Does Seed Size Affect Alfalfa Establishment and Productivity in Saline Seedbeds?

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Key Words: alfalfa, emergence, height, seed-size, salinity, tolerance, yield

Abstract

Large, medium and small seeds of Rangelander alfalfa, were sown in saline media in Canada's Salt Tolerance Testing Lab. The emergence and survival data indicate that large-size seeds confer a degree of salinity tolerance to their emerging and developing seedlings. The large seeds emerged in numbers 10 and 23 % greater than the plants from medium and small seeds grown in 18 and 24 dS m^{-1} solutions, respectively. The seed-size advantage, evident in plant heights just 14 days after seeding, persisted into forage harvests which also showed increased biomass yields at all salinity levels at the first harvest cut. Although the seed-size yield advantages diminished with successive harvests, higher yields persisted at the 12 and 18 dS m^{-1} salinity treatments for the crops planted with large seeds.

Introduction and Methods

Alfalfa (*Medicago sativa* L. & *Medicago falcata* L.) ranks as one of the most desirable forage crops, but it is susceptible to salinity during establishment. Saline seedbeds reduce the emergence and survival of alfalfa by affecting seed germination, hypocotyl growth, and emergence (Waissman Assadian and Miyamoto, 1987). Grieve and Francois (1992) found that the larger seeds of irrigated wheat countered reductions in the leaf-appearance rate, number of main-stem leaves and tillers, leaf area, and grain yield per plant caused by root-zone salinity. Rangelander alfalfa seeds from one seedlot, provided by Ponderosa Ag Sales, were screened and separated into one of three relative sizes: large, medium, and small. Their respective 1000-seed weights averaged 2.16, 1.55, and 1.30 g. Pre-tested for germination percentage under standard seed-testing conditions, these seeds registered 78.0, 67.0, and 71.5 % respectively, for the large, medium, and small seeds.

The experiment utilized Canada's Salt Tolerance Testing Laboratory (Steppuhn and Wall, 1999), which features an environmentally-controlled greenhouse with large hydroponically-nourished sand tanks. A modified Hoagland's nutrient solution to which appropriate proportions of Na_2SO_4, $MgSO_4$, NaCl, and $CaCl_2$ were added in the preparation of saline solutions measured 1.4, 4, 8, 12, 18, and 24 dS m^{-1} in solution electrical conductivity. Three randomly-selected tanks per seed-size group and solution treatment were flushed four times daily with one of the six treatment waters to uniformly salinize the seedbeds and root zones. Each tank was seeded to alfalfa to a depth of 10 mm using seeds of one size. Day length was appropriately adjusted during the experiment and set to mimic a seeding date of April 23rd at 50°N. A template guided placement of each seed into a known position within each seedbed, allowing assessment of emergence and survival associated with each treatment on a daily basis.

As plants emerged and grew, the canopy of the alfalfa stand in each tank began to close. Before complete closure, the stands were thinned to a number of plants per unit area (88 plants m^{-2}) about equal to that for producing a maximum yield of irrigated alfalfa hay. Growth in the tanks was maintained under the test conditions for a seasonal period of 146 days producing three hay forage cuts.

Results

Emergence and early survival were evaluated by comparing percent maximum emergence and survival (E_{max}), where E_{max} equals the maximum cumulative emergence and survival under each specified salinity level in percent of the best experimental total attained at 1.4 dS m^{-1}. Among the seeds planted in the 1.4, 4, 8 and 12 dS m^{-1} tanks, differences in E_{max} were narrow with only very slight, if any, advantages to successive sizes resulting from the large to medium to small seed-size groups (Figure 1). At 18 and 24 dS m^{-1}, however, the percentages clearly favoured successively larger seeds, although the absolute counts in all sizes were depressed because of salinity. Of note, survival at the peak emergence in either of the two most severely saline environments was not fully sustained for any of the seeds in any size group.

