

SALT AND SODICITY TOLERANCE OF BARLEY, OAT AND SUGARBEET

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Barley and oats are some of the most salt and sodicity tolerant annual crops producers can profitably grow in North Dakota. At certain salinity and sodicity levels, even barley and oats can result in significant losses. Especially important are the levels of salinity and sodicity in the top six inches of the soils. To determine the economic threshold of soil salinity (Electrical Conductivity or EC) and sodicity (Sodium Adsorption Ratio or SAR) for barley, oats and other major annual crops, four barley and four oat varieties were planted at the Langdon REC site in 2024 at three different levels of soil salinity and sodicity. This trial-demonstration was a repeat of 2020-2023. Additionally, six sugarbeet varieties were added in 2024 to compare salinity and sodicity tolerances of sugarbeets versus barley and oat crops.

Soil Analysis Results

Two-foot deep composite soil samples separated into 0-6- and 6-24-inch depths were taken on April 11, 2024 from each level of salinity and sodicity by taking three cores for each sample. The three levels of salinity and sodicity were described as Levels 1, 2 and 3. Level 1 was described as having low to moderate levels of salinity and sodicity, Level 2 having moderate to high levels and Level 3 having very high levels based on the 0-6-inch depth soil EC and SAR results. These descriptions were based on the salinity and sodicity tolerances of annual crops of barley and oats and not the sensitive crops such as soybeans. Soil EC and SAR were analyzed by using the saturated paste extract method (Table 1).

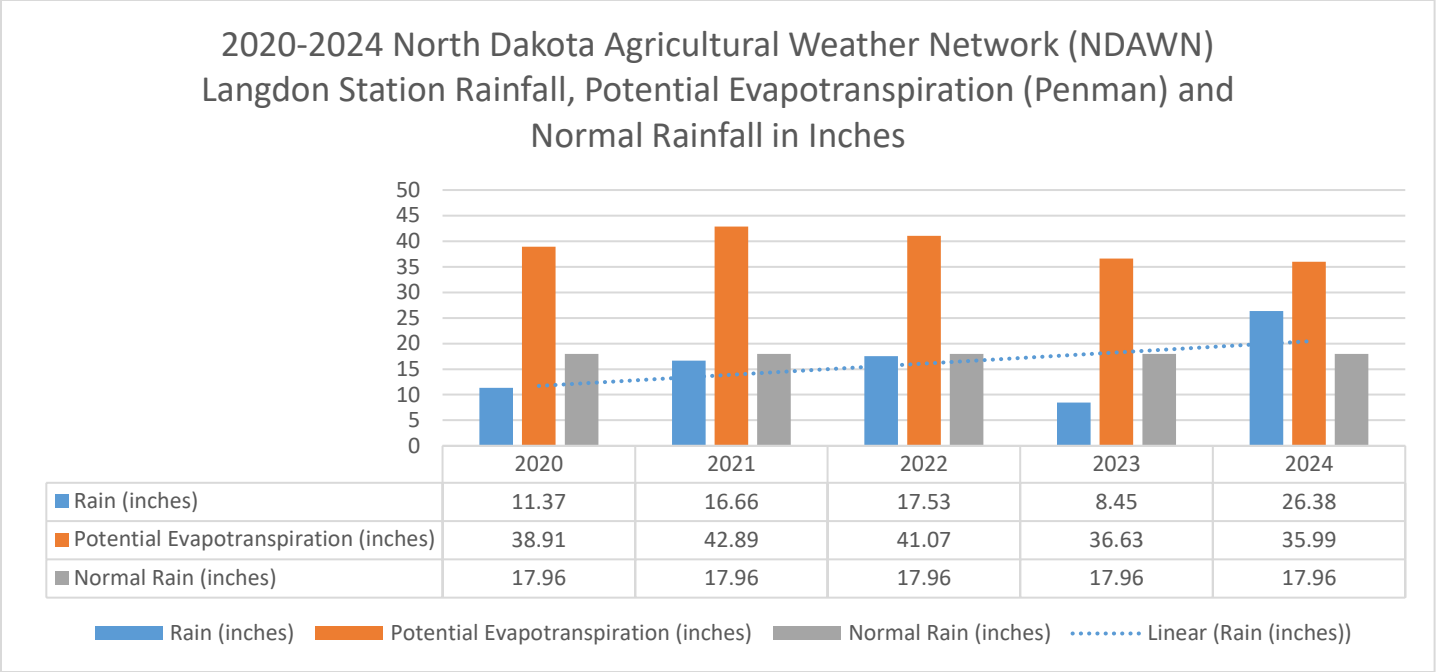
Table 1. The 2020-2024 soil EC and SAR results of the three levels for the 0-6- and 6-24-inch depths.

