Agriculture and Agri-Food Canada's Salinity Tolerance Testing Laboratory

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Background

Agricultural salinity refers to a state where dissolved constituents in soil-water solutions concentrate beyond the needs of the crop plants rooted in a soil. All natural waters contain dissolved solids and gases and, therefore, possess a degree of salinity. In fact, the growth of field crops depends on the dissolved nutrients contained within soil solutions. Problems develop when the concentrations of dissolved salts in root zones exceed those required by the plants. Salinity limits crop establishment, slows growth, and reduces yield. (Ayers and Westcot 1985) defined salinity as a problem that exists if the salts in a soil accumulate to concentrations that cause reductions in growth and crop yield for plants rooted in the soil. Thus, agricultural salinity refers to the effect of salinity (primarily those of root-zone solutions) on crop plants. The severity of the plant damage, or crop loss, defines the magnitude of the salinity problem. Conversely, the degree to which plant growth and crop yield remain unaffected by the root-zone salinity defines the salinity tolerance of the plants (Steppuhn and Wall 1999). The accumulation of white crusts on soil surfaces indicates that the crop will definitely produce significantly less, if at all, due to salinity. White crusts commonly appear on soils whose root-zone salinity has reached moderate and severe salt concentrations. Many Canadian crops, such as beans, camelina, peas, flax, and wheat, will decrease in productivity when grown in only slightly saline soils where the telltale white crusts rarely show (Figure 1). These salinity problems led Agriculture and Agri-Food Canada researchers at Swift Current to design, fabricate and operate a world class tolerance testing facility, primarily for determining salinity tolerance of Canadian crops.

Figure 1. Field showing yield variability due to salinity.

Importance of the Research

Across the prairies about 20 million out of 67 million ha (30%) of agricultural land either openly showed salinization (6 million ha) or were at risk of becoming salinized (Steppuhn 1996, and Wiebe et al. 2007) (Figure 2). As well soil samples sent to the Saskatchewan Soil Testing Laboratory during 1992, 1993, and 1994 possessing slight to moderate salinity, indicated an areal extent of low-level salinity extrapolated across the prairies on about 7 million ha of cropland and 3 million ha of permanent pasture (unpublished data from a collaborative study between SPARC and Plains Innovative Lab, Dr. R.E. Karamanos, Director). If for example, wheat was grown on 10.5 million ha across western Canada, and produced 22 million tonnes of grain valued, on average $287/t and the effects of slight to moderate salinity reduced yields by an

