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An Evaluation of the Salt Tolerance of Selected Clones of *Agropyron elongatum*

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AN EVALUATION OF THE SALT TOLERANCE OF SELECTED CLONES OF *AGROPYRON ELONGATUM*

by

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Approved:

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INTRODUCTION

Salt-affected soils make up much of the bottom-lands of the arid and semiarid areas of the western United States and are especially prevalent in irrigated regions. Such soils require special remedial measures, management practices, and salt tolerant crops if they are to have economic value.

When selecting crops for salt-affected soils, particular attention should be given to the salt tolerance of the crop. Tall wheatgrass (*Agropyron elongatum*) has proven in past studies to produce well under these conditions. However, because of the variability within the species, further study is necessary to isolate desirable salt tolerant strains.

The objective of this study is to determine the effect of increasing levels of salinity on the survival and forage producing ability of selected clones of *Agropyron elongatum* and to study relationships between plant type and salt tolerance.

REVIEW OF LITERATURE

Salt-affected soils

A salt-affected soil is one that has been adversley modified for growth of most crop plants by the presence or action of soluble salt. The term includes soil having an excess of salt or an excess of exchangeable sodium or both. The source of the salt that accumulates in a soil is usually the irrigation water. In some cases, however, the soil may have been salty in the virgin state, or the salt accumulation may have resulted from a high water table (Israelson, 1950).

The United States Salinity Laboratory staff (1958) refered to three types of salt-affected soils: saline soil, sodic soil, and saline-sodic soil. Since different management and reclamation practices may be required, it is important to distinguish between these different salt conditions.

A saline soil is one that contains sufficient soluble salt to interfere with the growth of most crop plants. For purposes of definition, it is a soil for which the electrical conductivity of the saturation extract is four or more millimhos per centimeter at 25° C. Sodium salts may be present but in relatively low concentration in comparison with calcium and magnesium salts. Saline soils are often recognized by the presence of white crusts on the soil, by spotty plant populations, and by stunted and irregular plant growth (Fireman and Hayward, 1955). Ordinarily the pH is lower than 8.5. Saline soils generally are floculated and the permeability is comparable with that of similar non-saline soils.

Hayward (1954) stated that the principal effect of salinity is to reduce the availability of water to the plant. In cases of extreme high salinity, there may be curling and yellowing of the leaves or firing of margins of the leaves or actual death of the plant. Long before such effects are observed, the general nutrition and growth physiology of the plant will have been altered.

A sodic soil is one which contains sufficient exchangeable sodium to interfere with the growth of most crop plants. For purposes of definition, it is a soil for which the exchangeable-sodium-percentage is 15 or more. Exchangeable sodium differs from soluble sodium in that it is adsorbed on the surfaces of the fine soil particles. It is not leached readily until displaced by other cations such as calcium or magnesium. These soils often are strongly alkaline with pH readings usually between 8.5 and 10.0.

Lyerly and Longenecker (1957) observed that as the proportion of exchangeable sodium increases, soils tend to become dispersed, less permeable to water, and of poor tilth. High sodium soils usually are plastic and sticky when wet and form clods and crusts on drying. These conditions result in reduced plant growth because of inadequate water penetration, poor root aeration and soil crusting. Sodic soils occur frequently in small irregular areas and often are referred to as "slick spots" or "black alkali" areas.

Sodic soils usually develop because of excessively high sodium in proportion to calcium and magnesium. This may result from a high percentage of sodium in the irrigation water or because of the precipitation of calcium and magnesium salts under certain conditions.

Saline-sodic soils occur when salinity and adsorbed sodium affect the soil at the same time. As long as excess soluble salts are present, the physical properties of these soils are similar to those of saline soils. The pH is seldom higher than 8.5, and the soil generally remains permeable to water. If the excess soluble salts are removed, these soils may assume the properties of sodic soils. This condition is encountered frequently immediately following heavy rains and may result in the death of young plants.

The above mentioned soil types correspond to the saline, nonsaline-alkali and saline-alkali soils referred to by the United States Salinity Laboratory staff (1954).

Crop response to salt-affected soils

Plant-growth responses of specific crops on saline soils have been discussed at great length by Hayward and Wadleigh (1949), Hayward (1954), Grillot (1954), and Hayward and Bernstein (1958); therefore, specific crops will not be discussed in this review.

A field of crop plants growing on salt-affected soil usually has barren spots, stunted growth of the plants with considerable variability in size, and a deep blue-green foliage color. However, the United States Salinity Laboratory (1954) indicated that these features are variable indicators of salinity. For example, barren spots may occur in nonsaline fields because of faulty leveling and the resultant inadequacy of irrigation. Also, retarded growth and abnormal color may result from nutrient deficiencies. While the appearance of a crop may be indicative of saline conditions, a reliable diagnosis usually requires additional evidence derived from appropriate soil and plant tissue tests.

Hayward and Bernstein (1958) reported that salt tolerance can be appraised in at least three ways: (1) the ability of a plant to survive on saline soils (salt tolerance based primarily on this criterion of survival has limited application in irrigation agriculture but is a method of appraisal which has been widely used by plant ecologists), (2) the absolute yield of a plant on saline soils (this criterion has the greatest agronomic significance), and (3) relative yield on saline soil compared to yield on similar nonsaline soil (This criterion is useful for comparing dissimilar crops whose absolute yields cannot be compared directly). The United States Salinity Laboratory (1954), in compiling its lists of salt tolerance, has used the third criterion.

It has been agreed that plants vary greatly in their ability to tolerate salt-affected soils and that much more work needs to be done using specific promising species.

Physiological basis of salt tolerance

Detailed reviews of the physiology of plants on salt-affected soils or salt mediums have been given by Hayward and Wadleigh (1949), Grillot (1954), Hayward (1954), and Bernstein and Hayward (1958). The presence of excessive concentrations of soluble salt in the root zone of plants may affect plant growth in a number of ways. Bernstein and Hayward (1958) suggest that plant growth may be hindered by osmotic inhibition of water absorption, by specific effects of the constituent ion(s) in the saline media, or a combination of the two. Furthermore, specific ion effects may involve direct toxicity or a variety of nutritional effects. Therefore, it is evident that a salt tolerant plant must be able to withstand these conditions.

Evidence available indicates that the salt tolerance of a given species depends upon three attributes: (a) the capacity to increase the osmotic pressure of the tissue fluids to compensate for increases in osmotic pressure of the substrate; (b) the capacity to regulate the intake of ions so as to bring about the increase in osmotic pressure and yet avoid an excess accumulation of ions; and (c) the inherent ability of the protoplasm to resist deleterious effects of accumulated ions. Economic crops which lack salt tolerance are unable to regulate adequately the intake of salt and the specific sensitivity of their protoplasm to accumulations of salt within the tissues.

Hayward and Bernstein (1958) concluded that experimental demonstration of the general occurrence of osmotic effects and the more restricted development of specific ion effects has cleared the way for further advances in understanding the nature of salt injury to plants. The similarity of toxic levels of accumulation of ions in widely diverse species suggests a common mechanism or condition which quantitatively distinguishes these species from non-sensitive species. The mechanism of salt toxicity and the distinguishing features of salt tolerance appear to be the major areas for study on salt tolerance of plants in the decade ahead.