Site	Sample ID	Depth (inches)	EC (dS/m)					SAR				
			2020	2021	2022	2023	2024	2020	2021	2022	2023	2024
Level 1	Low to moderate salinity-sodicity	0-6	3.99	4.63	1.64	5.44	3.90	7.12	6.20	4.95	6.68	4.37
		6-24	7.32	7.49	6.70	8.02	6.57	15.05	14.72	15.50	12.52	16.05
Level 2	Moderate to high salinity-sodicity	0-6	7.80	13.20	7.92	10.30	7.40	18.13	22.88	16.28	17.07	18.18
		6-24	10.39	12.29	11.03	12.27	10.21	20.92	21.14	39.54	19.12	28.93
Level 3	Very high salinity-sodicity	0-6	10.50	14.90	11.21	11.99	9.37	27.30	32.74	30.00	22.06	28.87
		6-24	9.86	12.98	11.10	11.44	12.32	32.87	32.04	31.83	22.32	37.91

The main difference between the three levels has been the low to moderate salinity and sodicity levels in the 0-6 inch soil depth of Level 1, while Levels 2 and 3 had moderate to high and very high levels in the 0-6 and 6-24 inch depths. The 6-24 inch depth of Level 1 had moderate to high salinity and sodicity levels. The lower salinity and sodicity levels in the 0-6 inch depth of Level 1 and corresponding germination, stands, yields and quality in 2020-2024 indicate that the levels of salinity and sodicity in the surface layers (0-6 inch) are more important than the subsurface layers (6-24 inches).

Annual snowfall, resulting spring-melt and rainfall in spring and the early growing-season also had an impact on salinity and sodicity, especially in the 0-6 inch depths. The weather in 2020 was slightly drier for the Langdon area, 2021 was normal (spring and early growing-season), 2022 was wet (spring and early growing-season), 2023 was mostly dry and 2024 was wet again. In 2021 there was a slight increase in EC in all levels at the 0-6 inch soil depths versus 2020. Wet weather in 2022 resulted in slightly lower EC levels compared to 2021. Dry weather in 2023 resulted in the highest EC levels in the 0-6 inch depth in Level 1. Due to high rainfall in 2024, EC levels dropped slightly in the 0-6 inch depth of Level 1. Lower EC levels combined with high moisture availability in 2022 and 2024 spring and early growing-season resulted in improved germination, stands and higher yields even at higher salinity and sodicity levels compared to 2020, 2021 and 2023. Details of the annual 2020-2024 North Dakota Agricultural Weather Network (NDAWN) Langdon station rainfall, evapotranspiration (Penman) and normal rainfall for the periods of April 1 to October 31 are in Figure 1.

Figure 1. The annual 2020-2024 North Dakota Agricultural Weather Network (NDAWN) Langdon station rainfall, evapotranspiration (Penman) and normal rainfall for the periods of April 1 to October 31.



It is also very important to differentiate between timely rains resulting in optimum soil moisture versus excessive rains resulting in saturated, cool soils and drowned out areas, especially during germination and other critical growth stages. 2022 weather provided optimum soil moisture conditions, and 2024 weather resulted in saturated and cool soils and drowned out areas.

Plot Sizes, Planting and Harvesting Details

Plot sizes were 4.5 X 22 feet. Planting and harvest details are in Table 2.

Table 2. 2024 crop, variety, planting date, seeding rates and depth, fertilizer rate and harvest date information.

Crop	Variety	Planting Date	Seeding Rates (live seeds/acre)	Seeding Depth (inches)	Fertilizer Application (lbs./acre)	Harvest Dates
2024 Planting Details						
Barley	AAC Synergy (2-row)	June 13, 2024	1.0 million	1 to 1.5	10 pounds of AMS + 1.6 pounds of urease inhibitor treated urea was hand broadcasted and then incorporated with one-pass of a cultivator. A total of 2.8 pounds of N (10 pounds of AMS had 2.10 pounds of N + 2.40 pounds of SO4-S and 1.6 pounds of urea had 0.73 pounds of N) + 2.4 pounds of SO4-S was applied to Level 1 only.	Level 1, 2 and 3 barley and oats were straight combined on October 1, 2024.
	ND Genesis (2-row)		1.25 million			
	ND Treasure (6-row)					
	Tradition (6-row)					
Oat	CS Camden		1.0 million			
	ND Heart					
	Rockford					
	ND Spilde					
Sugarbeet	Seedex 1815		175-180 plants per 100-foot length			
	BTS 8927					
	BTS 8018					
	Hilleshog					
	Crystal 912					
	Crystal 793					

