-desert-shrub vegetation type in the inter-mountain region. This species dominates a large portion of the 41 million acres occupied by this vegetation type. Shadscale reaches greatest importance at lower elevations of Utah and Nevada, where despite the low productivity due to its harsh habitat, this vigorous shrub furnishes considerable winter grazing for sheep and cattle. Gates et al. (1956) have observed that poor drainage conditions, coupled with low precipitation, results in the concentration of salts, a chief habitat factor determining the growth and distribution of this species. Fautin (1946) found pure stands of Shadscale in the drier valleys of Utah, usually where a saline sub-soil occurred.

Vest (1962) in his study of plant communities in the Great Salt Lake desert found that shadscale was adapted to the soils where salt concentration increases sharply downward from 0.35 per cent at the surface to 1.4 per cent at one foot depth. The zone of salt accumulation probably begins at the lowest level to which water penetrates.

Bleak et al. (1965)have observed that heavy grazing of salt-desert-shrub vegetation has caused a serious depletion of this range type. Palatable grasses and shrubs have decreased and relatively less desirable vegetation has invaded the range with serious reduction in forage production.

Cook et al. (1954) have observed that shadscale is a good forage. Sheep graze pure stands over relatively long periods without becoming dissatisfied. This shrub produces an abundance of seed and foliage especially during early winter.

Shadscale is comparatively less palatable and nutritious than some of the other components of this vegetation type such as winterfat. Under heavy use disappearance of more desirable species is accompanied by a relative increase in less desirable or undesirable vegetation. West (unpublished) has observed that there is evidence to indicate that shadscale is increasing in terms of relative composition and areal extent in the salt-desert-shrub type in Utah at the expense of more desirable species. This situation is causing concern to those involved in livestock operations.

What is the major ecological explanation for the increase of this species? What habitat factors contribute to the advantage this species has over others? What inherent characteristics in this species help its expansion under similar climatic and edaphic conditions? What are the specific germination requirements of this species which are easily met in the habitat and which help its establishment and ultimate increase? These are some of the questions to which answers have to be found in order to solve this range problem.

This study is aimed at contributing to the basic understanding of the germination requirements of shadscale to improve interpretation of causes of change in the vegetation composition.

In areas, where environmental factors favor the growth of only shadscale, this species has to be treated as a "key species" in management. In order to ensure rehabilitation of the depleted ranges in the shadscale zone artificial reseeding would be an important objective of management. An adequate knowledge of germination behavior of shadscale will, therefore, go a long way to help in the achievement of this objective.

Another important factor is the inherent or genetic variation of a species occurring over its total distribution. Thus germination requirements of the seed collected from one site may be different from those collected from another locality. No work has been done to explore the possibilities of ecotypic variation in this species.

The purpose of this study is to determine some germination responses of shadscale seed. The study includes the following investigations:

1. Determination of germination variability as related to seed source.
2. The effect of time of seed collection on germination.
3. The effect of certain preconditioning treatments on germination.
4. The effects of salt concentrations on germination.
5. The effects of selected temperature regimes on germination.
6. Viability of shadscale seed.

CHAPTER II

REVIEW OF LITERATURE

A plant passes through a number of growth stages during its development from zygote to zygote. Each growth stage has its special requirements as far as external conditions are concerned. Whereas most of these stages have rather similar requirements, germination is usually entirely different from other development stages. Koller (1964) has observed that of all developmental phases of the plant, germination is probably the one which is most subject to control by environment. The very existence and specifity of a variety of germination-regulating mechanisms and their frequent complexity are proof that they are physiological and ecological adaptations which increase the potential for survival of the species.

Hilton (1941) has observed that adjustment of a plant to a new set of conditions involves the three essential functions of reproduction, germination and growth. Germination is the first critical process of ecesis. Upon it depends the vital problem of establishment. An understanding of this basic function is essential for the regeneration and expansion of perennial forage species on the depleted ranges.

Went (1957) has observed that the distribution of plants in nature can be explained on the basis of their response to a large number of individual

environmental factors or a combination of them acting on germination and other phases of growth.

Wareing (1963) while discussing the physiological characteristics of the seed has observed that "it is a small propagule in which the embryonic tissues show a high degree of dehydration. In this form the tissues are usually very much more resistant to unfavorable environmental conditions and may survive for a long period of time. Since the embryo is unable to carry on photosynthesis, it is dependent in the early stages of germination upon organic nutrient reserves present in the cotyledons, endosperm, or other tissues, and which are mobilized during germination. Many seeds will germinate readily when provided with conditions of moisture, temperature, and oxygen supply favorable for growth. Some seeds will not germinate under these conditions as soon as they are ripe but need certain pretreatments i.e., they show various forms of dormancy."

