Response of Seedling Alfalfa Plants to High Levels of Chloride-Salts

Dale Smith, A. K. Dobrenz, and M. H. Schonhorst

Department of Plant Sciences
University of Arizona

SUMMARY

Greenhouse studies with 4- to 5-week-old plants of alfalfa (Medicago sativa L.) showed that injury and killing from exposure to various salts was due primarily to the presence of the chloride (Cl^-) ion. Chloride damage increased as rate of Cl^- applied was increased, and as temperature or soil moisture were increased. Light intensity had little influence. Plants exposed first to non-lethal levels of Cl^- developed tolerance to higher rates applied later. This information was needed to establish a screening procedure to identify salt-tolerant genotypes of alfalfa.

****

Salinity is a problem in many soils of Arizona and other southwestern states. Alfalfa is only moderately tolerant of saline conditions. Yet, it is a very important economic crop in Arizona, and is grown in many areas where salt is a problem in the soil and/or irrigation water. This problem will increase in the future, as alfalfa is shifted to poorer soils, as water supplies for leaching are reduced, and as the salt content of irrigation water increases. Thus, more information is needed concerning the effect of salts on young alfalfa plants. Such information is essential in breeding alfalfa for increased salt tolerance.

Plant damage from high salt concentration in the external medium most commonly is due to, 1) reduced water potential that makes it difficult for the plant to obtain water, and 2) toxic effects due to certain ions. One of the most prevalent ions in southwestern soils and water is chloride (Cl^-), and alfalfa is readily damaged by the Cl^- ion. Smith and Struckmeyer (1977) showed that alfalfa leaflets accumulate higher levels of Cl^- than the stems. Chloride-damaged leaflets were yellowed, thickened, and deformed. Hypertrophy of all mesophyll cells resulted in few intercellular spaces, some necrosis, and an absence of chloroplasts.

The chloride problem occurs in the humid, northern areas of the U.S., as well as in the dry Southwest, but the reason is different. In the North, high levels of Cl^- may arise when KCl fertilizer is applied to the seedbed before seeding alfalfa and damages the germinating seed, or when established alfalfa stands are topdressed with high amounts of KCl. Under desert conditions of Arizona, Cl^- may be applied in the irrigation water or accumulate in the soil. Chloride is highly mobile in the soil, except under low rainfall conditions. Alfalfa has a deep root that readily absorbs Cl^-, which accumulates in the plant tissue without becoming incorporated into organic molecules.

Most studies of salt tolerance in alfalfa at the University of Arizona have been conducted using seed germinated in various concentrations of salt solutions, usually NaCl (Khatib and Massengale, 1966; Stone, Marx, and Dobrenz, 1979; Dobrenz et al., 1980, 1981). Additional studies, however, were needed to evaluate the response of young, established alfalfa plants to salt under controlled conditions. We initiated a series of greenhouse experiments with alfalfa seedling plants to determine their response to several common salts, their survival to increasing levels and adaptation to Cl^-, and the influence of plant age, temperature, soil moisture, and light on survival. This information is needed in order to establish a screening procedure for the alfalfa breeder to identify salt-tolerant alfalfa genotypes in the interest of developing salt-tolerant strains or cultivars.

MATERIALS AND METHODS

These studies were conducted in the greenhouse with plants of Lew alfalfa grown from seed in one-liter, plastic pots filled with Mohave sandy loam soil (2.7 pounds of soil/pot). Twenty or 25 plants/pot were grown to 4 to 5 weeks of age (5 to 7 inches tall) and treated with a salt solution, usually KCl. Plant survival was evaluated four weeks after salt treatment. Except at time of salt treatment, plants were watered only with distilled water.

RESULTS

Seedling alfalfa plants survived the application of moderate rates of Cl^- (405 to 810 lbsCl/a), but survival decreased markedly as rate of Cl^- was increased above this level. All rates of Cl^- were applied on a surface-area basis. Few, if any, plants survived when 2430 lbsCl/ha were applied in a single dose.

Plant survival was not significantly different whether the chloride salt was NaCl or KCl, as long as equal amounts of Cl^- were applied (Table 1). Survival was much higher with the application of high rates of K_2SO_4, Na_2SO_4, and Na_2HPO_4 than with KCl or NaCl.

Table 1. Survival of Lew alfalfa with the application of some common salts at high rates.

Salts applied	Treatments	Plant survival, % Exp. 1	Exp. 2
KCl	2022 lbsCl/a as KCl (2230 lbsK/a)	17	17
NaCl	Same amount Cl^- as from KCl; 2022 lbsCl/a	8	7
NaCl	Same amount total salt as KCl; 4252 lbs/a of NaCl or 2578 lbsCl/a	3	11
K_2SO_4	Same amount K as from KCl; 2230 lbsK/a	89	95
Na_2SO_4	Same amount Na as from NaCl in Treatment 2; 1310 lbsNa/a	66	100
Na_2HPO_4	Same amount Na as above	--	79
LSD, 0.05		9	12

The chloride salt chosen for use in subsequent trials was KCl. In these small-pot studies, the Na^+ ion from NaCl caused the soil to deflocculate, especially at the soil surface, and hindered water movement through the soil.

Young alfalfa plants increased in Cl^- tolerance as they matured. At all ages tested (2- to 7-week-old plants), a higher percentage of the plants was killed when the herbage was removed just before the Cl^- was applied. Plants with their foliage intact probably were able to dilute the Cl^- absorbed from the soil and thereby reduce the amount of damage.

Plants survived the application of Cl^- better at moderate (80^oF) than at high (100^oF) temperatures and when the soil was dry rather than when it was wet. However, plant survival was not significantly affected by light intensity.

