

# SALT AND SODICITY TOLERANCE OF BARLEY, OAT AND DURUM

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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. However, 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. Sensing the need to determine the economic threshold of soil salinity (Electrical Conductivity or EC) and sodicity (Sodium Adsorption Ratio or SAR) for barley and oats, four barley and four oat varieties were planted at the Langdon REC site in 2021 at three different levels of salinity and sodicity. This trial was a repeat of 2020 trial. In addition, three durum varieties were added to the trial in 2021 to compare salinity and sodicity tolerances of the durum varieties side by side with barley and oats.

## Soil Analysis Results

Two-foot deep composite soil samples separated into 0-6 and 6-24 inch depths were taken on May 20, 2020 and April 23, 2021 by taking three cores for each sample. The three levels of salinity and sodicity were recognized as replications 1, 2 and 3 and were sampled separately. Replication 1 was described as having low to moderate levels of salinity and sodicity, replication 2 having moderate to high levels and replication 3 having very high levels. These descriptions were based on the salinity and sodicity tolerance of crops like barley and oats. However, these levels would be considered high for sensitive crops such as soybean. Soil EC, SAR and pH were analyzed by using the saturated paste extract method (Table 1), whereas, standard methods were used to analyze NO<sub>3</sub>-N, P and K (Table 2).

Table 1. The 2020 and 2021 soil EC, SAR and pH results of the three replications for the 0-6 and 6-24 inch depths.

Site	Sample ID	Depth (inches)	EC (dS/m)	EC (dS/m)	SAR	SAR	pH	pH
			2020	2021	2020	2021	2020	2021
Rep 1	Low to moderate salinity-sodicity	0-6	3.99	4.63	7.12	6.20	7.18	7.54
		6-24	7.32	7.49	15.05	14.72	7.71	7.97
Rep 2	Moderate to high salinity-sodicity	0-6	7.80	13.20	18.13	22.88	7.61	8.17
		6-24	10.39	12.29	20.92	21.14	7.95	8.21
Rep 3	Very high salinity-sodicity	0-6	10.50	14.90	27.30	32.74	7.59	8.14
		6-24	9.86	12.98	32.87	32.04	7.81	8.16

The soil EC levels of 0-6 and 6-24 inch depths in replication 1 remained roughly the same in 2020 and 2021. However, EC levels of replication 2 and 3 had an increase in 2021 in both soil depths versus 2020. That could be due to the drier weather and resulting increase in capillary rise of soil water in 2021. Despite some differences in soil SAR levels in 2021 versus 2020, changes were mostly inconsistent. The 2021 soil pH results remained higher than 2020. That could be due to the differences in soil moisture levels at the time of soil sampling in 2021 versus 2020.

Table 2. The 2020 and 2021 soil NO<sub>3</sub>-N, P and K results of the three replications for the 0-6 and 6-24 inch depths.

Site	Sample ID	Depth (inches)	NO <sub>3</sub> -N (lbs/A)	NO <sub>3</sub> -N (lbs/A)	P (ppm)	P (ppm)	K (ppm)	K (ppm)
			2020	2021	2020	2021	2020	2021
Rep 1	Low to moderate salinity-sodicity	0-6	5	37	20	15	299	450
		6-24	6	24	5	4	137	115
Rep 2	Moderate to high salinity-sodicity	0-6	6	53	29	24	247	350
		6-24	6	24	2	4	148	200
Rep 3	Very high salinity-sodicity	0-6	5	46	51	32	270	330
		6-24	6	27	4	6	169	180

All three replications showed an increase in available soil nitrate-nitrogen levels in 2021 versus 2020. That could be the residual nitrogen due to the application of 120 pounds of N applied in the spring of 2020 at the time of planting barley and oats. Before 2020, a mix of perennial salt-tolerant grasses was growing at the site with no fertilizer application since 2013. Soil P levels showed a moderate decrease in 2021 as no P was applied in 2020. Soil K levels in 2021 showed a slight increase versus 2020. Like pH, that could be due to the differences in soil moisture levels at the time of soil sampling.

## Trial Design, Plot Sizes, Planting and Harvesting Details

Trial design was randomized split block and plot sizes were 4.7 X 22 feet. Details are in Table 3.