Selection and breeding for salt tolerance

In the past there has been very little work done in selection and breeding for salt tolerance of forage crops. This appears to be the most promising avenue of endeavor to maintain production on salt-affected soils which can not be economically reclaimed.

Funk (1956) observed that large varietal differences in salt tolerance existed in birdsfoot trefoil, tall fescue, and Reed canarygrass. He indicated that the selection and breeding of crop plants for use on salt-affected soil is worthwhile.

Olsen (1958) also noted significant differences in salt tolerance between selections, strains, and varieties within species. He suggested that excellent opportunities exist in the selection and development of varieties and strains of forage crops for use on salty soils.

In Russian work, reported by Strogonov (1954), cotton yields were improved when direct and reciprocal crosses were made between plants grown on highly saline soil and those from a part of the field where the concentration of salt was low.

Fuchs (1955) stated that breeding for resistance to salinity is limited due to a lack of knowledge of the nature of resistance. For this reason, major achievements are predicted as soon as the necessary knowledge has been obtained.

Evaluating grass for salt tolerance

Of all crops tested, forage plants, grasses and legumes, as a rule exhibit the highest degree of salt tolerance on saline lands. There are marked specific differences in this regard, grasses generally being more salt resistant than the legumes (Hayward and Wadleigh, 1949).

Hayward and Wadleigh (1949) and Hayward (1954) reviewed the early work done on the salt tolerance of this group of plants in the United States. The United States Salinity Laboratory (1954) has reviewed previous work and summarized the experimental work at the Laboratory with respect to the relative salt tolerance of the forage crops, expressing the degree of salt tolerance in relation to the electrical conductivity of the saturation extract of soil in millimhos per centimeter.

Among the grasses which have shown good salt tolerance in the United States, as listed by Bernstein (1958) are alkali sacaton (*Sporobolus airoides*), saltgrass (*Distichlis stricta*), Nuttall alkali grass (Puccinellia nuttalliana), Bermuda grass (Cynodon dactylon), tall wheatgrass (Agropyron elongatum), and Rhodes grass (Chloris gayana). These grasses are able to tolerate soils having an electrical conductivity between 8 and 12 millimhos, and some of them may survive at salinity levels up to 14 millimhos. Less tolerant forage grasses are orchard grass (Dactylis glomerata), blue grama (Bouteloua gracillis), meadow fescue (Festuca elatior), Reed canarygrass (Phalaris arundinacea), smooth brome (Bromus inermis), and meadow foxtail (Alopecurus pratensis). It must be realized that environmental factors such as altitude, humidity, day length, temperature, moisture, etc., may alter the salt tolerance of any species.

Because of the difficulty of evaluating the salt tolerance of crops under field conditions due to the variations encountered, the United States Salinity Laboratory (1954) has developed some techniques for use in testing the salt tolerance of crop plants.

The artificially salinized field plot technique is used for evaluating the salt tolerances of crops. It utilizes 14 x 14 foot square basins. These are enclosed by borders and carefully leveled to insure even distribution and penetration of the salinizing water. Salinization is accomplished by irrigation with waters artificially salinized with equal parts of sodium chloride and calcium chloride added in prescribed amounts. These two salts are used in order to avoid the development of sodic conditions in the soil. If the soil is sufficiently permeable and adequate irrigations are applied, the salt concentration in the plot tends to reach a steady value following the first few irrigations. The salt concentration in the soil may be slightly lower than that of the applied water.

With drum culture, salinity is established by adding salt in the initial irrigation of the drum or by mixing the salt with dry soil. In order to maintain a relatively uniform distribution of salt in the soil, it is necessary to irrigate alternately by surface and subirrigation.

Sand and water cultures allow for precise control of the substrate. This involves the addition of various salts to a base nutrient solution. Provision for adequate nutrition is made by using a base nutrient solution. Proper control of the pH of the solution must be maintained and adequate aeration provided.

For the cell physiological tests developed by Repp and McAllister (1959), freehand tangential sections containing the epidermis and several subjacent cell layers of the lower portions of the stem were placed in sodium chloride solutions of various molal concentrations. After 24 hours these sections were transferred to a slightly hypertonic solution of glucose for from three to four hours and then examined under the microscope for plasmolysis. Plasmolized cells are considered uninjured while cells which fail to plasmolize are considered injured or dead.

Tall wheatgrass and its relationship to salted soils

Tall wheatgrass (*Agropyron elongatum*), a native of the saline meadows and seashores of Southern Europe and Asia Minor, was introduced into the United States from Turkey in 1909. It is a coarse, nonlodging, late-maturing bunchgrass two and one-half to six feet tall. Usually reported as resistant to cold and drought, it makes excellent fall and spring recovery and remains green three to six weeks longer than most other grasses. The grass is fairly palatable and highly salt tolerant, producing high yields on subirrigated alkaline soils (Weintraub, 1953).

Beetle (1955) described tall wheatgrass as a blue-green or glaucous, tall, erect, glabrous, perennial bunchgrass which becomes coarse as it approaches maturity. It has the outstanding qualities of hardiness, drought resistance, late maturity, and the ability to produce excellent forage on soils too alkaline to grow any other useful crop.

Thorne and Bennett (1952) reported outstanding production of both herbage and seed by tall wheatgrass on soils of high salt concentration. It is being planted on many saline soils in Utah and Nevada. A common practice is to drill the seed in the bottom of irrigation furrows and to follow with an irrigation. Good emergence and survival of this species have been obtained where most other grasses and legumes have failed.

Pearson and Bernstein (1958) found that tall wheatgrass was the most tolerant to exchangeable sodium of several species tested at the United States Salinity Laboratory.

Tulley (1958) reported that tall wheatgrass is being used by Wyoming ranchers on land too salty to produce other hay crops, with great success.

Cameron (1958) reported that tall wheatgrass is producing well on alkali spots in Reno County, Kansas. It is producing as good or better hay and pasture for beef cows than native grasses on good land.

Peterson (1958) stated that of all the grasses tested at the Utah Experiment Station tall wheatgrass is most adapted to the adverse conditions of saline lands. On poorer lands it is often slow to become established after planting. It can be grazed early in the season and then allowed to produce seed. When grown on the poor land it often improves the physical condition of the soil.

MATERIALS AND METHODS

In 1951 and 1952 a planting of tall wheatgrass *Agropyron elongatum* was established on saline soil on the Ed Williams' Farm located approximately 3.7 miles west of Springville, Utah. From this planting a selection of 30 plants was made in 1953 and another selection of 20 plants in 1954. These plants were transferred to nonsaline soil on the Evans Experimental Farm south of Logan, Utah. Forty-eight clonal selections of second generation progeny from these plants were used for this study. The original plant data are shown in table 1.

This study consisted of comparing the performance of 48 clones of tall wheatgrass at four levels of salinity, employing the artificially salinized field plot technique on 14 x 14 foot basins. Figure 1 shows the arrangement of the basins on the Greenville Experimental Farm at North Logan, Utah. The five basins on the south west corner of the arrangement were used for a salt study on ornamentals by Mr. Ralph Monk. Basins I, II, III, IV were not used because of an existing sodic condition. Basin RC was a 1957 planting of Reed canarygrass and Canada wildrye, basin BT was a 1957 planting of birdsfoot trefoil and strawberry clover, basin TW was a 1957 planting of tall wheatgrass, and basins A1, A2, A3, were 1957 plantings of alfalfa. Dr. Douglas R. Dewey also had 12 basins located just east of the arrangement shown in which he was growing other grasses, mainly crested wheatgrass.