Results and Discussion

Similar to 2020-2023, there were differences between the three levels in seedbed, germination, plant growth and vigor, maturity, yield, and quality in 2024.

Differences in Seedbed

Similar to previous years, the seedbed was rough and cloddy with an increase in soil sodicity (Levels 2 and 3) compared to areas with low sodicity (Level 1) in the surface layers (0-6 inch depths). This effect has been decreasing every year due to continuous tillage, but was still observed in 2024. An increase in soil sodicity always resulted in wet, saturated and drowned out areas in cases of heavy rains. That was also evident from the field-readiness of each level for tillage or planting. On May 31, 2024 the low to moderate level seemed 100% ready in terms of soil moisture, moderate to high level seemed wet, and the very high salinity and sodicity level was very wet. See seedbed pictures 1-3 below for comparisons.



Pictures 1-3 from left to right: Differences in seedbed between Level 1 (low to moderate salinity-sodicity on left), 2 (moderate to high salinity-sodicity in the middle) and 3 (very high salinity-sodicity on right) on May 31, 2024.

Differences in Germination

There was no germination in the AAC Synergy and ND Genesis plots due to a very poor seed germination issue not related to seedbed, salinity or sodicity issues in Level 1 and Level 2. In Level 3, all four barley plots/varieties were drowned out right after planting and there was standing water in those plots for days (Figure 2).

Figure 2. Level 1 (furthest), Level 2 (in the middle) and Level 3 (closest) north side plots, were planted with barley varieties on June 18, 2024. Level 3 barley plots drowned out right after planting (June 13, 2024) for days, which resulted in zero germination in all plots.



There was standing water in tire tracks between the plots with saturated soil in the plots in Level 1. Level 2 and 3 barley plots were drowned on the north side of the trial area (Figure 2). It took Level 3 drowned out plots days to dry versus Level 2 drowned out plots resulting in no germination in Level 3 barley plots regardless of the variety. Tradition and ND Treasure germinated well in Levels 1 and 2. In Level 1, barley and oats started germinating 9-10 days after planting, and sugarbeet started germination 11-12 days after planting. In Level 2, barley and oats took 11-12 days to start germinating and sugarbeets 14-15 days. In Level 3, oats started germinating 9-10 days after planting, and sugarbeets took 14-15 days.

This pattern of germination between the three levels of salinity and sodicity was very similar to 2022, meaning higher soil moisture will result in rapid germination even at moderately high and very high salinity and sodicity levels in the surface layers (0-6-inch depth). Higher moisture levels at a level when soils are saturated or drowned out for days actually is detrimental to germination.

Differences in Growth, Vigor, Stands and Maturity

Early in the growing-season, barley always looks better than oats, however, oats catch up with time. Sugarbeets also germinated slower compared to barley and oats but looked much better with time. Due to the very poor seed germination issues for AAC Synergy and ND Genesis barley varieties, plots of these two varieties in Level 1 and Level 2 had zero germination. All four barley varieties had zero germination as plots drowned out due to heavy rain on saturated soil right after planting in Level 3. Oat plots germinated and had good stands in all three levels. All six sugarbeet varieties also had good stands in all three levels. Excess moisture resulted in good germination and stands in Level 2 and 3, but too much moisture resulted in standing water and saturated soil conditions that negatively affected germination, slowed growth and resulted in slightly less vigor, especially early in the growing-season. Later in the season, when there was adequate soil moisture and weather warmed up, oat and sugarbeet plots looked very good in Level 2 and Level 3. The oat plots in Level 3 seemed more mature compared to the Level 1 and 2 oat plots on September 5, 2024. In the past, Level 3 and Level 2 always matured late compared to Level 1. See pictures 4-6 showing barley, oat and sugarbeet stands growing in Level 1, Level 2 and Level 3 on September 5, 2024.



Picture 4. Barley (left), oat (middle) and sugarbeet (right) varieties growing in Level 1 on September 5, 2024.