The above observation made by Wareing is the nucleus around which all problems connected with germination revolve. Not only this, it also forms a basis for ecological adaptations of various species determining their occurrence and distribution. This also points to the necessity of investigation into these phases of germination in order to know the various environmental requirements of the species which must be met for its establishment.

During the process of ripening, the seed loses water so that when fully mature it may contain only 10 per cent or less water. Certain seeds retain their vitality for years if dessicated and kept in a vacuum. Thus seeds are far

more drought resistant than the growing plants of the same species. Under dry conditions seeds can also withstand great extremes of temperature.

Seeds stored in the soil can retain viability for a long time. Darlington (1931) has stated that in 1879, Dr. Beal buried a range of seeds in soil and samples were removed for testing at intervals. Appreciable germination was still given by a number of species after 50 years. According to Went (1957) seeds of three of these species were still viable after 80 years.

According to Wareing (1963) seeds of some Leguminosae will survive in soil without taking up water until the seed coats have been removed by the activities of the soil micro-organisms. Presence of seeds in soil for a long time in the unimbibed condition has been explained by the fact that high CO_2 concentration in the soil brings about "narcosis" of the seed. Seeds which are dormant in the soil in the imbibed condition for a long time must have very low respiration rates if the reserve materials are not to be rapidly consumed.

Temperature also plays an important role in controlling germination. Minimum temperatures at which germination can occur vary considerably from species to species. Seed of beech will germinate at temperatures only a little above freezing. Seeds of tropical and sub-tropical plants have higher temperature requirement. Most species germinate under constant temperature conditions but some require a daily alternation in temperature. Very high temperatures have an unfavorable effect on germination due to the adverse effects on proteins and other substances.

Crocker (1948) has observed that maximum temperature for germination often changes with time. Freshly harvested seeds of some species have a rather low maximum temperature, but after a period of storage they germinate at higher temperatures.

Mayer and Mayber (1963) have observed that viability is retained best under conditions in which metabolic activity is greatly reduced i.e., low temperature and high carbon dioxide concentration. In addition other factors which determine seed dormancy are also important. Periods for which seeds retain viability is determined by genetics and environmental factors.

The seeds of some species can germinate immediately after they are shed, but many seeds will not do so even when sown under favorable conditions without some pre-treatment. Such seeds are said to exhibit "dormancy."

Crocker (1916), Mayer and Mayber (1963) recognized the following causes of dormancy.

1. Immaturity of embryo
2. Hard seed coats
3. Need for after-ripening in dry storage
4. Requirement for light or darkness
5. Requirement for chilling
6. Interference with oxygen uptake by seed coats

In most germination tests which fail to show adequate results "inherent dormancy" of the seeds is probably the major cause. Thus an understanding of this phenomenon is important for any research in this field.

According to Wareing (1963) further development of immature embryos can be ensured by imbibing the seed with water and maintaining them under favorable temperature conditions.

Seeds of some species fail to germinate if sown immediately after harvesting even though the embryo is fully mature. The seeds emerge from dormancy if stored under suitable conditions. Causes of this need for after-ripening are not known. Wellington (1956) is of the view that drying of the seed during storage becomes responsible for the removal of dormancy. Harrington (1923) and Johnson (1935) have observed that drying has little effect on the period of dormancy and that after-ripening involves an increase in the permeability of seed coats to oxygen.

In some species exposure to light is necessary for germination. In other species germination is inhibited by light. The responses of light sensitive seeds are markedly affected by temperature. Many seeds which are light requiring at, say 25^{o} C germinate in the dark at lower temperatures.

Barton and Crocker (1948) have observed that seeds of many species if sown in fall and exposed to winter conditions, will germinate readily in the following spring. This practice is called "stratifying." Thus exposure to winter cold or chilling the seed before growing is considered necessary to break the dormancy of many seeds.

Presence of testas or seed coats may sometimes induce dormancy. Some seeds which have chilling requirements will germinate without chilling if the testa are removed. Many seeds which show a requirement for after-ripening in dry storage will germinate if seed coats are removed.

Evanari (1949) is of the view that dormancy in seeds is possibly controlled by specific regulating substances—germination inhibitors, when seeds fail to germinate under favorable conditions.

Mayer and Mayber (1963) have observed that all those compounds which are generally toxic to living organisms will also, at toxic concentrations, prevent germination, simply by killing the seed. Some substances prevent germination without affecting the seed irreversibly. The simplest case is that of osmotic inhibition. If a seed is placed in a solution of high osmotic pressure, such as sugar or salt, germination is prevented. When the seed is removed from this solution and placed in water it germinates. According to the same authors another type of inhibition is that caused by substances which interfere with normal metabolism. Compounds such as cyanide, dinitrophenol, azide, fluoride and hydroxylamine interfere with metabolic process and prevent germination. Herbicides like 2,4-D and auxins in high concentration also act as inhibitors. Some substances like potassium nitrate, gibberellins and thiourea kinetin, however, promote germination. Nord and Van Atta (1960) found saponin in the bracts of Atriplex canascens reduced germination.