Fifteen of the 16 basins used in this study had been subjected to salinization treatments in previous years. Soil samples were taken

Table 1. Original plant data of tall wheatgrass clonal selections made August 1957 on the Evans Experimental Farm.

Rand. No.	Clone No.	Matur. mlk-1 ripe-4	Avg. ht. (ft)	Base dia. (in)	Leaf char.	Gm. per. 100 seeds	Seed size = w. + caryopsis l. + seed l. (in)
1	4-11	2	4.5	10	smooth	.63	.78
2	5-52	3	4.0	8	rough	.57	.77
3	6-11	2	3.5	9	smooth	.60	.72
4	8-50	2	4.5	10	smooth	.65	.75
5	10-07	2	4.5	9	smooth	.67	.70
6	11-12	2	4.0	8	rough	.73	.72
7	12-20	2	4.5	7	smooth	.76	.71
8	12-26	2	5.0	9	smooth	.63	.73
9	12-34	2	3.5	9	rough	.67	.69
10	13-37	2	5.5	9	smooth	.77	.75
11	15-62	4	5.0	9	smooth	.54	.71
12	16-45	3	4.5	9	smooth	.50	.72
13	17-33	3	5.0	9	rough	.45	.68
14	18-45	2	5.0	10	smooth	.54	.70
15	17-10	2	5.0	10	smooth	.77	.77
16	19-30	3	5.0	9	smooth	.65	.69
17	24-26	2	5.0	8	smooth	.90	.76
18	24-31	2	5.0	8	rough	.81	.72
19	24-35	1	5.0	9	smooth	.73	.69
20	24-45	2	4.0	8	smooth	.61	.69
21	25-14	2	4.5	8	smooth	.74	.70
22	26-11	2	4.0	9	smooth	.77	.77
23	27-50	2	4.5	9	smooth	.65	.75
24	28-33	2	4.5	9	smooth	.91	.76
25	29-18	2	5.0	9	smooth	.80	.74
26	29-52	2	5.0	10	smooth	.79	.70
27	30-12	2	3.5	11	rough	.58	.67
28	30-40	3	5.0	9	smooth	.67	.73
29	31-23	2	4.0	9	rough	.64	.71
30	31-25	2	4.5	9	smooth	.75	.70
31	32-15	2	5.0	10	smooth	.73	.71
32	36-08	2	4.5	9	smooth	.71	.82
33	36-24	2	4.5	8	smooth	.78	.74
34	37-16	2	5.5	9	smooth	.64	.79
35	37-27	3	4.5	9	smooth	.80	.78
36	37-29	3	4.5	9	smooth	.56	.72
37	37-33	2	4.5	10	smooth	.60	.70
38	37-37	2	4.5	8	smooth	.76	.72
39	37-52	2	5.0	10	rough	.73	.75
40	39-02	2	4.0	10	smooth	.71	.67
41	40-43	2	4.5	8	smooth	.82	.75
42	40-45	2	4.5	9	smooth	.67	.68
43	41-38	2	4.5	9	rough	.64	.72
44	42-04	3	5.0	9	smooth	.87	.74
45	42-40	2	4.5	8	rough	1.00	.74
46	44-27	2	5.0	10	rough	.76	.68
47	45-39	2	4.0	8	smooth	.62	.60
48	46-41	3	4.5	9	smooth	.74	.73

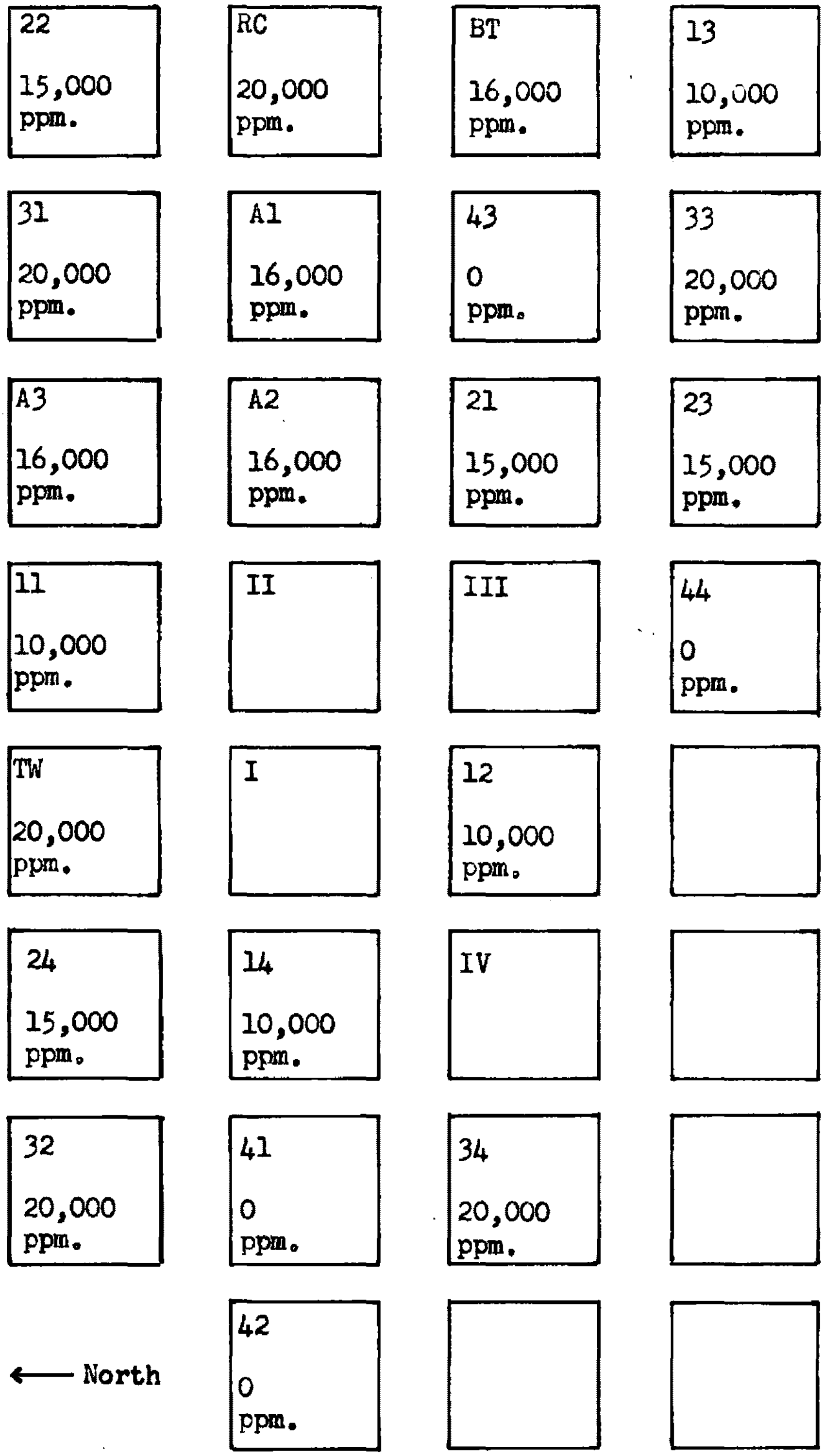

Figure 1. Salt basin arrangement on the Greenville Experimental Farm at North Logan, Utah, in 1958

from each basin and analyzed. Samples were taken at 0-6, 6-12, 12-24, 24-36, 36-48 inch depths in each basin. Experiments by the United States Salinity Laboratory (1954) showed that the analysis of soil samples taken from salinized plots during the period of salt application gave comparable concentrations to those of the irrigation water being applied; however, Olsen (1958) showed a slight decrease in salt concentration of the soil as compared to that of the irrigation water. These soils were analyzed by use of the conductivity bridge and also the saturation extract methods to determine the salt content.