Table 3. 2020 and 2021 barley, oat and durum varieties, planting dates, seeding rates and fertilizer rates per acre, planting depths, and harvest dates.

Crop	Variety	Planting Date	Seeding Rates (live seeds/acre)	Seeding Depth (inches)	Fertilizer Application (lbs./acre)	Harvest Date
<b>2020 Planting Details</b>						
Barley	AAC Synergy (2-row)	June 1, 2020	1.25 million live seeds per acre	1 to 1.5	Based on soil NO <sub>3</sub> -N, P and K analysis a uniform rate of 120 lbs. of N was applied through Urea to all three replications.	September 15 (rep 1) and 23 (rep 2 and 3), 2020
	ND Genesis (2-row)					
	Pinnacle (2-row)					
	Tradition (6-row)					
Oats	CS Camden		1.00 million live seeds per acre			
	ND Heart					
	Rockford					
	Souris					
<b>2021 Planting Details</b>						
Barley	AAC Synergy (2-row)	May 13, 2021	1.00 million live seeds per acre	1 to 1.5	Based on soil NO <sub>3</sub> -N, P and K analysis, replication 1 received an NPK rate of 59-26-0, replication 2 received 43-20-0 and replication 3 received 47-20-0 pounds per acre through Diammonium Phosphate on the morning of May 13, 2021.	September 8, 2021
	ND Genesis (2-row)		1.25 million live seeds per acre			
	Pinnacle (2-row)					
	Tradition (6-row)					
Oats	CS Camden		1.00 million live seeds per acre			
	ND Heart					
	Rockford					
	Souris					
Durum	ND Stanley	1.50 million live seeds per acre				
	Divide					
	Joppa					

## Results and Discussion

There were significant differences between the three replications starting from seedbed preparation, seed germination, plant growth and vigor, maturity to yield, and quality.

### Differences in Seedbed

In 2020 and 2021, the seedbed was very mellow in replication 1, whereas, it started getting hard and cloddy with the increase in sodicity in replication 2 and 3. It seemed that sodicity had a prominent effect on seedbed quality, which is consistent with what sodicity does to soil aggregates and resulting structure and pore space. See seedbed pictures 1-3 below for comparisons.



Pictures 1-3: Differences in seedbed between replication 1 (low to moderate salinity-sodicity), 2 (moderate to high salinity-sodicity) and 3 (very high salinity-sodicity) on June 1, 2020.

### **Differences in Germination**

In 2020 and 2021, germination was delayed in replication 2 and 3 compared to replication 1 due to the increase in soil salinity and sodicity levels. That was a result of decreased soil water due to salinity and poor seedbed due to sodicity. In addition, both years, barley completed germination three to five days earlier than oats and was more vigorous than oats initially. Despite slightly slower growth early on, oats did catch up with barley and had similar or better growth. Durum germination was even slower than oats in 2021.

In 2020, barley and oat germination in replication 1 started around seven days after planting (June 8<sup>th</sup>) and completed in about eleven days (June 11<sup>th</sup>). In replication 2, germination started around June 16<sup>th</sup> and completed around June 23<sup>rd</sup>. So, replication 2 germination was eight to twelve days delayed compared to replication 1. In replication 3, all four barley varieties had zero germination, whereas, some oat seeds started germinating around June 29<sup>th</sup>.

In 2021 as well, barley and oats started germinating around seven to eight days after planting in replication 1, whereas, it took durum around nine to ten days to start germinating. Germination for barley and oats completed around thirteen days after planting (May 26<sup>th</sup>), whereas, durum took three to four more days to complete germination. Germination in replication 2 was about 10 days delayed compared to replication 1 and barley, oats and durum (only Joppa and ND Stanley varieties) started germinating around seventeen days after planting. Germination completed in all four barley and oat plots around 22 days after planting (June 3<sup>rd</sup>). In durum plots, ND Stanley had decent germination (70-80%), whereas, Joppa had poor germination (10-15%). Divide durum variety had zero germination. In replication 3, barley and oats started germinating 22 days after planting (June 3<sup>rd</sup>) and completed germination around 28 days after planting (June 9<sup>th</sup>). All durum varieties had zero germination in replication 3.

