

# GROWTH OF STRAWBERRY CLOVER VARIETIES AND OF ALFALFA AND LADINO CLOVER AS AFFECTED BY SALT

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IN RECENT years considerable interest has been shown in strawberry clover, *trifolium fragiferum*, because of its ability to grow under conditions of moderate salinity, and because of its applicability in the reclamation of water-logged, saline soils now considered as waste lands in the western United States (9, 13).<sup>3</sup> This legume, one of the more recent clover immigrants, is a perennial and native of eastern Mediterranean countries and of southern Asia Minor. It is believed to possess several advantages over alfalfa in that apparently it will tolerate more salinity (1, 11), will withstand flooding-over for as much as two months at a time (9), is shallow-rooted, and may be used to replace alfalfa when the prevalence of dwarf disease makes the growing of alfalfa no longer profitable or possible.

Kearney and Scofield (12) stated that strawberry clover, "is as tolerant of salinity as most of the native or introduced grasses, or even more tolerant". Ahi and Powers (1), working with sand and solution cultures, found that alfalfa and strawberry clover would tolerate 2,800 and 5,600 p.p.m. of salt obtained by diluting sea water, respectively. They concluded that, "strawberry clover was found the most promising resistant legume for salinity, followed by sweet clover, then alfalfa".

The Bureau of Plant Industry and others have made several introductions of strawberry clover and a number of strains have since been identified in the states ranging from Washington to Colorado. A comparison of some of these strains for their tolerance to salinity was suggested.<sup>4</sup> In order to compare the behavior of strawberry clover under saline conditions with other legumes, alfalfa and Ladino clover were included in these tests.

Alfalfa is the most widely grown forage crop in the western United States and, as in this study, is commonly included as a standard in tests of forage crops (11). Harris (7) cites considerable data on the tolerance of alfalfa to alkali, giving the maximum salt tolerated equal to 6,000 p.p.m. of sodium sulfate in the soil. More recently, in a survey (17) of salinity conditions in the Pecos River Valley of New Mexico and Texas it was found that alfalfa growing well where the soil solution extracts (extract from a soil at the saturation

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<sup>1</sup>Contribution from the U. S. Regional Salinity Laboratory, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Dept. of Agriculture, Riverside, Calif., in cooperation with the eleven western states and the Territory of Hawaii. Received for publication April 26, 1943.

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<sup>3</sup>Figures in parenthesis refer to "Literature Cited", p. 879.

<sup>4</sup>Suggested by Dr. E. A. Hollowell, Senior Agronomist, Division of Forage Crops and Diseases, Washington, D. C.

point) had a conductance (KX  $10^5 @ 25^\circ \text{C}$ ) of 800 and contained about 5,000-6,000 p.p.m. of salts in the extract. These salts were usually 50 to 60% sulfates and 30 to 50% chlorides. The soils in this region contain large quantities of gypsum. Harris (7) states further that, "the high resistance of alfalfa may be assigned to its deep feeding habits in many cases, the feeding roots not being in the alkali zone but being in the purer solutions below".

Ladino clover, *Trifolium repens*, var. Ladino, a perennial and a native of Italy, is presumed to be a large form of white clover. This crop is rapidly growing in popularity throughout the United States (2, 3, 10, 11, 14, 18, 19), and for irrigated pastures in California it ranks first in popularity and is being recommended in 37 of the 40 counties (13). The popularity of this plant for pastures rests mainly upon the quantity and quality of forage produced, its ability to recover rapidly following grazing or clipping, and the fact that all of its growth is leafy and succulent rather than stemmy. Though little is known of its salt tolerance, preliminary observations have led to the assumption that it is not a very salt-tolerant crop (11, 14).