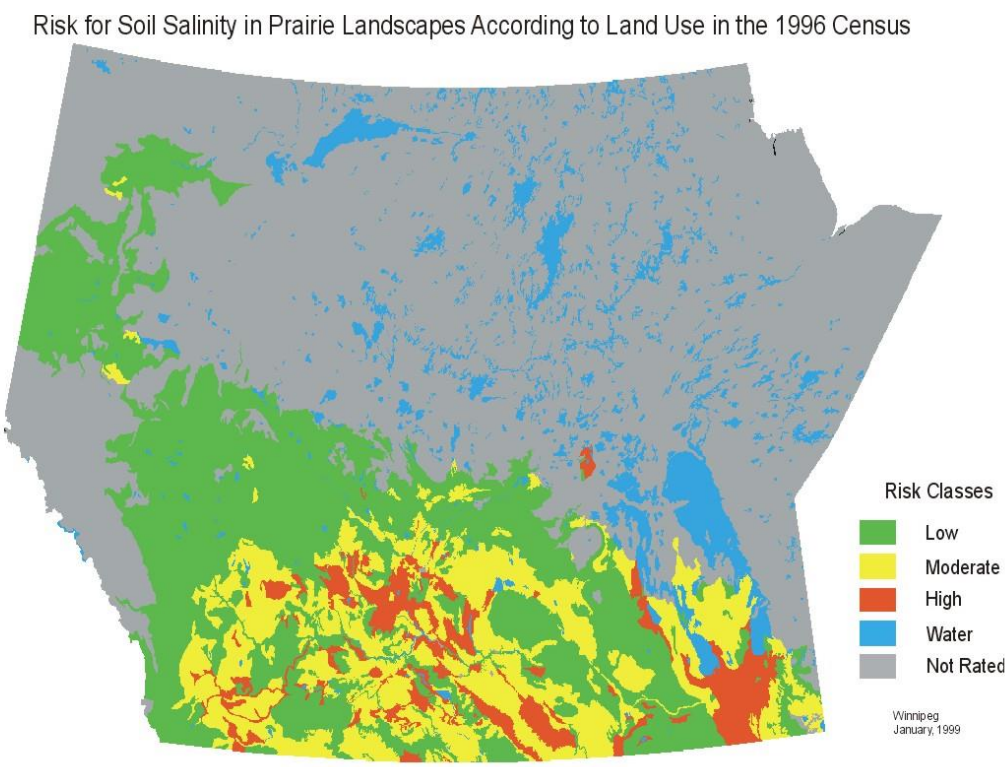

Figure 2. Taken from Wiebe, Eilers, Eilers, and Brierley, 2007.

average of 12% on 30% of this wheat acreage, the lost revenue would equal $226 million. If breeding efforts could reduce the reduction in yield to 8% the increase in income to producers would be substantial. There are only two salinity tolerance testing research facilities in North America, one located in Riverside, California U.S.A., and the facility at SPARC located in the northern prairies. The latter facility provides researchers the capability to evaluate crops for salinity tolerance specific to the semi-arid climate of the northern prairie region. Salinity tolerance testing in a field environment can be complicated by variable soil profile conditions such as texture, available soil moisture, nutrient levels, and salt content in the soil. As such, in extreme conditions, salinity levels in western Canadian soils can vary from very slight to very severe within a few metres (Eilers 1998), making replicated field trials difficult. The level of root-zone salinity can also vary with time and changes in the weather. Root-zone salt concentrations increase or decrease in response to infiltration of water from rainfall or snowmelt and to the loss of soil water by evapotranspiration. Such variability makes it impossible to evaluate the salt tolerance of crops in the field. In the Salinity Lab at SPARC, plants growing in sand tanks or cones and irrigated with hydroponics are subjected to constant concentrations of salts throughout the testing period and can thus be confidently evaluated for salinity tolerance.

One of the main roles of the Salinity Lab has been to test crops and varieties for their salinity tolerance to provide recommendations for farmers with salt-affected land. Most of the main agricultural crops grown on the Canadian prairies have been tested for and characterized for their salinity tolerance. However, as new varieties continue to be developed and new crops integrated into cropping systems, there will be a need to continue testing of new lines and cultivars. Crops that have been tested in the Salinity Lab include several different classes of wheat, including durum wheat, CWRS, CPS, SWS, barley, canola, camelina, as well as many Brassica sp. and some of the mustards. Many grasses and alfalfa cultivars and lines have been tested as well. Field testing has been conducted as part of some trials in order to attempt to verify lab results with field growing conditions.

Description

Researchers at the Semiarid Prairie Agricultural Research Centre, located at Swift Current, SK. recognized a need for an environmentally-controlled salinity testing facility. Their objective was to design and fabricate a world-class, salinity tolerance testing facility primarily for Canadian crops (Figures 3 and 4). Historically, crop salinity tolerance recommendations for Canadian agriculture were extrapolated from studies conducted at the United States Salinity Laboratory located in Riverside, California, USA. With the completion of Agriculture and Agri-Food Canada's Salinity Lab, it became one of only two such research facilities in North America.

Figure 3. AAFC's Salinity Tolerance Testing Facility (Salinity Lab) located at the Semiarid Prairie Agricultural Research Centre at Swift Current, SK.