Griffiths (1942) conducted experiments on germination and found that moisture content was more critical than temperature during storage. Raising moisture content from 5 to 10 per cent caused a more rapid loss of viability than a temperature rise from 20° to 40° C.

It is evident that the characteristics of germination are important in controlling the distribution of plants. Evolution of physiological

characters in desert plants has been directed more towards germination control than towards any other single character (Went, 1957).

Mayer and Mayber (1963) observed that probably the most critical factor in determining germination was a suitable combination of temperature and moisture. In arid regions survival of a species is determined by mechanisms which ensure that germination occurs at a time when suitable combination of temperature and moisture exists.

Went (1957) has suggested that in certain desert seeds germination occurs only if the rate of reformation of an inhibitor in the seeds, when they are moistened, is slower than the process of germination itself. Such a situation might occur only under specific conditions of moisture and temperature.

Cloudsley-Thompson and Chadwick (1964) are of the view that high salt content does not have much effect upon desert seeds in an air dry condition. However, it considerably affects these seeds at the time they become moist and begin to germinate.

According to Mayer and Mayber (1963) many of the halophytes are distinguished by a high salt tolerance in various stages of their development, including germination, rather than by a positive salt requirement. High salt tolerance is not, therefore, a proof that plant is halophytic. However, some plants such as Atriplex halimus show a definite requirement for a certain salinity and germinate better in the presence of low concentration of salt, and their subsequent development is also better. According to the authors even in this plant the tolerance to salt during growth and development is ten to one

hundred times greater than during germination. As a result germination occurs when the salt content of the habitat has reached its lowest level after rains. Effect of salt in germination of Atriplex halimus has been illustrated graphically by the authors.

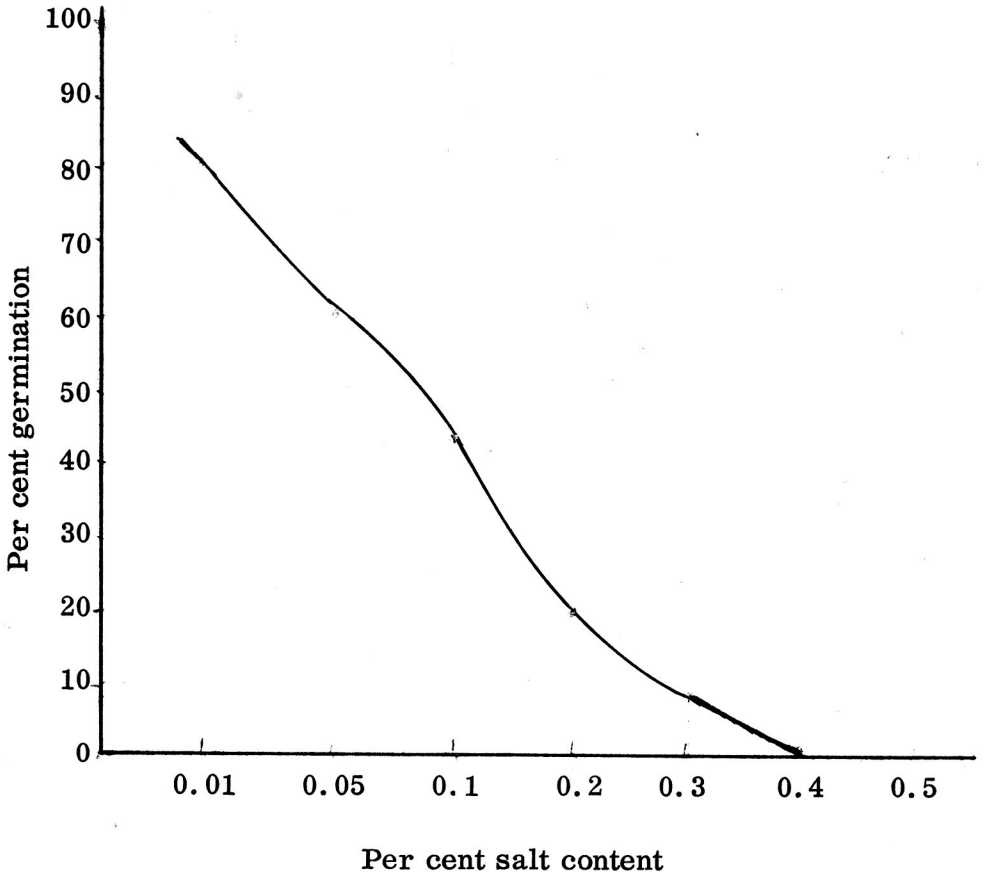

Figure 1. Effect of salt in germination of Atriplex halimus

The curve indicates that seeds of Atriplex halimus do not germinate at all at a salt content of 0.4 per cent, and above. Germination is 8 per cent at 0.3 per cent salt content, 20 per cent at 0.2 per cent, 42 per cent at 0.1 per cent, 60 per cent at 0.5 per cent and about 80 per cent at 0.01 per cent salt content.