Picture 5. Barley (right), oat (middle) and sugarbeet (left) varieties growing in Level 2 on September 5, 2024.



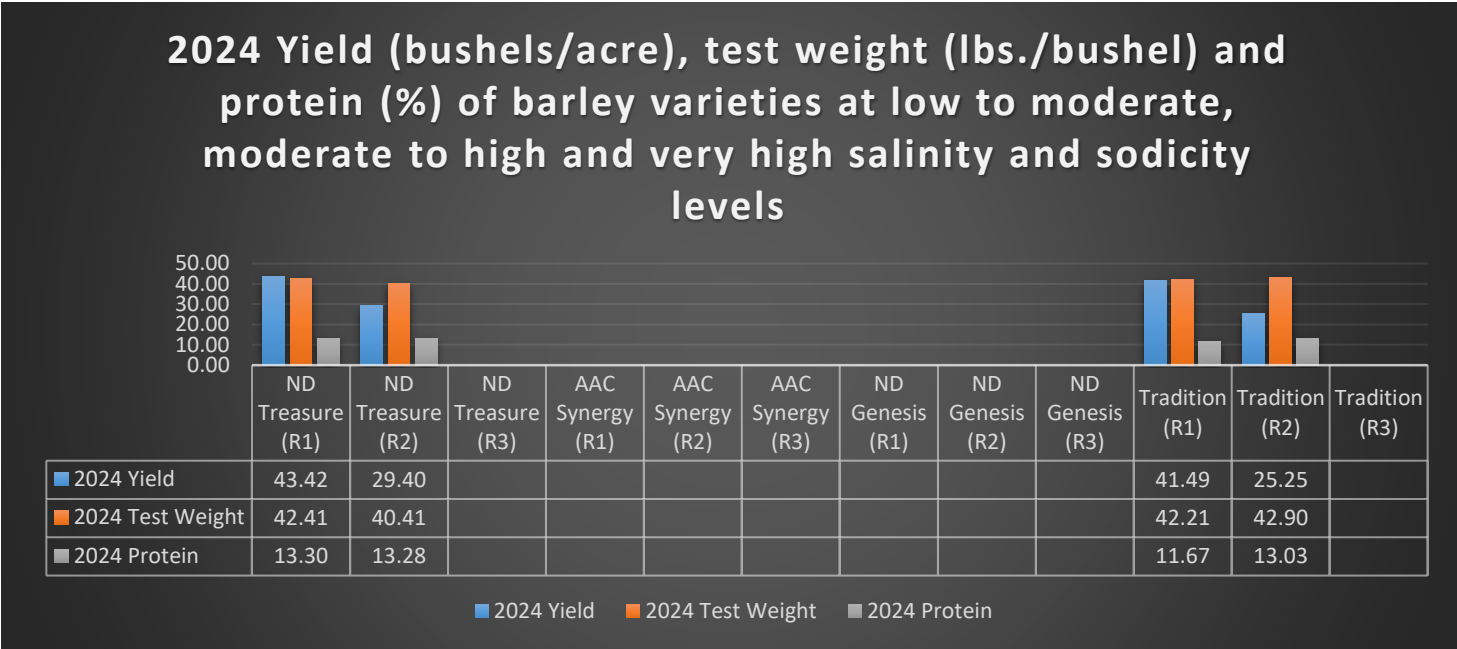
Picture 6. Barley (left), oat (middle) and sugarbeet (right) varieties growing in Level 3 on September 5, 2024.

Differences in Yield and Quality

Barley

The seed for AAC Synergy and ND Genesis varieties had zero germination, which was not known at the time of planting. No observations on these varieties were obtained at any level. In Level 3, ND Treasure and Tradition also had zero germination and zero yields. It was a low yielding year for barley in Level 1 and Level 2 despite high moisture levels during spring and growing-season, which was similar to 2022. The main difference between 2024 and 2022 was excess soil moisture instead of optimum soil moisture (26.38-inches versus 17.53-inches). That indicates increased soil moisture does help annual crops on saline and sodic areas. ND Treasure and Tradition yields in Level 2 were 32.28 and 39.14% lower compared to the yields of these two varieties in Level 1. These differences in yields between Level 1 versus Level 2 were better than 2020, 2021 and 2023 and were similar to 2022. Level 2 barley had slightly higher protein % than Level 1. Details are in Figure 3.