### **Differences in Growth, Vigor and Maturity**

Like germination, increase in salinity and sodicity negatively affected vigor of barley, oat and durum plants and delayed growth stages and maturity.

In 2020, on July 17<sup>th</sup>, average barley plant heights in replication 1 were 21.1 to 27.7 inches with 5 to 100 percent heading completed. Oat plant heights were 22.2 to 25.5 inches with 80 to 90 percent heading completed. In replication 2, barley plant heights ranged between 10.0 to 15.5 inches with no heading initiation. Oat plant heights in replication 2 were 9.1 to 15.2 inches with 5 percent heading completed only in the ND Heart plot. No data was taken from replication 3 due to no barley and very negligible growth of oats.

In 2021, on June 28<sup>th</sup>, average barley heights in replication 1 were 17.7 to 19.9 inches with zero heading initiation. Average oat plant heights were 12.3 to 17.6 inches and plants were in late boot growth stage. Durum plant heights ranged between 14.3 to 15.7 inches and crop growth stage was jointing. In replication 2, barley heights were 8.8 to 11.1 inches and growth stages were tillering to early boot. Oat heights were 5.1 to 10.1 inches with growth stages of five-leaf, tillering and early boot. Heights of ND Stanley and Joppa (durum) were 8.0 and 8.6 inches with growth stages of tillering to five-leaf. In replication 3, barley heights were 5.5 to 6.6 inches with growth stage of four to five-leaf. Oat heights were 6.1 to 8.8 inches with growth stage of five-leaf to tillering. There were no durum plants in replication 3.

It is important to note that despite some germination initially in replication 2 in 2021, ND Stanley and Joppa plants did not produce any quantifiable yields (zero to three grams per plot). Same was true for all four barley varieties in replication 3,



which did germinate initially, however, did not produce any yield in 2021. In 2020, all four barley varieties had zero germination in replication 3. Oat varieties did produce very low yields in replication 3 in 2020 and 2021. However, in 2021, Rockford, CS Camden and Souris did not yield at all in replication 2, which had slightly lower salinity and sodicity levels compared to replication 3. That could be caused by a difference in salinity and sodicity levels within replication 2.

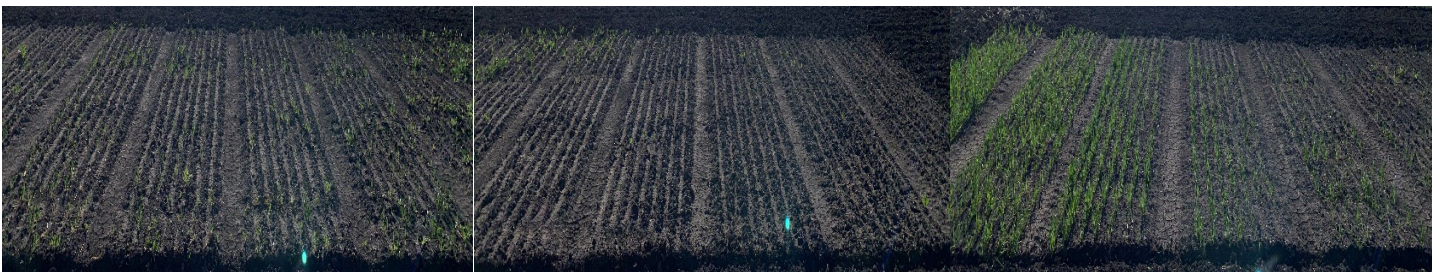
See pictures 4-12 below of replication 1, 2 and 3 to compare the differences in vigor of barley, oat and durum plots.



Pictures 4-6: Barley, durum and oat varieties growing in replication 1 (low to moderate salinity-sodicity) on June 24, 2021.



Pictures 7-9: Barley, durum and oat varieties growing in replication 2 (moderate to high salinity-sodicity) on June 24, 2021.



Pictures 10-12: Barley, durum and oat varieties growing in replication 3 (very high salinity-sodicity) on June 24, 2021.