Hilton (1941) conducted germination tests with Eurotia lanata and found that there was no germination above 3.0 per cent salt level. Germination with 0.5 per cent salt was slightly higher than that in the distilled water. This shows that there is noticeable variation in salt requirement for germination in various species of the Chenopodiaceae family. In the same experiment it was found that maximum germination of 86 per cent occurred at 70^{o} F temperature.

Henderson (1937) in his study on the effects of sodium chloride on germination of Eurotia lanata found that total germination decreases as salt content of the soil increases. He also observed that 1.7 per cent salt in soil was apparently fatal to germination of seed enclosed in the pericarp.

Springfield (1964) while reporting results of germination tests with Atriplex canescens observed that germination varied with source of seed. Of the eight sources tested, seed collected from Isleta, New Mexico showed significantly higher germination than seed from other sources. The author also found that embryos in seeds from some sources exhibited a greater dormancy than seeds from others. Germination was higher at temperatures from 42^{o} to 58^{o} F than at temperatures of 73^{o} to 77^{o} F. The study also indicated that optimum temperatures may vary with the source of seed.

Beadle (1952) has observed that some Australian species of Atriplex

have seeds which differ in color and size within the species. These differences are accompanied by variability in the germination characteristics.

Beadle (1952) presents evidence to support the theory that possession of differing seed types by a species is of ecological and adaptative significance. Field observations in Australia show that there has been a steady replacement of two perennial species of salt bush that lack hard seed by two annuals that possess hard seed.

Inhibitors in seed coats and bracts may be responsible for low germination percentage. Beadle (1952) found that germination of some species of Atriplex in Australia was inhibited by substances diffusing from the fruit bracts. also Vest (1952) Atcon The inhibitor was classed as a chloride. The author also found that percentage germination decreased as the concentration of salt increased. In all cases 0.2 per cent salt does not appreciably suppress germination whereas 0.3 per cent reduces germination by 20 per cent.

Koller (1957) found, in studies with an annual Atriplex in Israel that while concentration of chloride ions was not responsible for germination inhibition the high osmotic pressure of the bract extracts was very likely to be the cause. Atriplex rosea, a non-halophyte annual from Israel was found to have bracts with a chloride content of 3.6 per cent. Salt can be removed by leaching the seed with water. Twitchell (1955) found that soaking of Atriplex canescens seed in water for several hours removed more than 90 per cent of the chloride present and increased germination.

Bleak et al. (1965) in a review of revegetation attempts in the shadscale zone in Utah and Nevada indicate that seed dormancy was beneficial

to the survival of native plants. Fall and winter germination was reduced and mortality from low temperatures and winter drought was minimized. The authors also found that dormancy of shadscale was decreased by storage, soaking the seeds in water at low temperatures, and moist cold stratification.

Waisel (1958) studied the germination of some halophyte species to see whether there was a high positive correlation between salt resistance of plants in germination and the salinity of their natural habitats. For species other than those of the genus Tamarix it was found that plants from the highly saline zones have a higher salt resistance in germination than plants from less saline zones. The author has further observed that inhibition of germination by high salt concentration of the substrate may exclude plants from certain groups and be responsible for plant zonation in saline habitats as much in the preferences of the vegetative plants. In the case of Tamarix species, however, the positive correlation between germination at high salt concentration and salinity of the habitat in which the species occurs is not found.

CHAPTER III

METHODS AND MATERIALS

Seed Sources

Cisco, White River and Rush Valley, located in three different physiographic regions in Utah, where shadscale predominates, were locales for seed sources. Seed was collected on one plot in each site which was considered representative of the region.

Times of Seed Collection

Seed was collected twice during the season. The first collection was made in the last week of september 1965. The second collection was made two months after the first collection, in the last week of November 1965.

Method of Seed Collection

A rectangular plot 25 x 4 meters was laid at each site. Thirty seed bearing shadscale plants were selected randomly according to a meter distance chart prepared from a random number table. All seed was removed from the plants and packed in paper bags, indicating site and date of collection.

Storage of Seed

Seeds from ten plants in each lot were stored in a cooler, at a temperature

of 35° F for an after-ripening period of about 90 days. The remaining two-thirds of the seed from each lot were stored at room temperature of 70° F.