#### MATERIALS AND METHODS

Selected California Common alfalfa seed was supplied by Dr. B. A. Madson, of the California Agricultural Experiment Station. Ladino clover seed (blue label) was obtained from The Grange Company, Oakdale, Calif. Seed of the following strawberry clover strains was obtained from the Bureau of Plant Industry:

- FC No. 22,797 strawberry clover (Nebraska)
- PC No. 22,798 strawberry clover (Colorado)
- PC No. 22,800 strawberry clover (Washington)
- PC No. 22,801 strawberry clover (Idaho)
- FC No. 22,802 strawberry clover (Oregon)

Seedlings, 20 days old, were transferred to 5-gallon containers (four seedlings per pot) of automatically-operated sand culture equipment (6). By means of this equipment each pot received 2 quarts of solution once each hour from 7 a.m. to 7 p.m., inclusive, with one additional delivery at midnight. With the daily addition of distilled water into the 5-gallon solution reservoir to replace water lost by evaporation and transpiration, and by means of the frequent irrigations, the plants were subjected to a culture solution almost constant in concentration. Decreases in concentration caused by salt absorption by plants were negligible based on the volume of solution used.

Experimental design.—Studies made at the Regional Salinity Laboratory (5, 8, 15) have indicated that the reduction of plant growth in saline substrates is better correlated with the osmotic concentration of these substrates than with any other index of concentration. Accordingly this basis was chosen to represent the concentration of solutions in the present experiment. Besides a base nutrient treatment of 0.5 atmosphere osmotic concentration, three additional treatments of 2.5, 3.5, and 4.5 atmospheres were obtained by the addition of sodium chloride to the base nutrient solution.

For alfalfa there were three replications and for Ladino clover and each strain of strawberry clover two replications. There were 10 pots per table, and treatments were randomized on the six tables.

*Culture solutions.*—The composition of the culture solutions is given in Table I.

TABLE I.—Composition of the culture solutions.\*

Osmotic concentration, atmospheres	Ca	Mg	Na	K	Cl	so.	H <sub>2</sub> PO <sub>4</sub>	NO <sub>3</sub>	HCO <sub>3</sub>	K × 10 <sup>6</sup> @ 25°C
Equivalents per million†										
0.5 (base nutrient)	5.9	2.7	2.1	3.25	1.8	4.3	0.75	7.0	2.1	154
2.5 .....	5.9	2.7	50.1	3.25	49.8	4.3	0.75	7.0	2.1	662
3.5 .....	5.9	2.7	74.1	3.25	73.8	4.3	0.75	7.0	2.1	918
4.5 .....	5.9	2.7	98.1	3.25	97.8	4.3	0.75	7.0	2.1	1,142
Parts per million										
0.5 (base nutrient)	118	33	47	128	64	20	74	434	129	154
2.5 .....	118	33	1,152	128	1,766	20	74	434	129	662
3.5 .....	118	33	1,704	128	2,617	20	74	434	129	918
4.5 .....	118	33	2,256	128	3,468	20	74	434	129	1,142

\*Micro-elements were added to all solutions as follows: Boron, 0.5 p.p.m. from boric acid; manganese, 0.5 p.p.m. from manganese chloride; and iron, 0.5 p.p.m. from ferric citrate. The tap water used in making up solutions was alkaline, but the inclusion of nitric acid in the composition of the solution reduced the pH to an initial value of 5.7.

†An equivalent per million (e.p.m.) is a unit chemical equivalent weight of solute per million unit weights of solution. Concentration in equivalents per million is calculated by dividing concentration in parts per million (p.p.m.) by the chemical combining weight of the substance or ion. This unit has also been called "milli-equivalents per liter" and "milligram equivalents per kilogram." The latter term is precise, but the former will be in error if the specific gravity of the solution is not exactly 1.0. A.S.T.M. Standards, 1940; part III, page 541.

From April 27 until May 23, 1942, all pots received only base nutrient solution. On May 23, 46 days after seeding, the alfalfa was cropped for it had attained a height of 35-40 cm and was at the incipient flowering stage. Following this cropping of alfalfa, there was a removal and replenishment of two-thirds of the base nutrient solution in all units. After a lapse of 3 days to permit some recovery following cutting, salt treatment on all crops was initiated. Starting on May 26 the solutions were brought up to final concentration at the rate of 1 atmosphere osmotic concentration of sodium chloride per day.

*Insect control.*—The greenhouse was fumigated with Nicofume on May 7 and June 3, 1942, to control thrips on alfalfa. Although the fumigation was intense enough to produce some visible symptoms of injury to the plants, the thrips were not fully eradicated on the alfalfa.

*Harvesting procedure.*—Plants were harvested at incipient to early flowering stage. Alfalfa was cut 4 inches from the level of the sand, while the Ladino and strawberry clovers were *cut off even with the top of the pot or container, i.e.,* at about the 1.5 to 2-inch level. Immediately after harvesting and weighing, the plants were dried rapidly in a large, forced-draft, gas-heated oven and oven-dry weights were obtained.

#### TREATMENT OF HARVEST DATA

One of the most important considerations in a comparison of forage crops is total production of a forage within a growing season. Therefore, although there were three croppings of alfalfa (May 23, June 15, and July 13, 1942) and two croppings of the clovers (June 15 and July 13, 1942) during the elapsed time of the experiment (97 days), only the total yield for the "season" is reported.

This basis is also preferable owing to the fact that different crops reach their peaks in the production of forage after different lengths of time.

Owing to differences in moisture contents of the species studied, the yield data are given on the dry weight basis. The percentage dry matter in the tops was within the range expected for each of the three species studied and, with increase in the salt concentration of the substrate, the percentage dry matter in the tops tended to increase. Alfalfa showed this trend at the time of the first harvest, but at the second harvest there was no consistent trend in the percentage dry matter with treatment. At the second harvest the tops of alfalfa contained approximately 23.5% dry matter. At this later harvest, the tops of the strawberry clover strains from any one treatment had very similar percentages of dry matter, averaging 16.7, 18.3, 20.1, and 21.5 for the treatments 0.5 (B.N.), 2.5, 3.5, and 4.5 atmospheres osmotic concentration, respectively.

In the same order of treatments the values for Ladino clover were 16.7, 19.0, 20.3, and 22.6% dry matter, respectively. It is reported in the literature that the addition of sodium chloride to the substrate resulted in an increase in the dry matter content of barley tops (4), a decrease in that of tomato tops (8), and no change in the dry matter of tops of dwarf red kidney bean (20).

Yield data may be interpreted on an "actual weight basis" or on a "relative weight basis" in which the growth of each crop under the base nutrient treatment is taken as 100%. From an agronomic point of view the principal consideration is total weight of forage produced. However, with crops of diverse weights such as these the yield data must be converted to the relative basis in order to determine the differential response of the various crops and strains to a given series of treatments. Thus, both bases are useful and both will be used in the following discussion.

Owing to the more rapid early growth of alfalfa, there was a pre-salt treatment harvest on the 46th day of the experiment, May 23, 1942, which yielded 9.28 grams of dry matter per pot (standard error, 0.25 gram). This weight is not included in any of the following data inasmuch as all pots were still receiving only base nutrient solution at this time.

Harvest weights are based on the average yield per pot of four plants for the entire experimental period.

## RESULTS

Combined dry weights of tops produced by the various crops at the different salt levels are shown in Table 2.

Pictures were taken of the crops just prior to the final harvest. The various strains of strawberry clover were so similar in appearance that the picture of the highest yielding Nebraska strain alone is shown, together with alfalfa and Ladino clover (Fig. 1).

## DISCUSSION OF RESULTS

The principal purpose of this experiment was to compare the tolerance of various strawberry clover strains to salinity. In the selection of a forage crop for use on saline land, tolerance to salinity is necessary. Usually, salty lands have a high water table and may be water-logged. In addition to salinity tolerance the crop must often be able to withstand water-logged conditions. It is believed that strawberry clover has achieved its popularity because it is

moderately tolerant to salinity and in addition is highly tolerant of a high water table. In our greenhouse tests the experiment was not designed to test the latter factor.

TABLE 2.—Dry weight in grams of tops of strawberry clover, alfalfa, and Ladino clover produced during 97 days of growth, April 7 to July 13, 1942.