### **How did Barley and Oats Survive High Levels of Salinity and Sodicity?**

It was observed that barley and oat plants adapted to different salinity and sodicity levels by keeping the bulk of the roots in the top six inches of soil instead of growing into the deeper depths where salinity and sodicity levels were high to very high. That was especially true for replication 1 that had low to moderate levels in the 0-6 inch depth and moderate to high levels in the 6-24 inch depth. However, once surface salinity and sodicity reached moderately high to very high levels in replication 2 and 3, germination and growth was poor to negligible.

### **Differences in Yield and Quality**

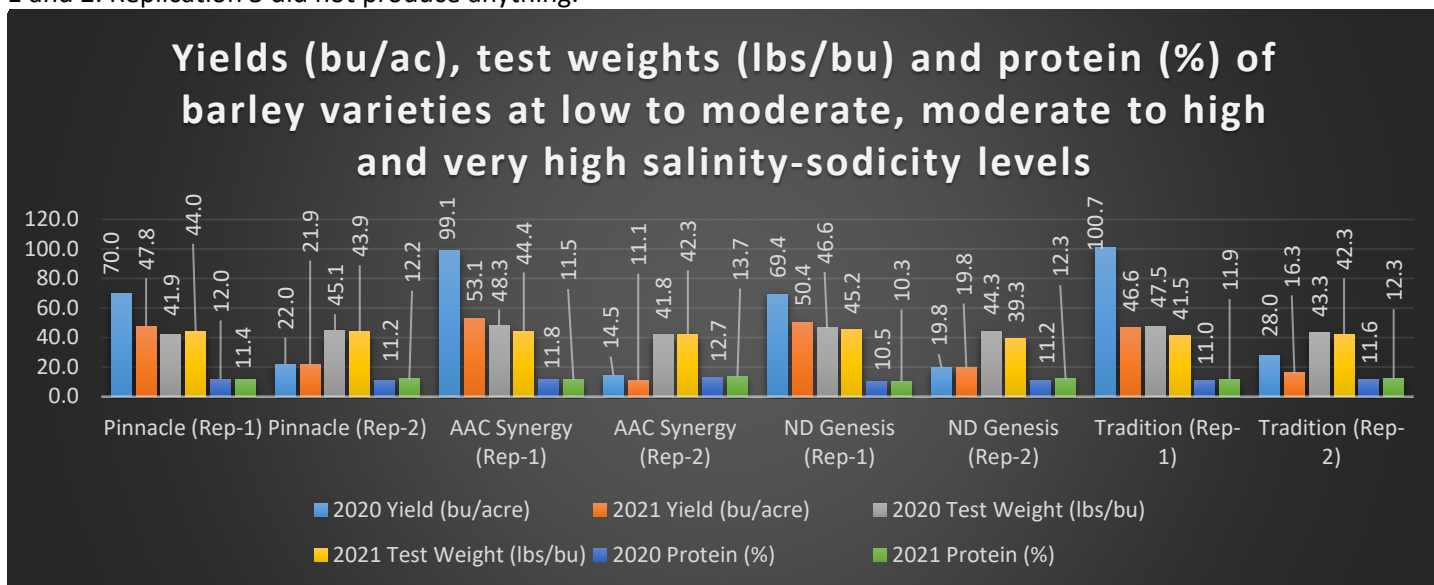
#### **Barley**

In 2020, average barley yield of replication 1 was 84.8 bu./acre versus 21.1 bu./acre of replication 2. That was a 75 percent reduction in yield (Figure 1). Replication 1 also had five percent higher average test weight compared to replication 2. However, average protein of replication 2 was slightly higher (0.36 percent) than replication 1. Replication 3 resulted in 100 percent loss. Tradition (six-row) barley had the highest yields in replications 1 and 2 versus the other three two-row varieties.

Due to dry weather in 2021, barley yields were lower than the 2020 yields. In addition, there was some shattering in barley plots. The average barley yield of replication 1 in 2021 was 49.4 bu./acre versus 17.2 bu./acre of replication 2. That was a 65 percent reduction in yield (Figure 1). Average barley test weight of replication 1 was also 4.1 percent higher than replication 2. However, protein percent of replication 2 was 11.8 percent higher than replication 1. Despite some barley germination in replication 3, all barley varieties did not yield anything.

The differences in yield and quality of barley varieties in 2020 and 2021 were very similar. The main difference was the change in weather.