Extraction of Embryos

Shadscale seeds have hard bracts which hinder germination. Their salt concentrations and other substances are ~~also likely~~ known to inhibit germination (Westand Cottam 1952) and confound treatments. Pericaps (bracteoles) were removed also, as completely as possible. Embryos were, therefore, extracted for germination tests.

Preconditioning Treatments

The following preconditioning treatments were given before starting the germination tests.

1. Storage of seed in a cooler for 3 months at a temperature of 35° F before extracting the embryos.

2. Storage of seed at room temperature for 3 months before extracting the embryos.

3. Storage of seed at room temperature for 3 months before extracting the embryos and then freezing the embryos for 24 hours at a temperature of -10° C before starting germination.

Salt Levels

The following six salt levels were selected to observe their effect on germination.

1. 0.0 per cent
2. 0.5 per cent
3. 0.1 per cent
4. 2.0 per cent
5. 3.0 per cent
6. 4.0 per cent

Temperature Levels

The following two temperature regimes were selected to determine their effect on germination. These two temperature regimes were selected as under natural conditions the seed is exposed to similar temperatures at the time of the year germination usually takes place.

1. 35^{o} F and 65^{o} F for 10 hours and 14 hours respectively.
2. 65^{o} F and 85^{o} F for 10 hours and 14 hours respectively.

Seed subjected to higher temperature levels were placed in mercoid control plexiglas germination chambers. Temperatures were changed manually at 10 p.m. and 8 a.m. respectively. Seeds to be tested under lower temperature level were placed in the controlled environmental chamber with automatic change of temperature.

Preparation of Germination Media

Six germinating solutions were prepared, one for each salt level. All the solutions contained 1.5 per cent agar agar. Percentage of salt varied from 0 to 4 per cent. Solutions were prepared on the basis of 1000 mg. The quantity

of distilled water varied in each solution according to the salt level. Ceresan at the concentration of 0.15 per cent was added for the first run. In the second run ceresan was eliminated.

Organization of the Experiment

The test was split up into two parts. Seeds collected in September were subjected to testing from January 15, 1966 to January 25, 1966. Seeds collected during November were tested from February 10, 1966 to February 20, 1966.

For each test there were several variables to be accounted for. There were three seed sources, two temperature levels, six salt levels and three preconditioning treatments. Each test was conducted in 108 petri dishes consisting of two sets of 54 dishes each for two temperature levels. Within each set of 54 dishes there were three sets of 18 dishes, one for each seed source. Each set of 18 dishes was separated into 3 groups of 6 dishes, one for each preconditioning treatment, the 6 dishes containing six different salt levels.

Fifty seeds were placed in each dish, five from each of the ten plants from each source. Thus there were 10 groups of 5 seeds from each of the ten plants. Total number of the seeds involved in the two tests should have been 10,800. Actually 10,164 seeds were tested as the required 5,400 good seeds were not available from the September collection.

Sterilization of Dishes and Equipment

Petri dishes half filled with solution were sterilized in an autoclave for

20 minutes at a temperature of 200° F and a pressure of 17 pounds per square inch. The dishes were covered with lids and properly numbered indicating their identity in relation to all variables. The dishes were allowed to cool in the autoclave so that the solution was solidified.

Imbibition of Seed

Embryos were put on the solidified solution in the dishes. The dishes were placed in the refrigerator for 24 hours to enable the embryos to imbibe before putting them in germinating chambers.

In the case of embryos which were to be frozen before testing, imbibition was allowed for 24 hours on filter paper saturated with 3 ml of distilled water. The frozen embryos were then transferred to dishes with solution.

Supervision of the Experiment

All the dishes were examined daily and the seed which had germinated were recorded. The dishes in the Mercoid control chambers were rotated on the shelves daily to account for variations of temperature within the chambers. Position of the shelves were also changed daily so that all dishes had equal opportunity to be exposed to the temperature conditions prevalent.

CHAPTER IV

EXPERIMENTAL RESULTS

Germination is generally equated with the protrusion of the radical from the embryo. In the case of species of the Chenopodiaceae family, the shoot (plumule) appears first at the time of germination. This fact has been confirmed in the case of Salsola by Mayer and Mayber (1963). In Atriplex confertifolia protrusion of shoot from the embryo also indicated germination. Thus record of seed that germinated was based on this criterion.

Results on the whole have not been encouraging. In the first test, in January 1966, involving 4,757 seeds, collected in the last week of September 1965, only 28 seeds germinated. Overall germination per cent amounted to 0.59. An effort was made to assess the causes of failure. All apparent factors which generally influence germination were considered individually. Due to this low level of response to treatment no statistical analyses have been performed.

In a previous germination test with winterfat, elimination of ceresan had shown increased germination rates and percentages. After the first experiment, it was thought that 0.15 per cent ceresan in the solution may have exercised some inhibiting effects on germination. Thus in the second germination test with seeds collected during November 1966 ceresan was eliminated from the solution.