Osmotic concentration, atmospheres	0.5 (B.N.)	2.5	3.5	4.5	Strain or crop mean*
<b>Strawberry clover strains:</b>					
Nebraska. . . . .	45.6	43.3	34.8	28.9	38.1
Idaho . . . . .	45.6	40.5	27.5	22.4	34.0
Colorado . . . . .	41.1	32.5	27.4	22.7	30.9
<b>Washington. . . . .</b>	<b>41.6</b>	<b>33.0</b>	<b>25.1</b>	<b>15.7</b>	<b>28.8</b>
Oregon. . . . .	36.8	30.6	24.3	19.4	27.7
Alfalfa?. . . . .	61.1	45.4	38.9	32.8	44.5
<b>Ladino clover. . . . .</b>	<b>96.3</b>	<b>64.8</b>	<b>55.4</b>	<b>42.7</b>	<b>64.8</b>

\*Difference between any two mean weights of strawberry clover strains needed for significance at the 5% level, 4.22 grams; for significance at the 1% level, 5.76 grams.

†A pre-salt treatment harvest of 9.28 grams dry weight was made. This is not included in the totals of this table.

#### INTERCOMPARISONS OF STRAWBERRY CLOVER STRAINS

**Dry weight of top.**—On the basis of actual yields, the Nebraska strain yielded significantly better than the Colorado, Washington, and Oregon strains, but its yield did not differ significantly from that of the second best Idaho strain. It is also evident from Table 2 that there was a highly significant difference in yield between any two treatments with the higher yield always in favor of the treatment with the lower concentration of salt.

**Relative dry weight of tops.**—Inasmuch as some strains made better growth than others under the base nutrient treatment, relative dry weights were calculated for comparing the response of the strains to salt treatment. On the relative basis there was a significant difference in yield only between the highest and lowest yielding strains, viz., Nebraska vs. Washington.

#### INTERCOMPARISONS AMONG THREE HIGHEST YIELDING STRAINS OF STRAWBERRY CLOVER, ALFALFA, AND LADINO CLOVER

An average of yields from all treatments on an actual weight basis (Table 2) shows that alfalfa yielded 1.3 and Ladino clover 1.9 times as great a weight of tops as strawberry clover (average for the three highest yielding strains). These results are in agreement with the field observations on these crops as reported by Jones and Brown (11). They have observed that, except under certain special conditions, Ladino clover outyields strawberry clover, and that under conditions where Ladino clover does not survive, strawberry clover usually makes only a very sparse growth. From June 15 to July 13, 1942, the daily temperatures in the greenhouse were comparatively high (maximum daily temperatures averaging around 99° F), and there was undoubtedly a "lag" in the growth of the Ladino clover, as has been reported by Jones and Brown (11) for the growth of Ladino clover during

hot weather. They report that alfalfa is relatively unaffected by such periods of hot weather. However, despite the "relative" depression in the growth of this crop as compared with alfalfa and strawberry clover, on an actual yield basis Ladino clover yielded the greatest amount of forage.