If the E_{max} values were divided by the best mean value attained in any salinity level and converted to a percentage, the evaluated differences among the higher saline treatments became evident (Table 1). Under 12 dS m^{-1}, the larger seeds increased emergence and survival by 8% over the medium and 5% over the small groups. Under 18 dS m^{-1}, alfalfa emergence and survival increased with the large seeds by 10.6 and 23.3 %, in relation to the medium and the small-sized seeds, respectively. Under 24 dS m^{-1}, the percentage increases were similar at 10.6 and 23.5%, respectively.

Table 1. Discriminating E_{max} Values (With the Difference From the Size and Salt-Free Mean Value^z in parenthesis) for Each Treatment, Based on Three Replicates.

EC_{sol} dS m^{-1}	Large %	Medium %	Small %
1.4	100.00 (+1.9)	100.00 (+1.9)	94.37 (-3.8)
4	91.81 (-6.4)	100.00 (+1.9)	100.00 (+1.9)
8	98.18 (+0.1)	92.83 (-5.4)	92.01 (-6.2)
12	96.37 (1.8)	88.52 (-9.8)	91.55 (-6.7)
18	75.45 (-23.1)	65.07 (-33.7)	52.58 (-46.4)
24	30.45 (-68.9)	20.10 (-79.5)	7.51 (-92.4)