The second test was started on February 10, 1966 with 5,400 seeds collected during November 1966. The experiment was designed on the same lines as the first test. The only exception was the elimination of ceresan from the solution.

The results were again disappointing. Out of 5,400 seeds only 49 seeds germinated. Over all germination was 0.91 per cent. The only difference observed in the second test was that germination started a little earlier than the first test and about 50 per cent more seeds germinated.

Results have been summarized as below.

Effect of Seed Source Variations on Germination

In the first test, 4,757 seeds obtained from three sources germinated as given below:

Seed source	No. of seeds tested	No. of seeds germinated	Per cent germinated
1. White River	1,572	0	0.00
2. Cisco	1,488	11	0.74
3. Rush Valley	1,697	17	1.00
Total	4,757	28	

In the second test 5,400 seeds obtained from three sources germinated as given below:

Seed source	No. of seeds tested	No. of seeds germinated	Percent germinated
1. White River	1,800	12	0.66
2. Cisco	1,800	11	0.61
3. Rush Valley	1,800	26	1.44
Total	5,400	49	

In the first test seeds from Rush Valley showed the maximum germination. Seeds from Cisco gave second best results. Seeds from White River did not germinate at all. In the second test again seed from Rush Valley showed maximum germination. Seeds from Cisco behaved exactly in the same manner as in the first test. The greatest variation was noticed in the germination behavior of seed from White River in the second test where 12 seeds germinated against nil in the first test.

Effect of time of Seed Collection on Germination

Germination per cent was 0.59 in the case of seeds collected during September 1965 and 0.91 in the case of seeds collected during November 1965. This germination per cent covers all variables including seed sources, temperature levels, and salt levels.

Effect of Pre-conditioning Treatments on Germination

Storage for 3 months at 35° F in a cooler

Germination per cent of seeds stored for about 3 months in a cooler at 35° F before the embryos were extracted are as follows:

Time of collection	Seed source	No. of seeds tested	No. of seeds germinated	Germination per cent
September 1965	White River	419	0	0.00
	Cisco	509	4	0.78
	Rush Valley	526	11	2.09
	Total	1,454	15	
November 1965	White River	600	4	0.66
	Cisco	600	7	1.16
	Rush Valley	600	12	2.00
	Total	1,800	23	

With this treatment maximum germination occurred in seeds collected in November 1965 from Rush Valley. Out of the 3,254 seeds subjected to this treatment, irrespective of time of collection and seed sources, only 38 seeds germinated. This gives a germination percentage of 1.16

Storage for 3 months at room temperature

Germination per cent of seeds stored for 3 months at room temperature was as follows:

Time of collection	Seed source	No. of seeds tested	No. of seeds germinated	Germination per cent
September 1965	White River	595	0	0.00
	Cisco	400	8	2.00
	Rush Valley	572	7	1.22
	Total	1,567	15	

November 1965	White River	600	8	1.33
	Cisco	600	5	0.83
	Rush Valley	600	13	2.16
	Total	1,800	26	

Under this treatment maximum germination was obtained from seed collected from Rush Valley during November 1965. Out of 3,367 seeds subjected to this treatment only 41 seeds germinated. Thus over all germination per cent was 1.21.

Storage at room temperature for 3 months and then freezing the embryos for 24 hours

Time of collection	Seed source	No. of seeds tested	No. of seeds germinated	Germination per cent
September 1965	White River	558	0	0
	Cisco	584	0	0
	Rush Valley	599	3	0.5
	Total	1,741	3	
November 1965	White River	600	0	0
	Cisco	600	0	0
	Rush Valley	600	1	0.16
	Total	1,800	1	

With this treatment seeds collected from Rush Valley during September 1965 gave the maximum germination. In other cases germination was almost

nil. Out of 3,541 seeds subjected to this treatment only 4 seeds germinated. Over all germination per cent is 0.11.

A comparison of the effect of three preconditioning treatments indicates that maximum germination of 0.21 was obtained from seed stored for 3 months at room temperature before the extraction of embryos. The lowest germination per cent of 0.11 was obtained from seeds which were stored for 3 months and embryos were frozen for 24 hours. This comparison does not take into account the possible effect of seed sources, temperature levels and time of collection.

Effect of Salt Levels on Germination

Effect of salt levels on germination follow. Effects of time of collection, seed sources and temperature regimes are discounted.