The basins were tilled, leveled, and prepared for planting during the last week in April 1958. On May 12 and 14, they were planted in a randomized block design with each propagule being randomly replicated three times in each basin. The plants were placed at one foot intervals with 12 plants in each row and 12 plants in each column. Each of the four levels of salt was replicated four times.

On June 11, 1.35 pounds of ammonium nitrate were applied to each basin, which was equivalent to 100 pounds of elemental nitrogen per acre.

In order to avoid salt shock to the plant, induced by an abrupt change in soil salinity, a one-half strength application was applied in the first treatment. This was increased to a three-fourth strength application for the second treatment and full strength for the third treatment. There was a total of eight salt treatments of which six were full strength.

Salinization treatments were started on July 11 after the plants were growing vigorously. The amounts of salts per concentration of the salinized irrigation water applied during the growing season are given in table 2. The plants were clipped on July 31, just prior to the first full application of salt. At full strength, the irrigation water contained 0, 10,000, 15,000, and 20,000 parts per million of added salt for the four treatments. Four inches of water was applied at each irrigation, which was sufficient to wet the top three feet of soil.

The plots were irrigated at 10 or 11 day intervals throughout the summer. The salinization treatments consisted of equal parts by weight of sodium chloride and calcium chloride added in prescribed amounts to the irrigation water. This was done in order to avoid the development of sodic conditions in the soil.

Each tall wheatgrass clone was evaluated on the yield of air dry forage produced when the plots were harvested on October 4, 1958.

Duncan's (1955) Multiple Range test was used to test the significant differences between clones. This test is based on the fact that the difference for significance between means varies with the number of means in the comparison. As means further apart in rank are compared, the difference required for significance increases. Any two means which are found in the same range have no significant difference between them. However, a significant difference does exist between those means which are not found within the least significant range.

Table 2. Pounds of salt required per salt concentration for each four inch application of water

Concentration (ppm)	NaCl (pounds)	$CaCl_2$ (pounds)
0	0	0
10,000	16.70	16.70
15,000	25.05	25.05
20,000	33.40	33.40

RESULTS AND DISCUSSION

The results of the soil analysis tests, performed by the conductivity bridge and saturation extract methods, are shown in table 3. This data indicated that the salt level of all basins to be used in this study was sufficiently low as to not hinder the growth of the clonal propagules. A record of the total soluble salts in these basins in the spring of 1957 (Olsen, 1958) is also shown in table 3 for comparison purposes. Also, for comparison purposes the salt levels on each particular basin are recorded in table 4.

The growing season of 1958 was hot and dry and because this probably had an effect on the results of this experiment, weather data are shown in table 5. A comparison of weather data for the past four years is given in table 6.

Table 3. Analysis of soil samples taken from salt basins planted to tall wheatgrass (April 5, 1958). Samples were taken prior to salinization treatments

Basin No.	Depth (in)	1958 pH (paste)	1958 EC_e	1957 T.S.S.%	1958 T.S.S.%
11	0-6	8.2	.95	.03	.04
11	6-12	8.3	1.11	.04	.04
11	12-24	8.4	1.11	.08	.04
11	24-36	8.2	2.37	1.20	.08
11	36-48	7.7	8.30	1.10	.30
12	0-6	8.3	.86	.03	.03
12	6-12	8.3	.95	.04	.03
12	12-24	8.2	1.50	.03	.06
12	24-36	7.6	9.46	.03	.33
12	36-48	7.5	18.92	.03	.69
13	0-6	7.8	.59	.02	.02
13	6-12	7.8	.64	.02	.02
13	12-24	7.8	.64	.02	.03
13	24-36	7.8	.81	.02	.03
13	36-48	7.8	.84	.02	.03
14	0-6	8.1	1.41	.02	.06
14	6-12	8.3	.93	.03	.04
14	12-24	8.1	2.28	.03	.09
14	24-36	7.6	8.87	.03	.42
14	36-48	7.6	9.75	.09	.45
21	0-6	8.1	1.06	.03	.03
21	6-12	8.2	1.08	.04	.04
21	12-24	8.3	1.36	.04	.04
21	24-36	7.7	7.43	.04	.25
21	36-48	7.6	18.52	.03	.60
22	0-6	8.2	.84	.02	.03
22	6-12	8.1	.93	.02	.03
22	12-24	8.0	1.67	.04	.06
22	24-36	7.7	4.24	.04	.15
22	36-48	7.5	6.82	.04	.23
23	0-6	8.2	.97	.02	.03
23	6-12	8.2	.99	.02	.03
23	12-24	8.3	.87	.04	.03
23	24-36	8.3	1.23	.03	.04
23	36-48	8.0	2.99	.04	.09
24	0-6	8.1	.98	.02	.03
24	6-12	8.2	.85	.02	.03
24	12-24	8.1	1.53	.03	.05
24	24-36	7.7	5.13	.02	.17
24	36-48	7.4	13.38	.02	.18

Table 3. (Continued)

Basin No.	Depth (in)	1958 pH (paste)	1958 ECe	1957 T.S.S.%	1958 T.S.S.%
31	0-6	8.2	.96	.02	.03
31	6-12	8.3	1.03	.02	.04
31	12-24	8.2	1.87	.04	.06
31	24-36	7.5	10.96	.04	.39
31	36-48	7.5	12.33	.04	.39
32	0-6	8.1	.76	.03	.03
32	6-12	8.1	.84	.02	.03
32	12-24	8.1	1.27	.03	.05
32	24-36	7.7	5.86	.03	.23
32	36-48	7.4	13.13	.02	.50
33	0-6	8.4	.85	.02	.03
33	6-12	8.4	.90	.02	.03
33	12-24	8.3	.82	.02	.04
33	24-36	8.0	3.03	.02	.09
33	36-48	7.7	8.12	.02	.18
34	0-6	8.3	1.03	.02	.03
34	6-12	8.4	1.06	.02	.03
34	12-24	8.3	1.49	.03	.06
34	24-36	7.7	6.49	.02	.30
34	36-48	7.5	7.93	.02	.60
41	0-6	8.1	1.36	.03	.04
41	6-12	8.3	1.12	.02	.03
41	12-24	8.2	1.71	.02	.05
41	24-36	7.5	10.05	.03	.34
41	36-48	7.5	13.93	.02	.60
42	Newly constructed. Not sampled.				
43	0-6	8.2	1.04	.02	.03
43	6-12	8.2	.88	.03	.03
43	12-24	8.3	.75	.04	.03
43	24-36	8.1	1.53	.03	.05
43	36-48	7.9	5.50	.09	.18
44	0-6	8.3	.88	.02	.03
44	6-12	8.3	.94	.02	.03
44	12-24	8.3	1.11	.04	.04
44	24-36	8.0	4.34	.03	.13
44	36-48	7.7	9.37	.04	.32
A1	0-6	7.9	.61	.03	.03
A1	6-12	8.1	.48	.03	.02
A1	12-24	8.1	.41	.04	.02
A1	24-36	8.2	.37	.09	.02
A1	36-48	8.1	.35	.16	.02