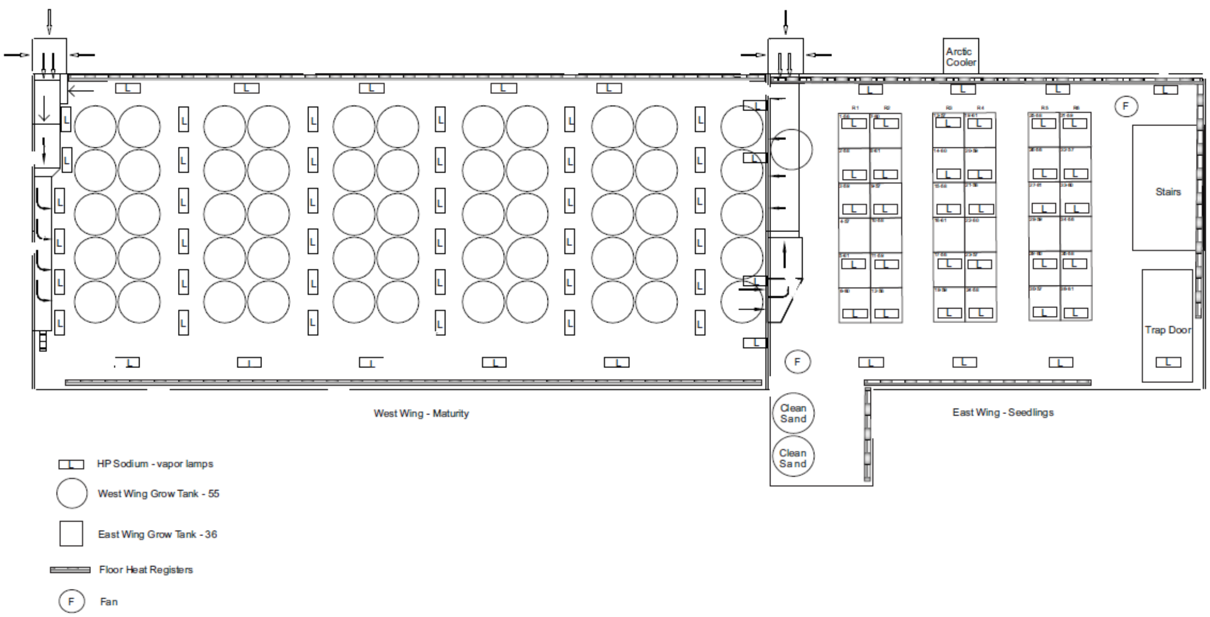

Figure 4. Overhead schematic, Salinity Tolerance Testing Facility (Salinity Lab) at Swift Current, SK.

The Salinity Lab facilitates the testing of crops at three different growth stages: (1) germinating seeds in a growth chamber (Figure 5), (2) seedlings in a small cone screening facility, capable of screening many genetic lines simultaneously "eastwing" (Figure 6), and (3) large sand grow tanks capable of growing crops to maturity (Steppuhn and Wall 1999) (Figure 7). The 55 large grow-tanks, 1.0 m tall and 0.95 m in diameter in the "westwing", are surface irrigated, bottom drained and supplied with solutions delivered individually from 55 separate

Figure 5. Growth chamber, for germinating seeds used for salinity tolerance testing.

Figure 6. View of grow tanks in the seedling wing and nutrient-brine supply tanks in the basement of AAFC's Salinity Lab.

storage tanks and effectively mimic field crop growing conditions (Figure 8). Tests can be conducted following any desired statistical design. Seeds (grown hydroponically) are placed in silica sand where the roots develop and anchor the plants. Nutrients and salts in solution periodically bathe the roots following preset irrigation and drainage schedules. The entire facility is housed in a thermally-controlled greenhouse.

Figure 7. Salinity Lab, grow tanks which are capable of growing crops to maturity. The dimensions of each tank are 1.0 m high by 0.95 m in diameter with a growing surface area of 0.57 m^2.

Recently the “seedling wing or eastwing” was redesigned and resulted in the construction of a cone/small pot screening facility. The sixty 8-L seedling pots were replaced with thirty-six 113-L square tanks (Figure 9). This redesign increases the lab’s capability to be very flexible in using several cone or small pot sizes with the capability of screening up to 3600 or more individual plants, depending on cone size used.