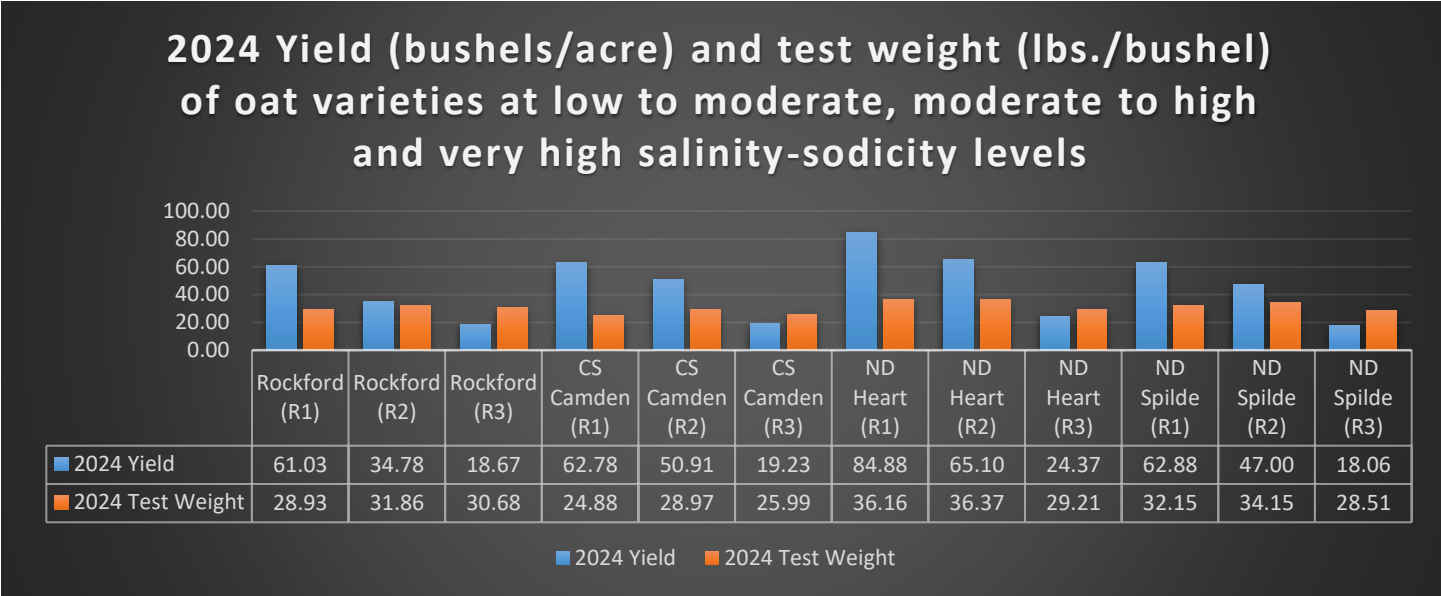
Figure 3. 2024 yield, test weight and protein of four barley varieties.



Oats

Yields of all oat varieties were lower than previous years, especially compared to 2022, which had increased but not excess soil moisture in the spring and early part of the growing-season. Increased soil moisture that does not lead to saturated soil conditions for longer periods of time results in improved germination and yield on saline and sodic soils. Overall, Level 2 yields were 18.90 to 43.01% lower compared to Level 1. Level 3 oat yields were 69.36 to 71.27% lower than the yields in Level 1. Level 3 oat yields were 46.31 to 62.56% lower than Level 2. Level 2 oats had the highest test weights compared to Level 1 and 3. Details are in Figure 4.