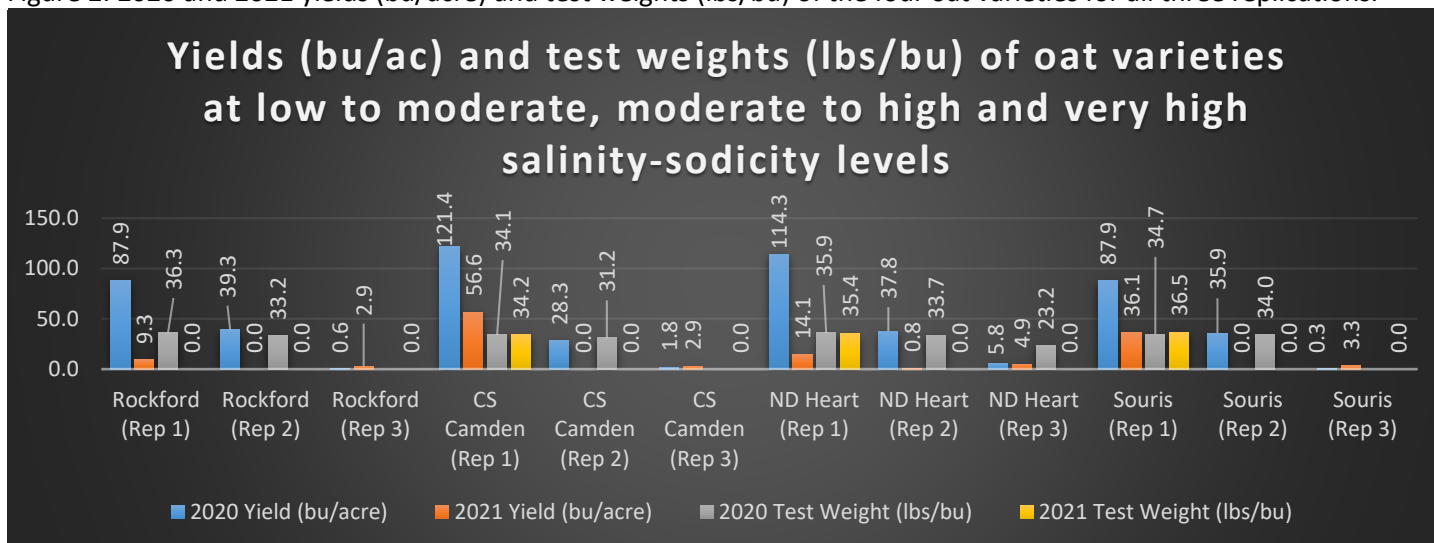
Figure 1. 2020 and 2021 yields (bu/acre), test weights (lbs/bu) and protein (%) of the four barley varieties for replications 1 and 2. Replication 3 did not produce anything.



### Oats

In 2020, average oat yield of replication 1 was 102.8 bu/acre versus 35.3 bu/acre of replication 2 and 2.1 bu/acre of replication 3. That was 65 and 98 percent reduction in yields (Figure 2). Also, replication 1 had 6.3 and 83.5 percent higher average test weight than replications 2 and 3. One key observation was that oats had some growth in replication 3, whereas, barley had zero growth pointing to a slightly higher salt-sodicity tolerance of oats compared to barley.

Figure 2. 2020 and 2021 yields (bu/acre) and test weights (lbs/bu) of the four oat varieties for all three replications.



Like barley, oat yields in 2021 were lower due to dry weather. However, oat plots had significant shattering, in some cases at least 30 to 40 percent. Shattering in oat plots was much more severe than the shattering that happened in barley plots.



See pictures 13-14 below of replication 1 and 3 to compare the level of shattering in oat plots in 2021. Oat growth in replication 2 was negligible.