^{z} Means of the three seed sizes at 1.4 dS m^{-1}: E_{max} = 98.12 %

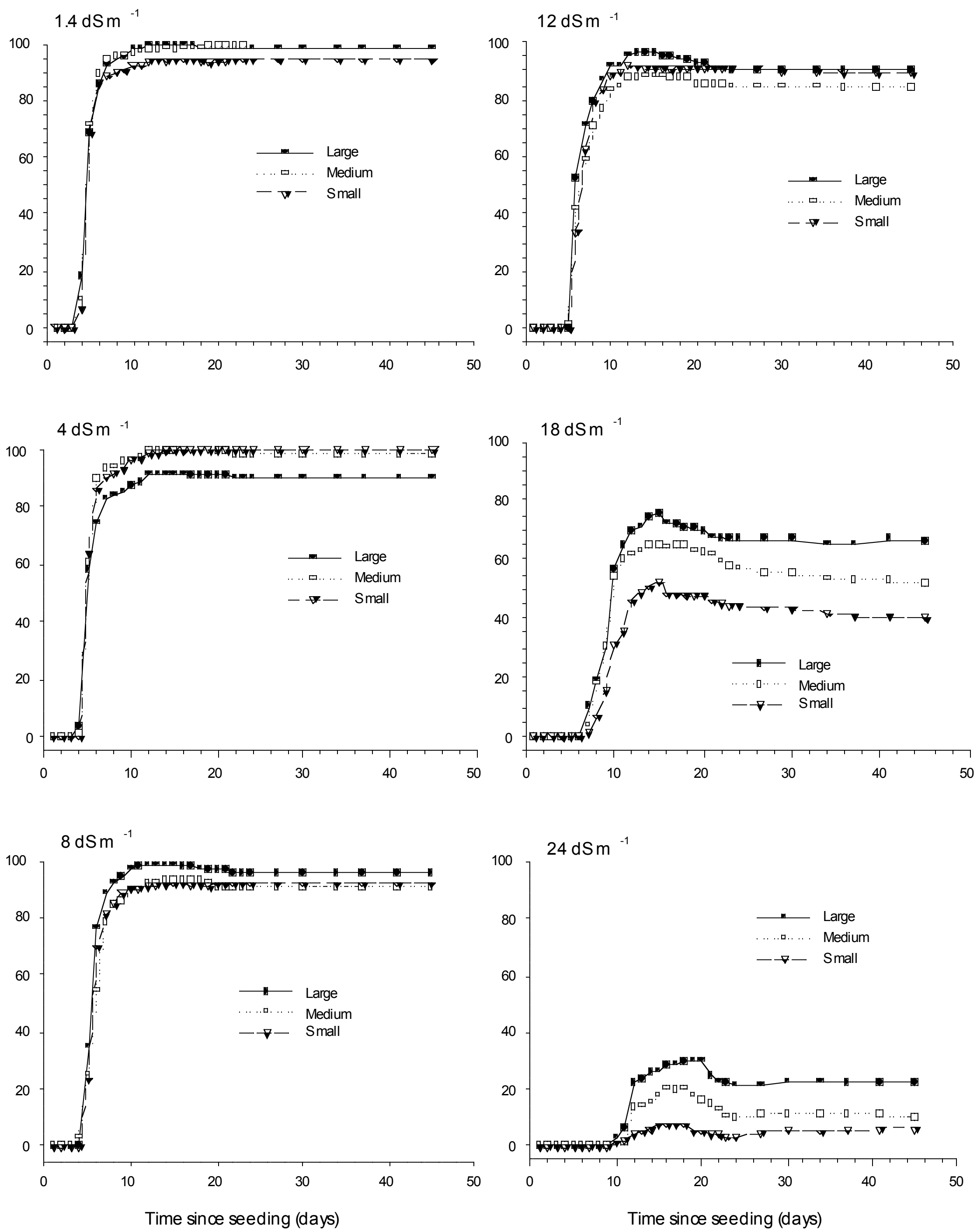

Figure 1. Average emergence and survival of Rangelander alfalfa for three seed sizes (large, medium, and small) and solution conductivities of 1.4, 4, 8, 12, 18, and 24 dS m^{-1} expressed as a percent of the maximum attained for each seed size.

The negative effect of root-zone salinity on alfalfa crop height was evident as early as 14 days after seeding (Figure 2). The benefits of planting large seeds were also evident at this early date in all salinity treatments except at 24 dS m^{-1}. With time, the seed-size benefits in plant crop height seemed to decline until at day 91 benefits in the salt-free alfalfa no longer showed. Nevertheless, a strong advantage in plant crop heights tended to persist in the 8, 12, 18, and 24 dS m^{-1} treatments to the second hay cut, 112 days after seeding and to a lesser extent beyond (Figure 3).

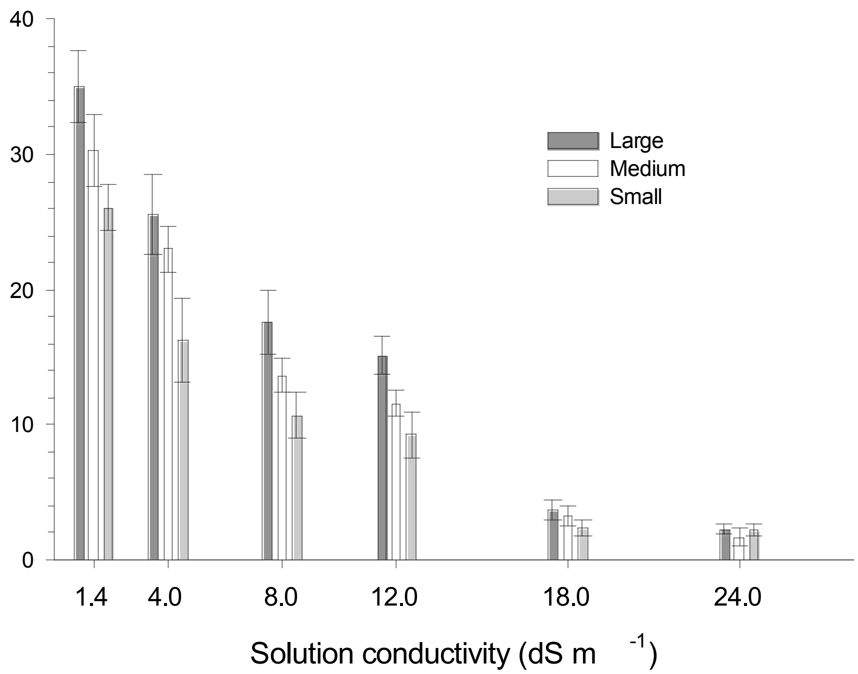

Figure 2. Average plant heights measured 14 days after seeding, comparing three seed sizes (large, medium, and small) of Rangelander alfalfa grown in increasingly saline rooting solutions; error bars indicate standard error.