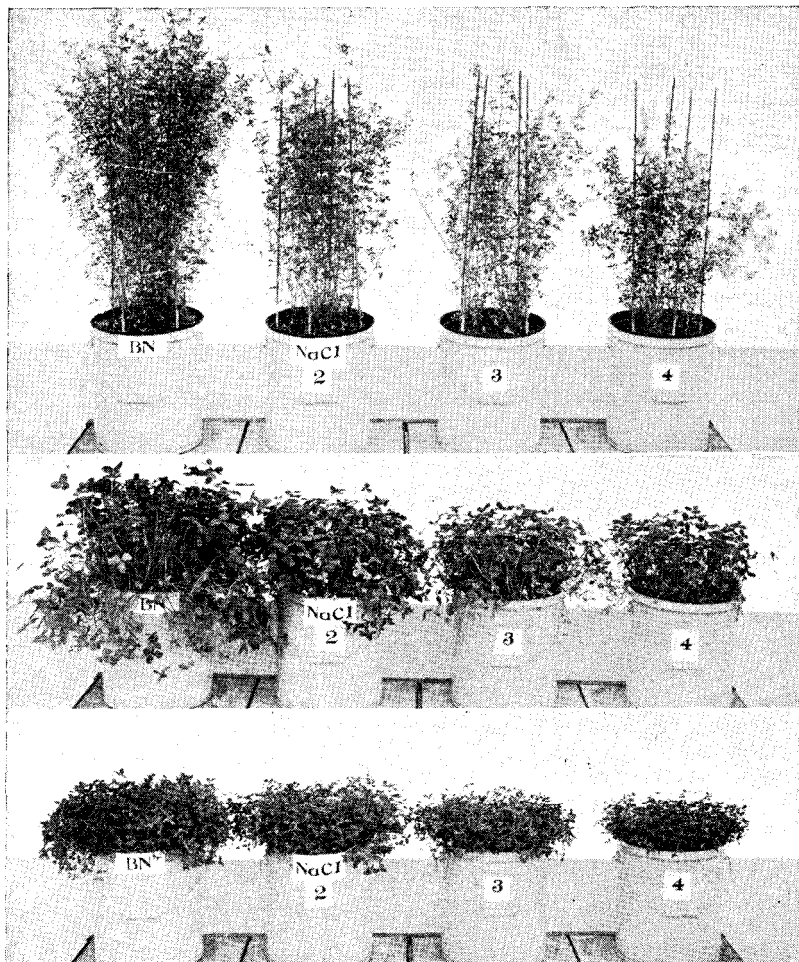


FIG. 1.—Appearance of plants at time of final harvest, July 13, 1942; 97 days from date of seeding. *Top*, alfalfa; center, Ladino clover; bottom, Nebraska strawberry clover. BN =base-nutrient; 2, 3, and 4=number of atmospheres osmotic concentration of sodium chloride added to the base-nutrient solution.

*Relative dry weight yields.*—The relative dry weights of tops for the three best strains of strawberry clover, Nebraska, Idaho, and Colorado, and for alfalfa and Ladino clover are shown graphically in Fig. 2.

In preparing Fig. 2 data for the Washington and Oregon strains of strawberry clover were omitted so as not to make the graph too confusing. In a statistical comparison, including these two strains, the only significant difference in response at the 5% level was between the Nebraska strain and Ladino clover.