Table 3. (Continued)

Basin No.	Depth (in)	1958 pH (paste)	1958 EC_e	1957 T.S.S.%	1958 T.S.S.%
A2	0-6	8.0	.84	.02	.03
A2	6-12	8.1	.82	.02	.03
A2	12-24	8.1	1.02	.02	.04
A2	24-36	7.8	3.78	.03	.15
A2	36-48	7.8	7.28	.03	.24
A3	0-6	8.3	.90	.04	.03
A3	6-12	8.2	.96	.04	.03
A3	12-24	8.4	1.22	.04	.04
A3	24-36	8.0	3.48	.04	.10
A3	36-48	7.6	6.24	.19	.30
RC	0-6	8.0	.58	.03	.02
RC	6-12	7.9	.54	.03	.03
RC	12-24	8.0	.43	.04	.02
RC	24-36	8.1	.60	.09	.02
RC	36-48	8.1	.42	.16	.02
BT	0-6	7.9	.96	.02	.03
BT	6-12	8.0	.61	.02	.03
BT	12-24	8.0	.55	.02	.02
BT	24-36	8.1	.59	.02	.02
BT	36-48	8.1	.46	.02	.02
TW	0-6	7.9	.83	.02	.02
TW	6-12	8.1	.69	.03	.02
TW	12-24	8.3	.79	.04	.03
TW	24-36	8.4	.87	.04	.03
TW	36-48	8.5	.86	.44	.03
I	0-6	8.2	2.63	.09	.08
I	6-12	8.2	2.52	.28	.08
I	12-24	8.1	2.65	.79	.10
I	24-36	7.7	7.04	.81	.25
I	36-48	7.5	14.69	.62	.69
II	0-6	8.2	2.06	.07	.07
II	6-12	8.2	2.68	.25	.09
II	12-24	7.7	7.20	1.10	.23
II	24-36	7.4	18.83	.79	.46
II	36-48	7.4	18.16	.60	.50
III	0-6	8.3	3.39	.06	.09
III	6-12	8.1	2.35	.08	.08
III	12-24	7.9	4.12	1.30	.16
III	24-36	7.6	9.31	1.40	.31
III	36-48	7.5	10.36	1.10	.37
IV	0-6	8.3	2.42	.08	.07
IV	6-12	8.1	1.81	.06	.06
IV	12-24	8.2	1.42	.33	.05
IV	24-36	8.4	.80	.32	.03
IV	36-48	8.4	.68	.52	.02

Table 4. Salt levels of irrigation water applied on particular basins during 1957 and 1958

Basin No.	1957 Salt level (ppm)	1958 Salt level (ppm)
11	10,000	12,000
12	10,000	24,000
13	10,000	Not used
14	10,000	16,000
21	15,000	16,000
22	15,000	8,000
23	15,000	8,000
24	15,000	16,000
31	20,000	12,000
32	20,000	24,000
33	20,000	12,000
34	20,000	24,000
41	0	24,000
42	0	Not used
43	0	8,000
44	0	12,000

Table 5. Weather data for the 1958 growing season at the Greenville Experimental Farm, North Logan, Utah

	June			July			August			September		
Date	Max.	Min.	Pptn.	Max.	Min.	Pptn.	Max.	Min.	Pptn.	Max.	Min.	Pptn.
1	79	50		80	44		89	53		86	48	
2	79	48		85	48		84	56		86	52	
3	78	44		85	49		86	62		82	47	
4	75	36		79	48		89	60		81	54	
5	87	45		83	53		90	55	.05	82	50	
6	87	57	.15	85	49		94	51		84	45	
7	82	57		85	54		94	53		88	47	
8	74	43		85	53		93	59		82	56	
9	74	43	.05	90	53		87	59		85	54	.06
10	79	47		90	56		89	58		84	51	
11	81	47		92	53		93	54		86	55	.03
12	78	47	.13	90	55		96	60		86	59	.13
13	76	40		86	54		96	62		74	45	.28
14	73	46		85	54		94	61		61	44	
15	82	45		87	51		88	62	.08	65	38	
16	80	49		89	57	.20	86	59		75	38	
17	82	49		88	50		87	65		68	43	
18	85	54		86	56		88	60	.06	74	45	
19	85	58		83	50		86	59	.01	78	42	
20	81	56		83	57		89	56		78	29	
21	84	53		86	52		89	58		78	30	
22	85	53		88	55		79	57	.27	81	40	
23	87	53		84	53		81	49		80	47	
24	87	58		84	59		84	51		61	32	.05
25	75	49	.08	85	56		89	52		60	27	
26	84	46		85	57		89	54		69	33	
27	91	50		84	50		87	55		62	35	
28	90	48		91	51		87	60	.20	75	40	
29	82	47		89	58		81	56	.02	75	42	
30	78	46		79	55	.35	79	47		70	39	
31				81	49		79	46				

Table 6. Comparison of weather data during the past four years

	June				July				August				September			
	AveTemp		Total		AveTemp		Total		AveTemp		Total		AveTemp		Total	
Year	Max	Min	Pptn	Evap	Max	Min	Pptn	Evap	Max	Min	Pptn	Evap	Max	Min	Pptn	Evap
1958	82	49	.41	7.7	86	53	.53	8.6	88	56	.69	7.8	77	44	.55	5.5
1957	78	49	1.58	6.4	87	54	.18	8.4	86	56	.62	8.1	77	42	.62	5.5
1956	83	47	.74	7.6	90	54	.36	8.9	86	50	.04	7.8	82	43	.06	5.4
1955	77	46	1.44	6.9	87	52	.24	9.0	86	55	1.29	7.0	76	44	1.22	4.9

The results of this experiment were analyzed in the three ways mentioned by Hayward and Bernstein (1958). (1) The absolute yield is analyzed at each level of salt and as a total of all basins in tables 8 to 12. This method is recognized as being of greatest agronomic importance. (2) The relative yield on saline soil compared to similar nonsaline soil in table 13. This method is useful for comparing the clones in case they are dissimilar in reaction. This method was used by the United States Salinity Laboratory (1954) in compiling salt tolerance lists among diverse crops. (3) The ability of the crop to survive on saline soils in table 14. This method has limited application in irrigation agriculture but has been widely used by plant ecologists.

Clones numbered 19-30 (16) and 29-52 (26) did consistantly well in all salt levels and were significantly better in absolute yield than any other clone tested. These two clones were also among the top seven in ability to survive and were found in the same range with the top survivor.

One should remember that tall wheatgrass grows best in the spring of the year and it is possible that a different picture would be seen if yield data were taken in the early summer instead of the late summer as it was.