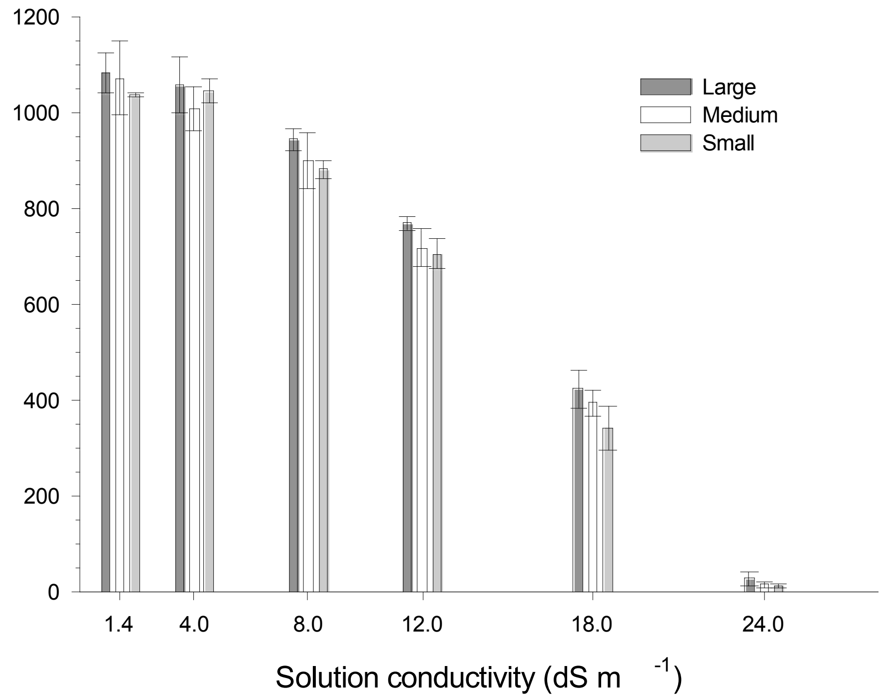

Figure 3. Average plant heights measured 112 days after seeding, (at 2nd hay cut) comparing three seed sizes (large, medium, and small) of Rangelander alfalfa grown in increasingly saline rooting solutions; error bars indicate standard error.

The negative impact of root-zone salinity on alfalfa forage production was observed in the first harvest, 70 days after seeding (Figure 4). The size of the planted seed within each salinity level also imparted a noticeable effect at most salinity levels. Generally, larger seeds were less affected by the salinity than the smaller seeds, but failed to fully compensate for the negative impact of the salinity. The forage production at the 4 and 8 dS m^{-1} treatment realized apparent benefits of 17 and 8 % from large seed plantings compared to the small seed results based on the large seed yield at 1.4 dS m^{-1}. The yield of the medium sized seeds was similar to the large seeds at the 4 dS m^{-1} treatment but about equal to the small seeds at the 8 dS m^{-1} level. At the 12 dS m^{-1} treatment, the mean salinity-induced alfalfa forage yield from the first harvest cut, was 23.7 % for the large seeds, while the yields for the medium and small seeds were 14.8 and 11.4 % of the large seed with no salinity. The large seed had an increased yield of 8.9 and 12.3 % respectively. When comparing actual yield at this salinity level, however, the large seeds more than doubled the yield from the small seeds. Although the large seeds displayed benefits in yield at the 18 and 24 dS m^{-1} salt treatments, the yields were 2 % or less of the large seed yield with no salinity.

By the second harvest cut on day 112 after seeding, any forage yield advantage with large seeds disappeared except for the apparent production within the 12 and 18 dS m^{-1} environments. Here, the mean alfalfa forage yield from large size seeds averaged 51.8 and 10.2 % of the yield of the large seed at 1.4 dS m^{-1}, the medium sized seeds followed with yields of 36.1 and 7.2 %, while the small sized seeds averaged 32.2 and 4.8 % respectively. The respective large seed yields appeared to gain 19.6 and 5.4 % over the small seeds in these environments. In actual yield comparisons, the small seeds yielded 62.2 % of the large seeds at 12 dS m^{-1}, and only 47.3 % in the 18 dS m^{-1} environment.