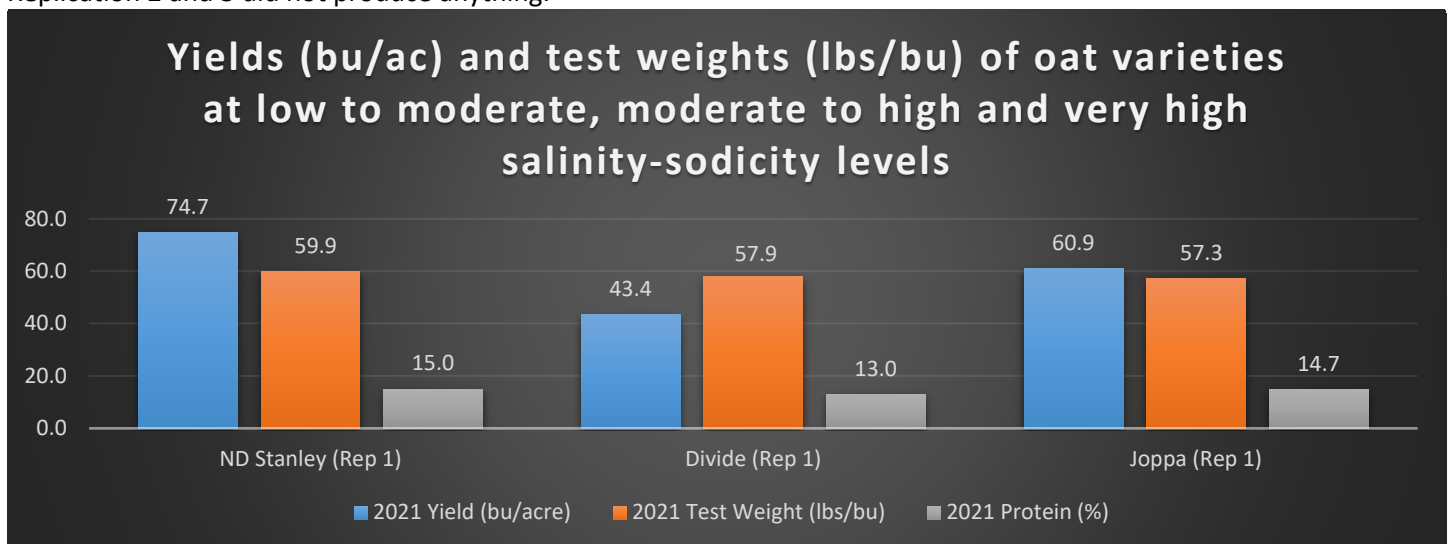
Pictures 13-14: Shattering in oat plots in replication 1 (low to moderate salinity-sodicity) and 3 (very high salinity-sodicity) on September 8, 2021.

In 2021, average oat yield of replication 1 was 29.0 bu/acre versus 3.5 bu/acre of replication 3 (Figure 2). That was a nearly 88 percent reduction in yield. In replication 2, it was only possible to record yield for ND Heart, which was 0.8 bu/acre. Rockford, CS Camden and Souris yielded zero in replication 2, which had slightly lower salinity and sodicity levels compared to replication 3. That could be a difference in salinity and sodicity levels within replication 2. Since there was not enough oats to record test weights for replication 2 and 3, no comparisons could be made between the replications for test weights.

**Durum**

The average 2021 durum yield for replication 1 was 59.6 bu/acre with an average test weight of 58.3 lbs/bu and average protein percent of 14.2 (Figure 3). ND Stanley yielded the most by producing 74.7 bu/acre, had the highest test weight (59.8 lbs/bu) and protein percent (15.0). Replications 2 and 3 resulted in 100 percent loss.

Figure 3. 2021 yields (bu/acre), test weights (lbs/bu) and protein (%) of the three durum varieties for replications 1. Replication 2 and 3 did not produce anything.





## Summary:

- It is very important that crops receive close to normal rain at crucial growth stages, especially during the early growing-season. Drier than normal weather conditions create further competition for water between plants and salts and drought effects can be severe at same salinity (EC) and sodicity (SAR) levels in dry years (Picture 15) versus a year in which rain would be just adequate.
- Uneven germination in the spring resulted in uneven maturity and delayed harvest. In addition, harvest was delayed for another 10 days due to wet weather in August. During that time high winds caused significant shattering, especially in oats.
- Generally, at EC levels of 4.00 to 4.50 dS/m and SAR of 7.00 to 7.50 in the 0-6 inch soil depths, both barley and oats can produce high yields and quality. Increased EC and SAR levels in the topsoil may result in significant economic losses.



Picture 15: A saline and potentially sodic headland in Cavalier County on April 29, 2021.