Table 15 summerizes the analytical data. F tests indicated that there were significant differences between clones in absolute yield, relative yield, and survival. There were also significant differences between clones in relative yield and survival when the interaction of salt x clone was tested. However, this test showed no significant

Table 7. Means of tall wheatgrass clones in salt basins. Each figure (except total) is the dry weight in grams of three propagules

Random No.	Clone No.	Added salt in ppm. (50% NaCl 50% $CaCl_2$) 0	10,000	15,000	20,000	Total
1	4-11	54.00	8.30	5.80	6.60	~~74.70~~
2	5-52	58.25	9.18	6.88	7.50	~~81.81~~
3	6-11	20.25	5.83	2.13	3.18	20 31.39 -
4	8-50	73.25	12.98	11.53	11.25	10 109.01 H
5	10-07	30.50	6.88	9.50	4.80	16 51.68 -
6	11-12	43.25	7.08	2.75	4.43	~~57.51~~
7	12-20	29.25	12.45	6.25	6.33	12 54.38 -
8	12-26	40.75	10.45	5.88	5.75	~~62.83~~
9	12-34	47.75	6.45	4.70	1.73	~~60.63~~
10	13-37	76.75	9.90	6.75	5.80	~~99.20~~
11	15-62	34.50	10.43	3.63	8.53	~~57.09~~
12	16-45	50.75	8.28	2.58	2.13	~~63.74~~
13	17-33	34.00	6.00	11.05	2.15	14 53.20 -
14	18-45	43.00	6.93	8.80	4.58	~~63.31~~
15	17-10	68.00	16.30	7.88	9.68	~~101.86~~
16	19-30	144.25	42.15	32.65	23.58	1 242.63 H
17	24-26	43.50	9.65	5.40	4.58	~~63.13~~
18	24-31	43.25	4.80	2.60	2.30	15 52.95 -
19	24-35	56.75	12.73	2.03	4.53	~~76.04~~
20	24-45	68.25	8.13	4.20	2.20	~~82.78~~
21	25-14	90.50	17.70	14.33	13.68	6 136.21 H
22	26-11	71.00	17.65	12.03	11.60	~~112.28~~
23	27-50	41.50	6.33	3.73	4.48	11 56.04 -
24	28-33	50.80	7.50	9.03	6.15	~~73.48~~
25	29-18	44.50	7.08	5.28	3.75	~~60.61~~
26	29-52	153.50	19.85	14.53	23.50	2 211.38 H
27	30-12	71.00	19.20	12.93	9.00	8 112.13 H
28	30-40	32.75	7.33	3.58	2.10	17 45.76 -
29	31-23	61.25	10.63	6.13	3.98	~~81.99~~
30	31-25	77.50	24.95	9.20	2.60	~~114.25~~
31	32-15	19.75	5.50	7.80	5.25	19 38.30 -
32	36-08	104.50	21.75	10.95	9.58	3 146.78 H
33	36-24	83.00	15.78	7.08	3.90	~~109.76~~
34	37-16	90.75	20.83	13.43	14.65	5 139.66 H
35	37-27	60.75	26.35	9.50	6.98	~~103.58~~
36	37-29	59.50	8.23	8.23	3.35	~~79.31~~
37	37-33	98.00	23.53	14.15	10.70	4 146.38 H
38	37-37	86.25	10.75	15.13	7.18	7 119.31 H
39	37-52	58.25	6.63	4.45	1.25	~~70.58~~
40	39-02	74.50	16.08	10.45	10.23	9 111.26 H
41	40-43	57.75	9.20	12.03	4.15	~~83.13~~
42	40-45	89.25	14.65	7.70	5.45	~~117.05~~
43	41-38	42.75	5.43	5.90	4.48	~~59.56~~
44	42-04	86.25	16.40	8.20	5.73	~~116.58~~
45	42-40	66.25	11.88	6.23	3.38	~~87.74~~
46	44-27	61.25	13.25	8.25	5.55	~~88.30~~
47	45-39	38.00	7.38	3.90	4.65	13 53.93 -
48	46-41	29.75	4.14	2.93	2.83	18 39.65 -

Table 8. Ranked means of the tall wheatgrass yields in basins receiving water containing 0 ppm salt

Rank	Random No.	Dry wt. 3 propagules in grams	Least significant ranges (Duncan's Multiple Range Test) 1 percent level
1	26	153.50	
2	16	144.25	
3	32	104.50	
4	37	98.00	
5	34	90.75	
6	21	90.50	
7	42	89.25	
8	44	86.25	
9	38	86.25	
10	33	83.00	
11	30	77.50	
12	10	76.75	
13	40	74.50	
14	4	73.25	
15	22	71.00	
16	27	71.00	
17	20	68.25	
18	15	68.00	
19	45	66.25	
20	46	61.25	
21	29	61.25	
22	35	60.75	
23	36	59.50	
24	39	58.25	
25	2	58.25	
26	41	57.75	
27	19	56.75	
28	1	54.00	
29	24	50.80	
30	12	50.75	
31	9	47.75	
32	25	44.50	
33	17	43.50	
34	18	43.25	
35	6	43.25	
36	14	43.00	
37	43	42.75	
38	23	41.50	
39	8	40.75	
40	47	38.00	
41	11	34.50	
42	13	34.00	
43	28	32.75	
44	5	30.50	
45	48	29.75	
46	7	29.25	
47	3	20.25	
48	31	19.75	

Table 9. Ranked means of the tall wheatgrass yields in basins receiving water containing 10,000 ppm salt

Rank	Random No.	Dry wt. 3 propagules in grams	Least significant ranges (Duncan's Multiple Range Test) 1 percent level
1	16	42.15	
2	35	26.35	
3	30	24.95	
4	37	23.53	
5	32	21.75	
6	34	20.83	
7	26	19.85	
8	27	19.20	
9	21	17.70	
10	22	17.65	
11	44	16.40	
12	15	16.30	
13	40	16.08	
14	33	15.78	
15	42	14.65	
16	46	13.25	
17	4	12.98	
18	19	12.73	
19	7	12.45	
20	45	11.88	
21	38	10.75	
22	29	10.63	
23	8	10.45	
24	11	10.43	
25	10	9.90	
26	17	9.65	
27	41	9.20	
28	2	9.18	
29	1	8.30	
30	12	8.28	
31	36	8.23	
32	20	8.13	
33	24	7.50	
34	47	7.38	
35	28	7.33	
36	25	7.08	
37	6	7.08	
38	14	6.93	
39	5	6.88	
40	39	6.63	
41	9	6.45	
42	23	6.33	
43	13	6.00	
44	3	5.83	
45	31	5.50	
46	43	5.43	
47	18	4.80	
48	48	4.15	

Table 10. Ranked means of the tall wheatgrass yields in basins receiving water containing 15,000 ppm salt