The third and final harvest cut (day 146), showed seed-size forage yield benefits comparable to those of the second cut. Large seed-size, forage-yield benefits only seemed to occur within the 12 and 18 dS m^{-1} treatments. The mean forage yields at 12 dS m^{-1} based on large seeds averaged 64.1 %, the medium seeds averaged 51.4%, while the small seeds averaged only 48.2 % of the large seed yield at 1.4 dS m^{-1}. The increase in forage yield for the large-seeded crop in comparison to the medium and small seeds was 12.7 and 15.9 %, respectively. At 18 dS m^{-1}, the relative yields were 22.4, 15.9 and 11.9 % for the large, medium and small seeds respectively. The forage yield increase equalled 6.5 % over the medium sized seeds and 10.5 % over the small seeds. In comparing actual yields, the small seeds yielded 75.3 % of the large seeds at 12 dS m^{-1} and 53.1 % at 18 dS m^{-1}.

Of note, the production of alfalfa at the 4, 8, 12 and 18 dS m^{-1} treatments tended to increase with each successive harvest relative to yields in the salt-free treatments (Table 2), indicating the plants were becoming more tolerant of salinity with maturity.

Table 2. Relative Forage Yields of Rangelander Alfalfa at Salinity Treatments of 4, 8, 12, and 18 dS m^{-1} Compared to Large Seed Yields Achieved at 1.4 dS m^{-1} of Each Successive Harvest.

EC_{sol} dS m^{-1}	Seed Size	First Cut %	Second Cut %	Third Cut %
4	Large	72.6	91.8	97.8
	Medium	72.5	104.0	107.3
	Small	55.7	87.0	96.6
8	Large	34.3	55.3	66.6
	Medium	27.6	62.8	74.2
	Small	26.4	60.2	83.4
12	Large	23.7	51.8	64.1
	Medium	14.8	36.1	51.4
	Small	11.4	32.2	48.2
18	Large	2.0	10.2	22.4
	Medium	1.3	7.2	15.9
	Small	0.8	4.8	11.9