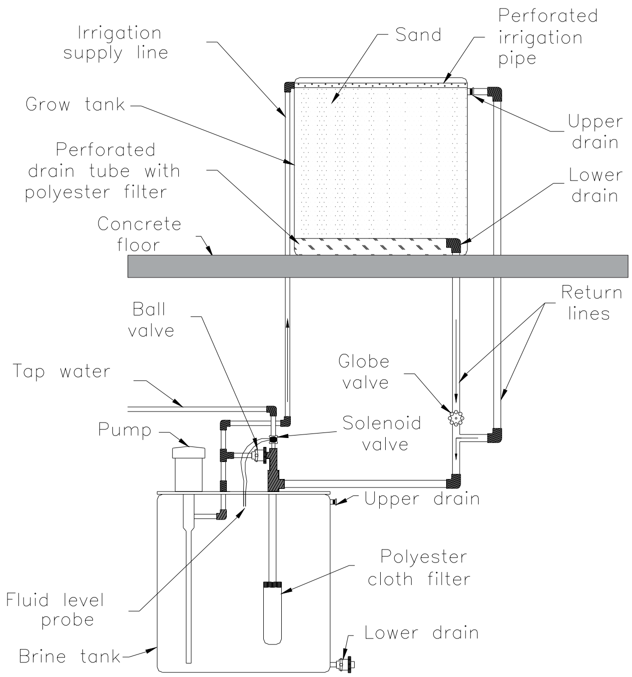

Figure 8. Side view of grow tanks and nutrient-brine supply tanks used to test crops grown to maturity.

Figure 9. Grow tanks in the Salinity Lab, newly renovated screening facility (East Wing).

Major Milestones:

- One of the initial major achievements which occurred in the Salinity Lab was work conducted by Dr. H. Steppuhn in determining that the salinity response function which consisted of a threshold linear slope function commonly used to evaluate crop tolerance to salinity did not accurately reflect the crop response to salinity. Ultimately it was discovered that a modified compound discount function more accurately described crop response to salinity (Figure 10). This led to re-working many of the results from the U.S. Salinity Lab and publishing two papers which have become the standard in salinity research (**Root-zone Salinity: I. Selecting a Product-Yield Index and Response Function for Crop tolerance,** and **Root-Zone Salinity: II. Indices for Tolerance in Agriculture Crops**). Using this function, researchers have developed salinity tolerance indices for crops tested at the U.S. Salinity Lab and Agriculture and Agri-Food Canada's Salinity Tolerance Lab.

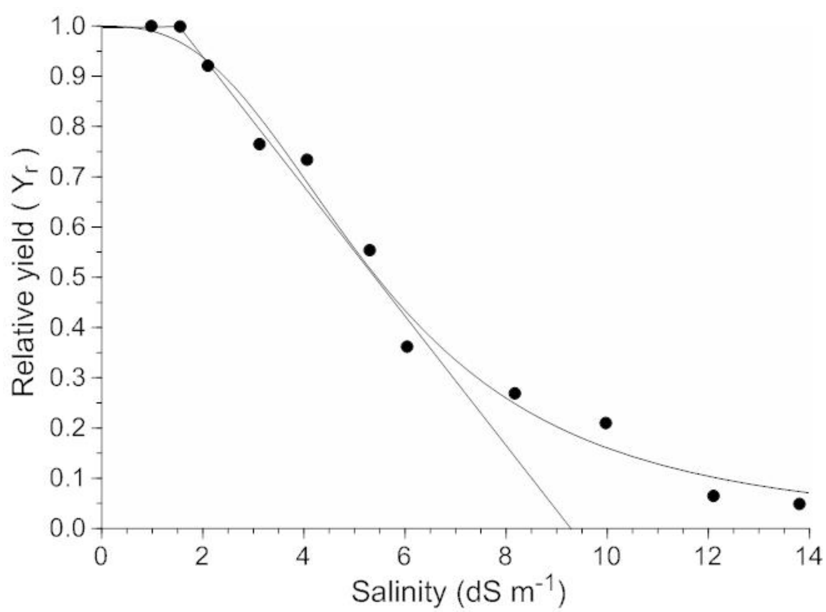

Figure 10. Example of a typical fit of crop response to salinity (Biggar CPSR wheat) using the modified compound discount function and the threshold linear slope function.

- Developed a salinity tolerant grass named green wheatgrass. Seed which occurred as a natural hybrid, originally obtained from Turkey was obtained from the ARS in Logan, Utah. Evaluations for resistance to root-zone salinity, winter hardiness, uniform plant color, vigor, leafiness and seed-set were conducted at the Salinity Tolerance Lab at SPARC. In 2006, "AC Saltlander" green wheatgrass was released (Steppuhn et. al. 1996). It is one of the most salinity tolerant grasses available and gives producers another valuable tool in economically utilizing salinity affected lands.