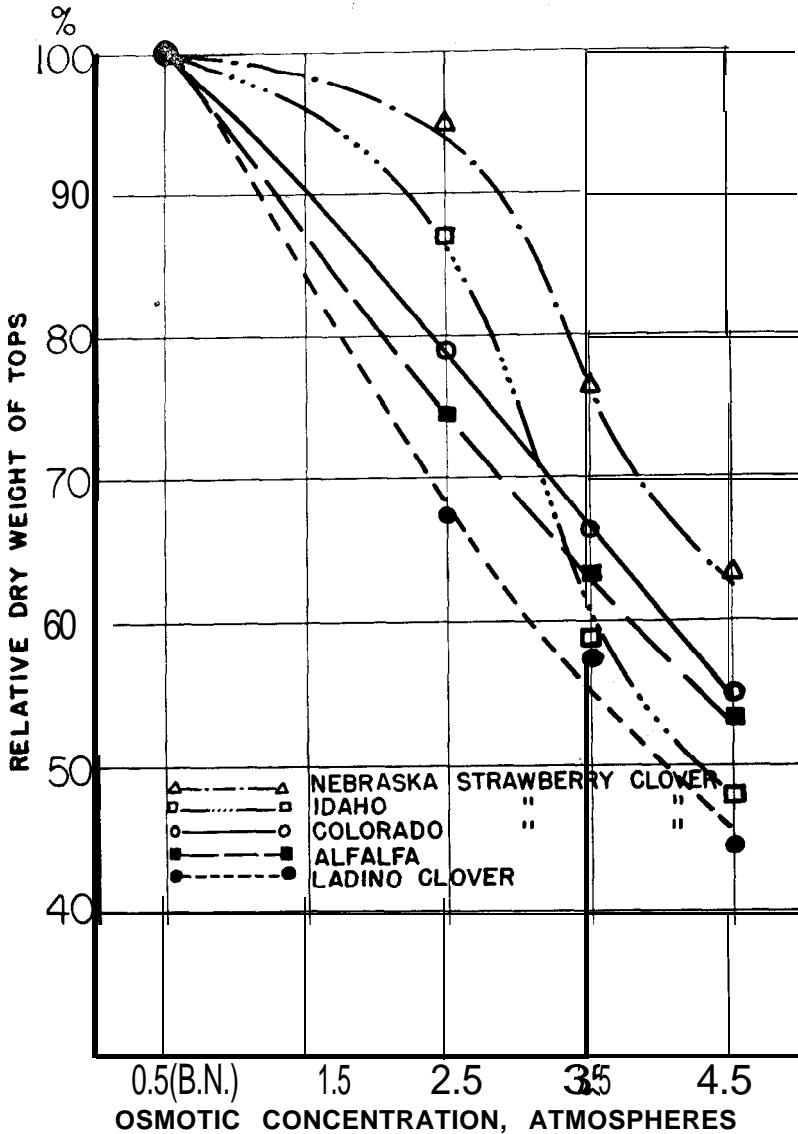


FIG. 2.-Relative dry weight of tops produced by the various strains of strawberry clover, alfalfa, and Ladino clover.

On a treatment mean basis involving the three best strains of strawberry clover, alfalfa, and Ladino clover, statistical analysis of the data showed that each increment of salt very significantly reduced the yield of tops.

### RELATIONSHIP OF TESTS TO PRACTICAL AGRICULTURE

In view of the present demand for an increase in livestock production it seemed especially pertinent to study the response of several of the most important forage crops to salinity per se. In the selection of a forage crop, tolerance to salinity is, of course, only one of several important considerations. For example, it is generally agreed that one of the main virtues of strawberry clover is its ability to withstand not only a moderate amount of salinity but also a high water table and a water-logged condition of the soil. Our results show that on a *relative basis* only one of the five strains of strawberry clover, the Nebraska strain, was less affected by salt than either alfalfa or Ladino clover. However, despite the greater, relative salt effect on alfalfa and Ladino clover, on an *actual weight basis* these two crops yielded 1.3 and 1.9 times more forage, respectively, than did strawberry clover. Therefore, unless there are other important factors to consider such as unfavorable soil conditions, wherever Ladino clover or alfalfa can be established, these crops would generally be preferable to strawberry clover. The choice between alfalfa and Ladino clover rests on certain characteristics of the soil in question. Madson and Coke (14) state that in California alfalfa will usually outyield Ladino clover on the deeper and more porous soils, while on the more shallow and heavier soils Ladino will usually outyield alfalfa.

Recently, Magistad and Reitemeier (16) studied 17 representative western soils to determine the range of soil solution concentration and composition, and correlated these values with the observed plant growth. By means of the particular technic which they used, it was possible to obtain soil solutions at soil moisture contents near the wilting range, and possible errors in, concentration and composition brought about by extrapolation back to field moisture contents were minimized if not altogether eliminated. Their data show the relationship between plant growth and soil solution concentrations in the wilting range. They give data showing that the concentration of soil solutions of saline soils may reach values of 40 atmospheres or more. At concentrations above three atmospheres plant growth was affected.

The range of salt concentrations used in the present study compare with concentrations of salt found in the soil solution of slightly saline soils by Magistad and Reitemeier (16).

### SUMMARY

The relative yields and tolerances of five strains of strawberry clover, alfalfa, and Ladino clover to serial increases in the concentration of salt (NaCl) in the substratum were determined. The



concentration of the nutrient solution in the sand culture ranged from 0.5 to 4.5 atmospheres. The following results were obtained:

1. On an actual yield basis, alfalfa and Ladino clover yielded 1.3 and 1.9 times as much forage, respectively, as strawberry clover.
2. On a relative basis the Nebraska strain of strawberry clover was less affected by salt than alfalfa or Ladino clover. The differences in favor of the Colorado and Idaho strains and of alfalfa over Ladino clover approached significance at the 5% level.
3. Of the five strains of strawberry clover tested, the Nebraska strain yielded significantly better than the Colorado, Washington, and Oregon strains, but was not superior to the second highest yielding strain (Idaho).
4. On both the actual and relative yield bases there was a highly significant difference in yield between treatments, with the higher yield always in favor of the treatment with the lower concentration of salt.
5. There was no evidence that there is a given concentration of solution which may be regarded as critical, but rather there tended to be a linear relationship between growth reduction and increase in salt concentration of the solutions as expressed in atmospheres.

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