Time of collection

Time of collection	Salt level	No. of seeds tested	No. of seeds germinated	Germination per cent
September 1965	0.0	816	28	3.4
	0.5	802	--	0.0
	1.0	810	--	0.0
	2.0	779	--	0.0
	3.0	809	--	0.0
	4.0	741	--	0.0
	Total	4,757	28	

Maximum germination occurred at zero per cent salt level. There was no germination at 0.5, 1.0, 2.0, 3.0 and 4.0 per cent salt levels. Out of these 28 seeds 11 germinated at 35-65° F, and 19 germinated at 65-85° F.

Time of collection	Salt level	No. of seeds tested	No. of seeds germinated	Germination per cent
November 1965	0.0	900	29	3.22
	0.5	900	17	1.88
	1.0	900	3	0.33
	2.0	900	-	-
	3.0	900	-	-
	4.0	900	-	-
	Total	5,400	49	

Maximum germination took place at zero per cent salt level. There was some germination at 0.5 and 1.0 per cent salt level. There was no germination at 2.0, 3.0 and 4.0 salt levels. Out of these 49 seeds 38 germinated at 65-85° F temperature level and 11 germinated at 35-65° F.

Seed sources

Seed source	Salt level	No. of seeds tested	No. of seeds germinated	Germination per cent
White River	0.0	567	6	1.06
	0.5	568	4	0.70
	1.0	562	2	0.35
	2.0	560	-	----

	3.0	560	-	----
	4.0	555	-	----
	Total	3,372	12	
Cisco	0.0	560	20	3.57
	0.5	544	3	0.55
	1.0	558	-	----
	2.0	529	-	----
	3.0	569	-	----
	4.0	528	-	----
	Total	3,288	23	
Rush Valley	0.0	589	31	5.26
	0.5	590	10	1.69
	1.0	590	1	0.17
	2.0	590	-	----
	3.0	580	-	----
	4.0	558	-	----
	Total	3,497	42	

Although most germination occurred at zero per cent salt concentration in all three sources, there is a noticeable variation in the intensity of germination in each source. Maximum germination of 5.26 per cent was obtained in seed collected from Rush Valley at zero per cent salt level. Seed from Cisco showed second highest germination of 3.57 per cent at zero per cent salt level. Seed

from White River showed the poorest performance as only 1.16 per cent germination occurred. Highest germination at 0.5 per cent salt level again occurred in seed collected from Rush Valley and lowest of 0.55 per cent in seed from Cisco.

Out of 77 seeds which germinated in the experiment 57 germinated under control (no salt), 17 germinated at .5 per cent salt level and 3 germinated at 1 per cent salt level. There was no germination at all at 2 per cent, 3 per cent and 4 per cent salt level. Again out of 57 seeds that germinated without salt 26 germinated at 35-65° F temperature level and 31 germinated at 65-86° F temperature level.

Effect of Temperature on Germination

Out of the 28 seeds that germinated in the first test 11 germinated under temperature 35-65° F and 17 under 65° F and 85° F. Out of the 49 seeds that germinated in the second test 11 germinated at 35-65° F and 38 germinated at higher level. Thus over all germination in both tests was 71.93 per cent under 65° and 85° F and 28.57 per cent under 35° F and 65° F.

Viability of Shadscale Seeds

Results of the experiments indicate that viability of shadscale seeds is generally low. Out of 10,157 seeds subjected to test in the two experiments only 77 seeds germinated giving an over all per cent germination rate of .0.75.

CHAPTER V

DISCUSSION

No information is available in the current literature about the germination behavior of shadscale seed. The experiment under discussion, although of a preliminary nature, is probably the first in this field. The results on the whole indicate some interesting trends in germination although by no means they can be regarded as conclusive. This is just the beginning. Much more needs to be done to explore the autecological characteristics of this important species.

Of the three seed sources tested, seed from Rush Valley showed the maximum germination. Seeds from Cisco performed second best. Seeds from White River did not germinate at all in the first test and only 12 out of 1,800 germinated in the second test. This variation in germination behavior of seed from three different localities may be due to ecotypic variations within the same species. Plants of the same species may develop genetic variations which enable them to adapt to different environmental conditions for their ultimate survival. This difference in behavior may be also due to other factors like time of collection, salt levels, temperature levels or pre-conditioning treatments. So nothing can be said conclusively at this stage. Further studies will solve the problem.

The time of collection showed some definite effect on germination. Only 0.59 per cent seeds germinated which had been collected in September and 0.91 per cent germinated which had been collected in November. This difference may be due to the fact that embryos of shadscale probably are not fully mature in September and need some more time on the plant to develop full viability. This variation may have been exhibited due to other factors such as inhibition induced by ceresan which was used in the first test and eliminated in the second test.

Effects of various preconditioning treatments have given some interesting indications. Maximum germination was obtained in seeds which had been stored at room temperature for about 3 months. Seeds which had been stored in a cooler for 3 months at 35^{o} F temperature gave second best results. Seeds which were frozen for 24 hours after a 3 months storage at room temperature showed an extremely poor performance. Only 4 seeds out of 3,541 germinated. It appears that chilling of seed to break the dormancy is certainly not a requirement for shadscale. There appears, however, a need for after-ripening in dry storage to remove the dormancy.