Rank	Random No.	Dry wt. 3 propagules in grams	Least significant ranges (Duncan's Multiple Range Test) 1 percent level
1	16	32.65	
2	38	15.13	
3	26	14.53	
4	21	14.33	
5	37	14.15	
6	34	13.43	
7	27	12.93	
8	22	12.03	
9	41	12.03	
10	4	11.53	
11	13	11.05	
12	32	10.95	
13	40	10.45	
14	35	9.50	
15	5	9.50	
16	30	9.20	
17	24	9.03	
18	14	8.80	
19	46	8.25	
20	36	8.23	
21	44	8.20	
22	15	7.88	
23	31	7.80	
24	42	7.70	
25	33	7.08	
26	2	6.88	
27	10	6.75	
28	7	6.25	
29	45	6.23	
30	29	6.13	
31	43	5.90	
32	8	5.88	
33	1	5.80	
34	17	5.40	
35	25	5.28	
36	9	4.70	
37	39	4.45	
38	20	4.20	
39	47	3.90	
40	23	3.73	
41	11	3.63	
42	28	3.58	
43	48	2.93	
44	6	2.75	
45	18	2.60	
46	12	2.58	
47	3	2.13	
48	19	2.03	

Table 11. Ranked means of the tall wheatgrass yields in basins receiving water containing 20,000 ppm salt

Rank	Random No.	Dry wt. 3 propagules in grams	Least significant ranges (Duncan's Multiple Range Test) 1 percent level
1	16	23.58	
2	26	23.50	
3	34	14.65	
4	21	13.68	
5	22	11.60	
6	4	11.25	
7	37	10.70	
8	40	10.23	
9	15	9.68	
10	32	9.58	
11	27	9.00	
12	11	8.53	
13	2	7.50	
14	38	7.18	
15	35	6.98	
16	1	6.60	
17	7	6.33	
18	24	6.15	
19	10	5.80	
20	8	5.75	
21	44	5.73	
22	46	5.55	
23	42	5.45	
24	31	5.25	
25	5	4.80	
26	47	4.65	
27	17	4.58	
28	14	4.58	
29	19	4.53	
30	43	4.48	
31	23	4.48	
32	6	4.43	
33	41	4.15	
34	29	3.98	
35	33	3.90	
36	25	3.75	
37	45	3.38	
38	36	3.35	
39	3	3.18	
40	48	2.83	
41	30	2.60	
42	18	2.30	
43	20	2.20	
44	13	2.15	
45	12	2.13	
46	28	2.10	
47	9	1.73	
48	39	1.25	

Table 12. Ranked means of the total tall wheatgrass yields in all salt basins

Rank	Random No.	Dry wt. 12 propagules in grams	Least significant ranges (Duncan's Multiple Range Test) 1 percent level
1	16	242.63	
2	26	211.38	
3	32	146.78	
4	37	146.38	
5	34	139.66	
6	21	136.21	
7	38	119.31	
8	42	117.05	
9	44	116.58	
10	30	114.25	
11	22	112.28	
12	27	112.13	
13	40	111.26	
14	33	109.76	
15	4	109.01	
16	35	103.58	
17	15	101.86	
18	10	99.20	
19	46	88.30	
20	45	87.74	
21	41	83.13	
22	20	82.78	
23	29	81.99	
24	2	81.81	
25	36	79.31	
26	19	76.04	
27	1	74.70	
28	24	73.48	
29	39	70.58	
30	12	63.74	
31	14	63.31	
32	17	63.13	
33	8	62.83	
34	9	60.63	
35	25	60.61	
36	43	59.56	
37	6	57.51	
38	11	57.09	
39	23	56.04	
40	7	54.38	
41	47	53.93	
42	13	53.20	
43	18	52.95	
44	5	51.68	
45	28	45.76	
46	48	39.65	
47	31	38.30	
48	3	31.39	

Table 13. The relative yield of tall wheatgrass expressed in average percent of the control basins (0 ppm)

Rank	Random No.	Avg. % of control basins	Least significant ranges (Duncan's Multiple Range Test) 1 percent level
1	7	28.53	
2	13	25.22	
3	35	23.55	
4	5	23.15	
5	16	22.63	
6	11	21.82	
7	31	19.90	
8	22	19.40	
9	27	19.33	
10	3	18.24	
11	8	18.03	
12	34	17.93	
13	21	16.76	
14	15	16.59	
15	37	16.45	
16	40	16.42	
17	4	16.21	
18	30	15.80	
19	14	15.70	
20	17	15.05	
21	24	14.89	
22	46	14.70	
23	41	14.63	
24	47	13.96	
25	32	13.53	
26	2	13.50	
27	28	13.22	
28	38	12.78	
29	1	12.76	
30	26	12.54	
31	43	12.32	
32	25	12.08	
33	44	11.73	
34	23	11.67	
35	19	11.31	
36	29	11.26	
37	48	11.09	
38	36	11.09	
39	6	10.97	
40	45	10.81	
41	33	10.70	
42	42	10.38	
43	10	9.73	
44	9	8.97	
45	12	8.52	
46	18	7.47	
47	20	7.07	
48	39	7.07	

Table 14. The count of living plants of tall wheatgrass in all salt levels

Rank	Random No.	Count of living Plants	Least significant ranges (Duncan's Multiple Range Test) 1 percent level
1	21	48	
2	34	48	
3	4	47	
4	16	47	
5	22	47	
6	2	46	
7	26	46	
8	40	45	
9	24	44	
10	35	44	
11	41	44	
12	8	43	
13	15	43	
14	27	43	
15	32	43	
16	37	43	
17	14	42	
18	42	42	
19	45	42	
20	33	41	
21	47	41	
22	36	40	
23	38	40	
24	46	40	
25	25	39	
26	5	38	
27	17	38	
28	23	38	
29	44	38	
30	7	37	
31	28	37	
32	30	37	
33	43	37	
34	48	37	
35	1	36	
36	9	36	
37	6	35	
38	13	35	
39	10	34	
40	29	34	
41	11	33	
42	18	32	
43	19	32	
44	3	31	
45	20	31	
46	39	31	
47	12	28	
48	31	28	

Table 15. Summary of analytical data of absolute yield, relative yield, and survival of tall wheatgrass clones in salted basins

Statistic	Added salt in ppm (50% NaCl 50% $CaCl_2$) 0	10,000	15,000	20,000	Total	Avg. % of control	Living plants
$\bar{X}$	61.69	12.31	8.12	6.49	88.61	14.74	39.18
F value (clones)	6.20**	6.69**	3.26**	5.10**	1.96**	5.70**	3.69**
F value (salt x clones)					.77	7.17**	1.53**
C.V. (%)	36.22	45.45	70.14	65.25	8.08	47.78	1.79
$S\bar{X}$	11.17	2.80	2.85	2.12	14.31	4.07	.70

** Significant at the 1 percent level.

difference between clones in absolute yield. This indicated that there was no significant difference in salt tolerance of the different clones or that the ability of all the clones to yield forage was similarly decreased at the different salt levels. In other words, if a clone had the ability to yield well on salt free soil it also had the ability to yield relatively well on salted soil.

These results proved to be visually observable. As the plants were being harvested it was quite evident which clones were high yielders. Before they were clipped and weighed they could be spotted in each basin no matter what the salt level. Likewise low yielding clones could also be picked by visual observation.

It was also observed that the plants in the salinized basins were smaller, tougher and more harsh than the plant from the same clone in the nonsalinized basins. This may be the reason that it has been believed that these factors were linked genetically with salt tolerance. There appeared to be no correlation between the coarseness of the original clone and its ability to yield in salt-affected soil. In fact, the top eleven absolute yielders in this study were originally selected for their smooth characteristics.