- Research by Dr. Surya Achara, a plant breeder at the Lethbridge Research Centre, led to the development of alfalfa populations with superior salinity tolerance. They were developed from several mass selections and outcrosses with salinity tolerant selections conducted in the Salinity Lab. As a result of this collaboration, the alfalfa variety Bridgeview was released. As well, several American varieties have been tested for salinity tolerance at the tolerance testing facility prior to release in Canada. Improving salinity tolerance in alfalfa is significant as it is a major forage crop across the prairies, has high water use capabilities and already possesses a degree of tolerance.
- Discovered that canola has similar salinity tolerance to that of barley.
- Hybrid canolas have more salinity tolerance than conventional canola.
- Camelina, although drought tolerant is significantly less salinity tolerant than canola.
- Characterized the salinity tolerance of many of the mainstream grasses seeded across the prairies.
- Through information developed at the lab regarding recommending and seeding forages for saline soils is a major contribution to the Saskatchewan Ministry of Agriculture's Forage Crop Production Guide.
- Salinity tolerance screening of many Brassica cultivars including *Brassica napus* (RR, LL, CL hybrids as well as open pollinated conventional cultivars and open pollinated CL varieties), *Brassica juncea* (brown, oriental and canola quality mustards), *Brassica rapa* (polish canola), and *Sinapis alba* (yellow mustard).
- Initiated and developed the use of sulphate based salts in testing crops to be grown in sulphate rich soils, rather than follow the conventional use of chloride salts.
- Conducted preliminary salinity tolerance testing of field pea, flax and bean cultivars, quinoa, kochia, several different classes of wheat, including durum wheat, CWRS, CPSR, SWS, and several barley cultivars.

New Research

With the retirement of AAFC's Senior Hydrologist, the Salinity Lab has taken a new direction. It has been converted to a service facility, accommodating the research needs and projects of scientists across AAFC's Science and Technology Branch as well as private industry. Currently, the most important focus of this facility is to provide the capacity to evaluate advanced breeding lines and germplasm in a controlled water use environment, thus determining the impact of nutrient use and salinity tolerance on plant growth and ultimately economic crop productivity. The agricultural sector is supported in the breeding and advancement of key agricultural crops and the evaluation and development of emerging crops such as *Brassica carinata*, camelina, and alfalfa and other forages often utilized in fields with higher salinity levels in the soil. Some of the latest collaborations include:

- Conducted a screening program of 190 camelina lines (PI-Dr. Margie Gruber) under slight and moderate salinity levels.
- Currently testing 30 lines of *Brassica carinata* for salinity tolerance under slight and moderate salinity levels (PI- Dr. Dwayne Hegedus).
- Currently involved in a project entitled "DNA Marker Technologies to Maximize Contributions of Forage Legumes to Sustainable Agriculture" (PI-Dr. Yves Castonguay). In this project, alfalfa plants were selected showing good salinity tolerance and poor salinity tolerance at a moderate salinity level from three cultivars, Apica frost tolerant line, Bridgeview, and Halo alfalfa. Four selections of salinity tolerant and non-tolerant plants, eventually producing Poly+4 and Poly-4 lines of alfalfa from each cultivar are planned. Each round of selected plants will be grown out and harvested for seed. The F4 seeds will be used in the identification of DNA polymorphisms and their validation of marker-assisted selections. This approach will hopefully detect useful associations and more rapidly enhance the production of more salt tolerant commercial cultivars.
- Conducted a salinity screening project under the proposal, "Genetic Improvement of Willows for Biomass and Environmental Applications", (PI-Dr. Raju Soolanayakanally). Screened 36 clones of willows at slight and moderate salinity levels.
- Under the ADF Project #20140152 "Development of Best Management practices for cost-effective and successful establishment of saline forages for Saskatchewan", conduct a flooding/salinity tolerance study for AC Saltlander green wheatgrass, (PI-Dr. Alan Iwaasa).

For further information regarding potential research collaborations please contact:

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