From the study of literature it is evident that shadscale prefers soils with fairly high salt content. According to Fautin (1946) and Vest (1962) saline sub-soil is also correlated with this species. However, the experiment has shown that maximum germination, under both temperature conditions, occurred under "control" where salt content was zero. In the first test all the 28 seeds germinated at zero per cent salt level. In the second test out of 49 seeds 29 germinated at zero per cent salt level, 17 at 0.5 per cent and only

3 germinated at 1 per cent salt level. There was no germination at 2, 3, and 4 per cent of salt level. From this observation it appears that although shadscale can tolerate high salt content in its growth and development, salt may act as an inhibitor in germination. Remarks made by Fautin (1946) and Vest (1962) appear to be relevant to this situation. Saline sub-soil may be tolerated during subsequent development and growth of shadscale but it can not interfere with germination of seed which always takes place at the surface where conditions are not so salty, particularly after the rains.

According to Mayer and Mayber (1963) 80 per cent germination, with Atriplex halimus, occurred at 0.01 per cent or less salt level and there was no germination at 0.4 per cent salt level and above. Result of this experiment, with Atriplex confertifolia, which is ecologically very similar to Atriplex halimus, conform to this observation. Most of the germination took place at zero per cent salt level and some at 0.5 and 1.0 per cent. It has been realized that experimentation with 1, 2, 3, and 4 per cent salt level was unnecessary. For future studies 0.01, 0.05, 0.1, 0.2, 0.3, 0.4 and 0.5 salt levels should be used.

This view has also been supported by Beadle (1952) who found that 0.3 per cent salt level inhibited the germination. The experiment has shown that temperature regime has a considerable effect on germination. Out of 28 seeds that germinated in the first test 60.7 per cent germinated under 65-85^{o} F temperature and 39.3 per cent germinated under 35-65^{o} F temperature. In the second test out of 49 seeds that germinated 77.5 per cent germinated under 65-85^{o} temperature and 22.5 per cent germinated under 35-65^{o} F temperature. Under natural

conditions shadscale seed is shed in the late fall. It remains on the ground during winter, often covered with snow, and germinates ~~in late spring when temperatures are high.~~ anytime Temperature on the soil surface where seeds germinate are much higher than air temperature. It is logical to expect a range of temperature varying from 65° F to 85° F on the surface of the ground in May and June when air temperature may be still lower. It is suggested that in future studies a temperature regime of 55° F and 75° F should be tested.

The experiments have shown poor viability of shadscale seed. This result can not be accepted as conclusive. Salt definitely acted as an inhibitor. High osmotic pressure of a solution due to the presence of salt has been recognized to exercise inhibiting effects on germination. Toxicity of the ions themselves may also be involved.

Another factor which may affect germination of shadscale favorably or adversely is the salt content of its seed coats. This view has also been supported by Mayer and Mayber (1963). The authors have observed that salt frequently accumulates in the organs of plants growing in saline habitats. In these plants germination is to some extent controlled by the salt content of the fruit. On the other hand seed coat may be helping germination under natural conditions by providing the salt requirement for germination by preventing the embryo from coming directly into contact of the soil with greater salt content than required. Further studies are needed to illucidate on this possible relationship.

CHAPTER VI

SUMMARY

The experiments reported here were started to study the germination requirements of shadscale. Seed from three physiolographic regions in Utah, where shadscale predominates, was collected during September and November 1965. The experiments were designed to study the effect of several variables on germination. These included three seed sources, two times of collection, two temperature levels, six salt levels and three pre-conditioning treatments. The experiment was completed in two phases. In the first phase seeds collected during September 1965 were tested. In the second phase seeds collected during November 1965 were tested. In a11 10,154 seeds were tested. The following results were obtained.

1. Maximum germination was obtained with seeds stored at a room temperature for about 3 months before testing.

2. Germination was extremely low in seeds which were stored at room temperature for 3 months and then frozen for 24 hours immediately before testing.

3. Most of the seeds germinated with zero per cent salt content and a few at .5 and 1 per cent salt level.

4. No germination took place at all at 2, 3, and 4 per cent salt levels.

5. On the average almost 69.1 per cent seeds germinated at 65-85^{o} F

temperature level and only 30.9 per cent germinated at 35-65° F temperature level.

6. Germination per cent was higher in seeds collected during November 1965 (.91 per cent) as compared with seed collected during September 1965 where it was .59 per cent.

7. Maximum germination was obtained with seeds collected from Rush Valley and minimum with seed collected from White River.

8. No clue was available about the viability of shadscale seed.

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