SUMMARY AND CONCLUSIONS

1. The objective of this study was to determine the effect of increasing levels of salinity on the survival and forage productivity of selected clones of Agropyron elongatum and to study relationships between plant type and salt tolerance. The artifically salinized field plot technique was employed.

2. Preliminary soil sample tests were made to determine suitability of the basins for use in the study. No basin had excessive amounts of salt.

3. Significant differences existed between tall wheatgrass clones in absolute yield, relative yield, and survival. Significant differences also existed between clones in relative yield and survival when the interaction of salt x clone was tested.

4. No significant differences existed between clones in absolute yield when the interaction of salt x clone was tested. This indicates that no significant difference in salt tolerance existed between clones. If a clone had the ability to yield well in a basin containing no salt it also had the ability to yield relatively well in basins containing salt.

5. Clones numbered 19-30 (16) and 29-52 (26) did consistantly well in all salt levels and were significantly better in absolute yield than other clones tested. These two clones also showed good survival.

6. This study showed no apparent relationship between the factors of coarseness and salt tolerance as was believed. The top eleven

absolute yielders in this study were originally selected for their smooth characteristics.

7. In as much as tall wheatgrass is basically a cross-pollinated species, it appears fortunate that two different clones have shown promising ability to yield well under salt conditions. This offers excellent opportunity for future crossing and development of a variety of tall wheatgrass to be used in the reclamation of salt-affected soils in the Intermountain region.

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APPENDIX

Figure 2. Salinized basins at the Greenville Experimental Farm at North Logan, Utah, in 1958

Figure 3. Tall wheatgrass on one of the nonsalinized basins

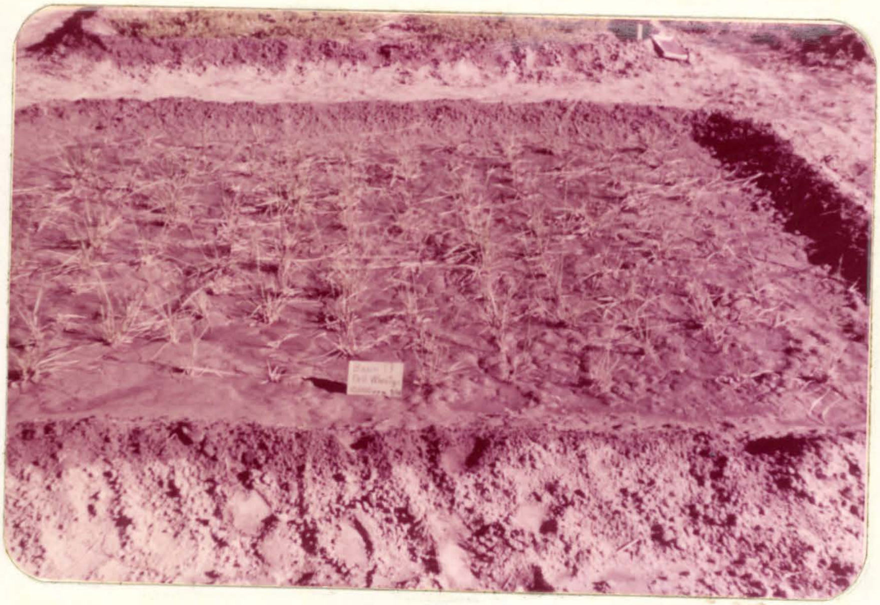

Figure 4. Tall wheatgrass on one of the four basins receiving 10,000 parts per million of added salt

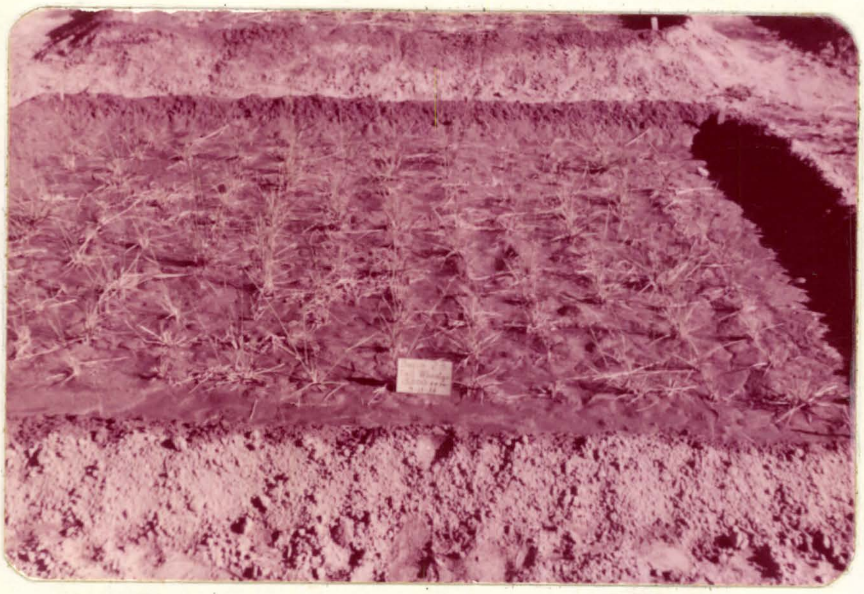

Figure 5. Tall wheatgrass on one of the four basins receiving 15,000 parts per million of added salt

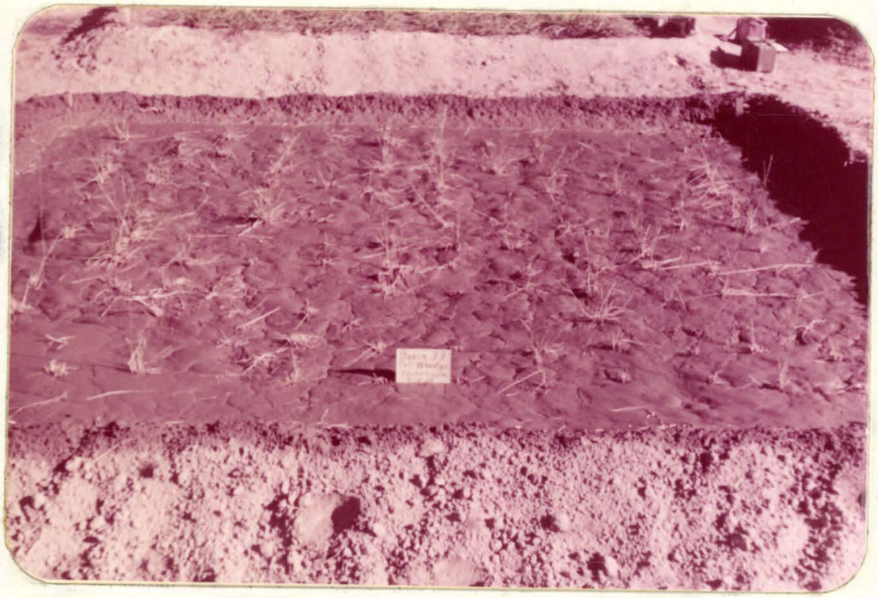

Figure 6. Tall wheatgrass on one of the four basins receiving 20,000 parts per million of added salt