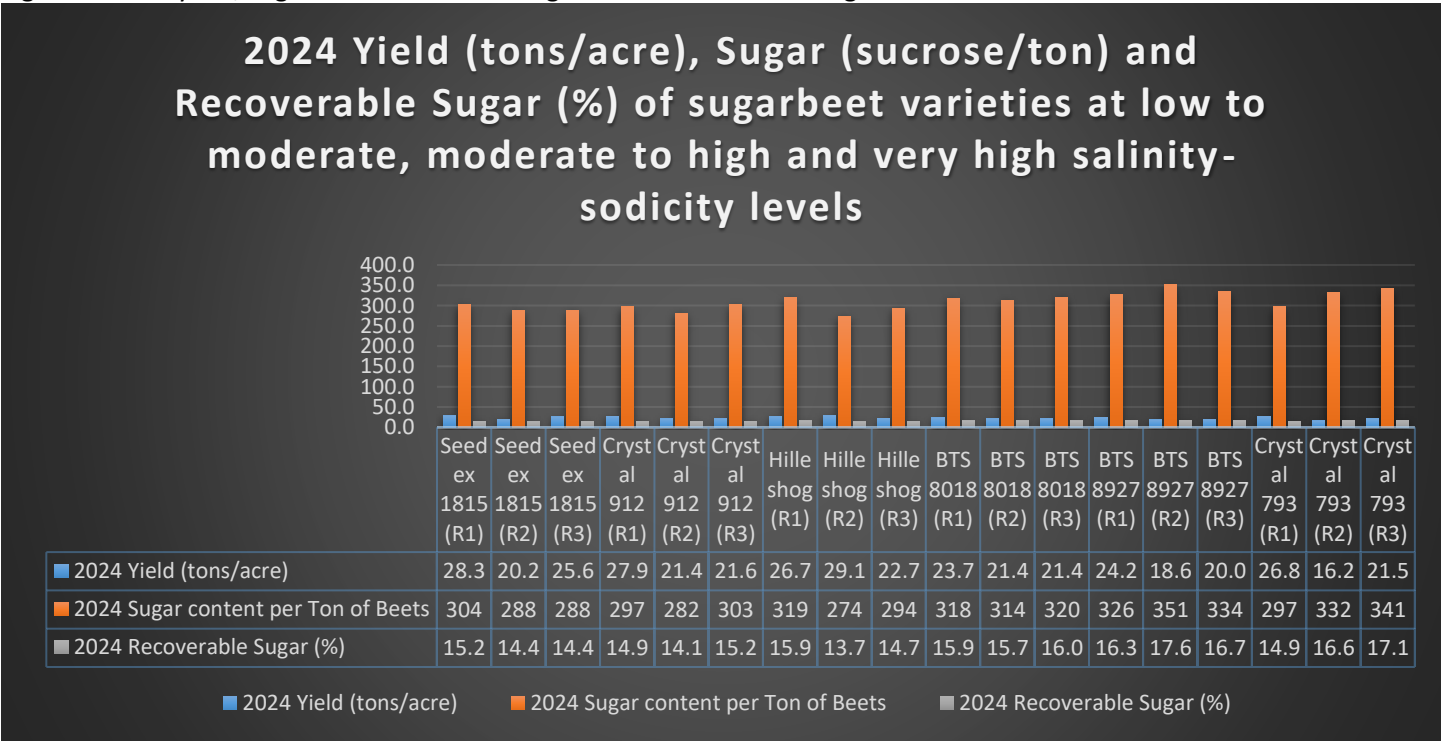
Figure 4. 2024 yield and test weight of four oat varieties.



Sugarbeet

All sugarbeet varieties performed well in all three levels of salinity and sodicity. Seedex 1815, Crystal 793, Crystal 912 and Hilleshog varieties were the highest yielding varieties out of the six sugarbeet varieties. All varieties produced roughly similar sugar contents per ton of beets and recoverable sugar percent. Details are in Figure 5.

Figure 5. 2024 yield, sugar and recoverable sugar contents of the six sugarbeet varieties.



Summary:

- Spring and early growing-season soil moisture levels have a significant impact on germination, growth, yield and quality even at moderately high and very high salinity and sodicity levels.
- Surface salinity and sodicity (0-6" depths) has more impact on germination, stand and yield than subsurface salinity and sodicity (6-24" depths).
- Excess soil moisture resulting in saturated soil conditions for extended periods of time negatively effects germination, stands and yield of salt-tolerant small grains such as barley and oats.
- Increased salinity results in delayed and uneven germination, poor growth and vigor, delayed maturity, yield and quality. An increase in sodicity results in poor seedbed, crusted surface layers, saturated soils and drowned out areas.
- Seed size and plant root structure matters when salinity and sodicity levels increase, especially in a dry growing-season. Bigger seed tends to germinate better through crusted soil surfaces and deeper tap roots help plants extract moisture from the deeper soil depths compared to shallow fibrous roots.
- All sugarbeet varieties have done very well at salinity and sodicity levels that are moderately high to very high in the 0-6-inch depths followed by sunflowers, oats and barley. Durum and canola can yield high at low to moderate levels of salinity and sodicity in the 0-6-inch soil depths, however, moderately high to very high levels negatively affect the yield and quality of these crops.