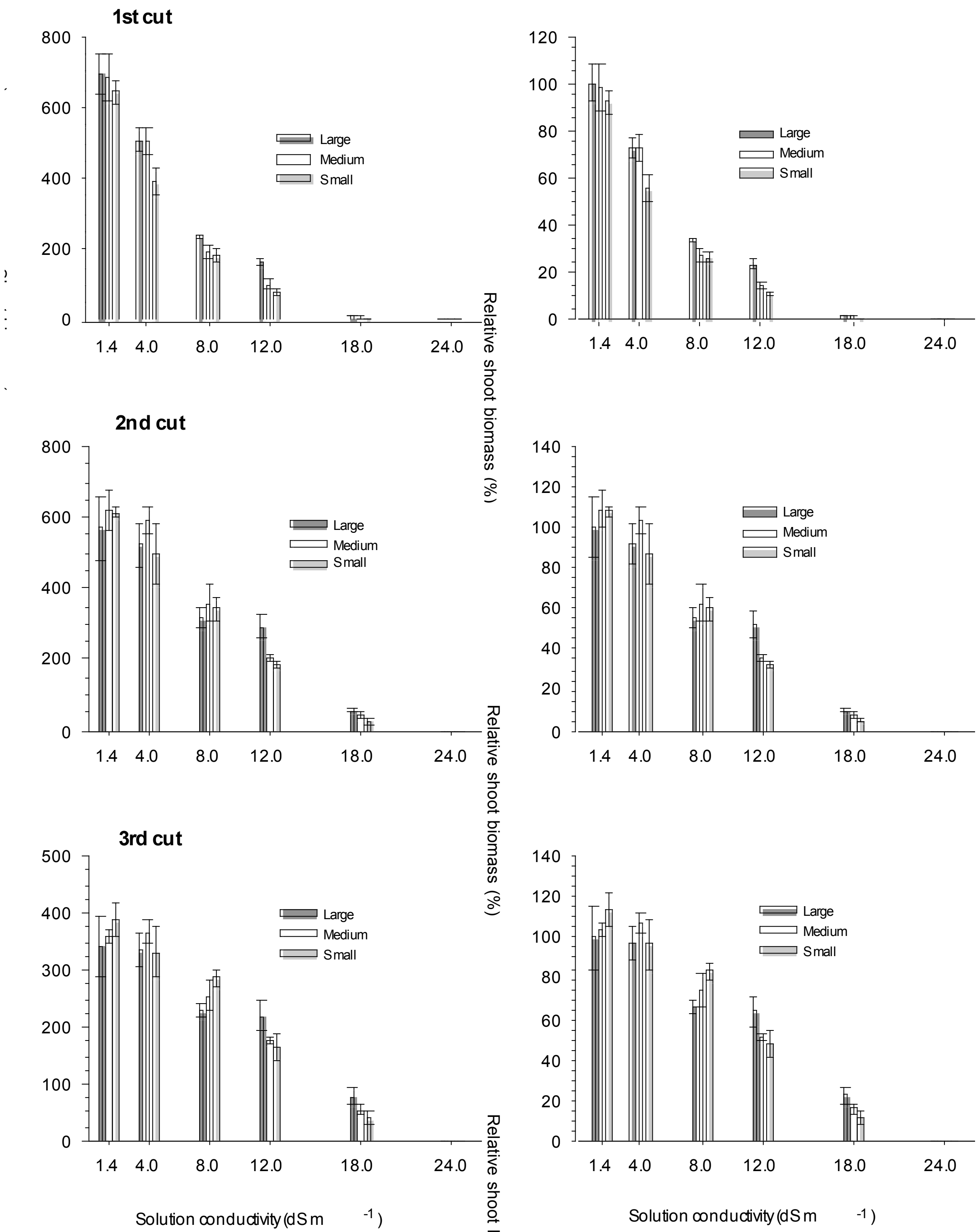

Figure 4. Actual and relative shoot biomass yields of Rangelander alfalfa, comparing three seed sizes (large, medium, and small) grown in saline rooting media with increasing solution conductivity; error bars indicate standard error.

Discussion

Likely, large alfalfa seeds planted in saline soils transfer greater vigour to their seedlings in comparison to the smaller seeds. And, this vigour likely promotes better hypocotyl growth despite the saline environment. The emergence and survival data clearly indicate that large-size seeds confer a degree of salinity tolerance to their emerging and developing seedlings. According to the plant height data, the benefits of large seeds seem to begin at emergence and continue to crop harvest. Also, the seed-size salinity-tolerance effect increases with the severity of the root-zone salinity, peaking near 12 to 18 dS m^{-1} for Rangelander alfalfa.

The answer to the question posed in the title of this study (Does seed size affect plant establishment and productivity of alfalfa in saline seedbeds?) is yes. Large seeds benefit seedling emergence and survival perhaps by as much as 23 %. Although no significant yield benefit was realized at the control treatment, forage production of large planted seeds tended to increase at all salinity treatments for the first cut. Second and third harvests revealed yield advantages for the large seeds at both the 12 and 18 dS m^{-1} saline environments. These emergence and production benefits, together with persistently taller crop heights likely reflect the establishment of larger root masses. Inherently, the largest benefit of seed-size to this crop occurs during the establishment year when the plants are more sensitive to root-zone salinity. However, these conclusions are based on one seed-lot, a simulated field environment, a uniform seed-size distribution, and the existence of constant, consistent levels of seedbed and root-zone salinity during the growth period. The primary impacts of the research conducted herein include: (1) the possibility of marketing larger alfalfa seeds for use in saline soils, (2) identifying a breeding trait (large seed size) for alfalfa improvement, and (3) suggesting further research pertaining to seed-size benefits.

References

Grieve, C.M. and L.E. Francois. 1992. The importance of initial seed size in wheat plant response to salinity. Plant and Soil 147:197-205.

Steppuhn, H. and K.G. Wall. 1999. Canada's salt tolerance testing laboratory. Can. Agricultural Engineering 41:185-89.

Waissman Assadian, N. and S. Miyamoto, 1987. Salt effects on alfalfa seedling emergence. Agron. J. 79(4):710-714.