At high rates of Cl^-, the foliage of treated plants showed wilting within two to eight hours and the topgrowth had collapsed by 24 to 48 hours after treatment with KCl. Most of the damage and killing of plants occurred within seven days, even though data on survival were not taken until four weeks after exposure to salt.

Plants survived high total application rates of Cl^- when they were allowed time to adjust following exposure to sub-lethal levels of Cl^-. This adaptive response would make it more difficult to select Cl^- tolerant plants under field conditions. Exposure to variable and unknown amounts of Cl^- in the soil and/or irrigation water during seedling establishment would make it difficult to decide on the amount of chloride-salt to apply to reach the selection pressure needed to identify resistant or tolerant plants.

Chloride accumulated in higher concentrations in leaflets than in stems. Lowest concentrations of Cl^- were found in the roots. All roots appeared to be alive at the end of the four-week recovery period, even those of plants where all shoots had been killed shortly after salt treatment.

Percentages of both K^+ and Cl^- in the herbage increased steadily as KCl application rates increased. High KCl application rates generally reduced herbage concentrations of N, P, Ca, Mg, S, B, and Mn, as compared with plants not treated (controls), and generally increased concentrations of Na, Cu, Fe, and Al. However, herbage concentrations of Fe and Al were variable, which may have resulted from contamination during growth in the greenhouse or during harvesting.

A Method to Screen Alfalfa for Chloride-Tolerance

The above results were used to develop a procedure to identify alfalfa seedling plants with Cl^- tolerance (salt tolerance). Screening to date at Arizona has been accomplished by germinating seed of the cultivar Mesa-Sirsa in high concentrations of NaCl solutions to eliminate 99% of the population (Dobrenz, Stone, and Schonhorst, 1981). Currently this project is in the fourth cycle of selection by

germinating seed in a NaCl solution of -18 bars. Following two cycles of selection, the seed germinated 33% better than seed from the original source at -13.5 bars and 77°F.

Tolerance to Cl^- during seed germination and during the young plant stage may be two completely different phenomena, as was found to be the case in soybeans (Glycine max (L.) Merr.). However, this needs to be studied for alfalfa. Therefore, alfalfa is now being screened at Arizona during seed germination and during the juvenile-plant stage.

In the seedling plant screening procedure, alfalfa is seeded in fertile, sandy-loam soil in wooden flats lined with black plastic or in solid, polyethylene flats (a soil depth of about 3 to 4 inches). The plants are grown to about 6 inches in height (4 to 5 weeks of age). All watering is with distilled water throughout the seedling establishment process to avoid adaptation due to exposure to noninjurious levels of Cl^-. This problem of plant adaptation can be readily encountered in the field. Very high levels of Cl^- may be needed in the irrigation water to eliminate a high percentage of the plants because of increased tolerance due to exposure to sub-lethal levels of Cl^- in the soil and/or water during early growth and/or their increase of foliage with advanced age. Thus, screening in the greenhouse and watering only with distilled water free or low in Cl^- seems to expedite the selection procedure.

When the seedling plants reach approximately 6 inches in height, they are treated with an application of about 3400 lbs/a of KCl (1620 lbsCl/a and 1780 lbsK/a) in solution calculated on the soil surface-area basis. The soil should be wet when the KCl is applied or the amount of KCl needed can be mixed in a large volume of water, which also will allow uniform application. Susceptible seedlings usually collapse within one or two days and most are dead within a week. The surviving plants usually are not transplanted to new soil until 3 to 4 weeks after exposure to Cl^-. Screening in small pots is also possible and will eliminate a transplanting. The potted plants or plants that survive Cl^- treatment can be removed from the drainage-cup, and the excess Cl^- flushed from the soil during subsequent watering.

Some adjustments may have to be made in the amount of KCl applied, depending on greenhouse temperatures and age of plants at time of salt treatment. The KCl rate may have to be increased in a cool greenhouse or with plants of advanced age (size), or decreased in a hot greenhouse or with very young (small) plants. Less than 1% survival is desired in the first cycle of selection in order to adequately identify Cl^--tolerant plants in the heterozygous population. (The full text of these studies with the data will be published in the Journal of Plant Nutrition 4(2), 1981).

REFERENCES

Dobrenz, A. K., J. E. Stone, and M. H. Schonhorst. Salt tolerance in alfalfa. p. 87-93. In, R. H. Delaney (ed.), Physiological and Morphological Criteria for Alfalfa Plant Breeding. Wyoming Agric. Exp. Sta. Res. J. 164 (1981).

Dobrenz, A. K., J. E. Stone, M. H. Schonhorst, and S. Riggins. Arizona Coop. Ext. Serv. and Agric. Exp. Sta. Forage and Grain Report Series P-50: 12 (1980).

Khatib, K. H., and M. A. Massengale. Prog. Agric. Ariz. 18:21 (1966).

Smith, Dale, and B. E. Struckmeyer. Can. J. Plant Sci. 57:293 (1977).

Stone, J. E., D. B. Marx, and A. K. Dobrenz. Agron. J. 71:425 (1979).

Small Grain Weed Control in Arizona - 1981

Stanley Heathman

During the 1981 wheat growing season growers often found it necessary to combat weeds. Wild oat and canarygrass remain the most difficult weeds to control. Some growers discovered again that using wheat seed contaminated with wild oat was a very expensive decision. Fields in Graham County which were previously free of wild oat have now reached levels of wild oat infestation where crop rotation or the use of herbicides will be necessary to achieve normal wheat yields.

The best advice to wheat growers we can make is to prevent new weed infestations from occurring. Some other important points are: