Is it Economical to Fertilize a Mature Forage Stand on a Severely Saline Site? Preliminary Results.

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Introduction

Agriculture and Agri-Food Canada scientists recently released 'AC Saltlander' green wheatgrass (Elymus hoffmannii Jensen & Asay), a perennial forage with salinity tolerance approaching and equal to that of tall wheatgrass (Thinopyrum ponticum (Podp) Lui & Wang) (Steppuhn and Asay 2005; Steppuhn et al. 2006). Green wheatgrass has shown excellent potential for use in vegetating saline soils. Consequently, AC Saltlander ranks among the few perennial forage species with potential for suppressing foxtail barley and other salinity tolerant weeds at all salinity levels, offering potential as a low-cost, pesticide reduced control. According to results from controlled testing, AC Saltlander can grow in saline root zones measuring well into the severe range.

Salinity slows crop growth (Shannon et al. 1994). This tends to reduce crop yield, especially for crops growing within the short growing seasons of the Northern United States and the Canadian Prairies (McKenzie 1988). Soils naturally contain water-soluble salts, many of which are used as nutrients by plants. However, in saline soils, these salts can accumulate to levels high enough to adversely affect plant growth. The major effect of salinization on plants is due to the increase of the osmotic potential of the soil solution which reduces the ability of plants to absorb water and nutrients (Bresler et al. 1982).

Although there are several different mechanisms that cause salinity, a common denominator is a shallow water table, saturated near surface soil profiles, and a moisture deficit environment. As the water at or near the soil surface evaporates, it leaves the salts behind (Hendry and Buckland 1990). Capillary action brings more water to the soil surface, and as it evaporates salts begin to accumulate in access. The driving force is soil moisture gradients generated by high evapotranspiration rates during the drier midsummer months. To stop this process the hydrologic connection between the soil surface and the water table must be broken. Growing salinity tolerant forage plants and depleting the near surface profile of water is one solution. Establishing plants on many of these saline sites, however, can be a challenge. If, and when, successful establishment is attained, producers are often reluctant to break up and reseed a mature stand of forage, even though yields tend to diminish over time. Reduced forage production on a field over time can be a result of several factors (Springer 1999):

- Decline in fertility;
- Unfavorable weather, particularly drought, untimely rainfall or frost;
- Soil related problems due to salinity, texture, poor water infiltration, or poor drainage; and
- Long-term management problems, which have resulted in the loss of desirable species and invasion of undesirable species.

Often it is a combination of these factors that result in declining forage production over time. Table (1) lists criteria used to assess the health and condition of tame pastures and hayfields which can be used as a tool to determine management practices and potential rejuvenation considerations to be implemented.

Table 1. Seeded pasture and hayland condition classes. (Modified from G. Ehlert, Alberta Agriculture, Food and Rural Development, 1990.

Condition		Criteria
Excellent	1.	At least 90 percent of the production coming from desirable species.
	2.	Vigour of desired species high.
	3.	Density of desired species is moderate (optimum)
		* maintain management practices.
Good	1.	75-89 percent of production coming from desirable species.
	2.	Vigour of desired species high.
	3.	Density of desired species is moderate (optimum)
		* maintain management practices.
Fair	1.	50-74 percent of production coming from desirable species.
	2.	Vigour of desired species medium to low.
	3.	Density of desired species is too high or too low.
		* requires rejuvenation and changes in management.
Poor	1.	Less than 50 percent of production coming from desirable species.
	2.	Vigour of desired species low.
	3.	Density of desired species is too low.
		* requires rejuvenation and changes in management.

A severely to very severely saline field near Swift Current had initially been seeded to AC Saltlander green wheatgrass in the spring of 2009. Excellent establishment was achieved and considering the severity of the salinity, the forage yields in 2010 and 2011 were beyond expectations, averaging 575.7 and 622.1 g/m^2 respectively (Figure 1). Moisture conditions were good to excellent each year. By 2012, even though moisture continued to be above average, forage yields began to decline. In 2013, yields declined again by almost 50% from the previous year to 263.2 g/m^2, even though 152 mm of precipitation fell during April, May and June. Since the condition of the forage according to Table (1) was rated as “good to excellent” and at least 90 percent of the production was coming from the green wheatgrass, fertilization was a viable option as a management tool to increase the productivity of this stand. As well, since this site is classed as severely to very severely saline, breaking and reseeding would be risky with a high chance of failure.

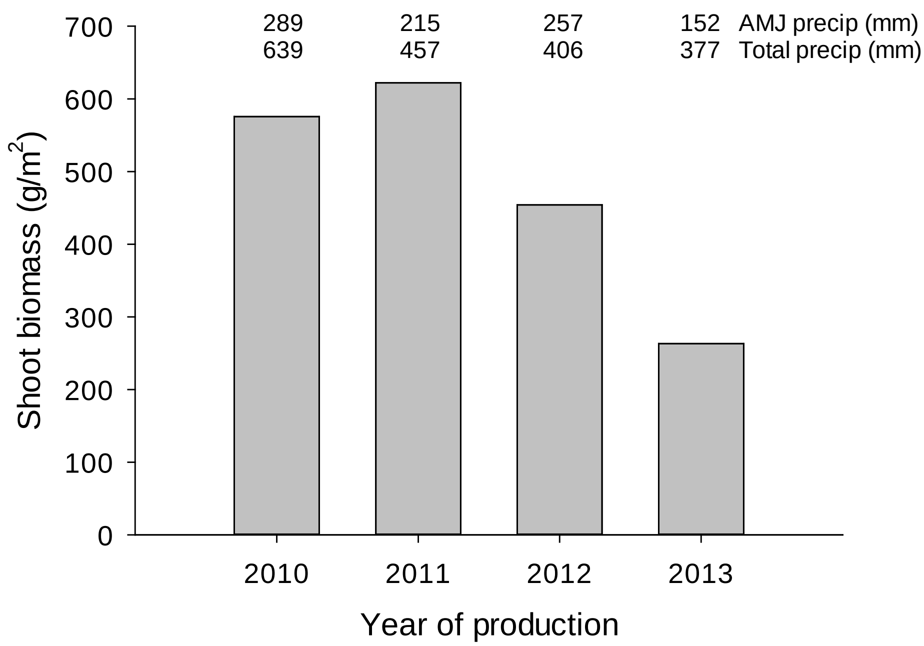

Figure 1. Mean yearly above-ground biomass (g/m^2) of AC Saltlander green wheatgrass seeded onto a severely saline site at Swift Current Research and Development Centre, North Farm. Site was originally seeded May 12th, 2009.

Objective

The objective of this study was to compare the productivity, economics and feed quality of two one-time fertilizer applications with a control treatment on a mature stand of green wheatgrass on a severely saline site.

Methods

A site located at the Swift Current Research and Development Centre (SCRDC) North Farm (SE 32-15-13 W3) was seeded in 2009. It was characterized as very severely saline (Table 2a & b and Table 3). Although differences in electrical conductivity were noted across plot replications (Table 3), the differences were non-significant for the test treatments (Table 2a and b). At any rate, the electrical conductivity of all reps and fertilizer applications was classified well into the severe range. Two treatments (nitrogen applications) were applied to plots measuring 6 feet wide by 40 feet in length (1.83 metres by 12.20 metres) (Figure 2). These were compared to check plots which received no nitrogen, except for that which was applied with the 11-52-0 (all plots received a broadcast application of 50 kg/ha of 11-52-0 as a source of phosphate). Each treatment was replicated 4 times. The nitrogen applications were 50 kg/ha of actual N (108.7 kg/ha of 46-0-0) and 150 kg/ha of actual N (326.1 kg/ha of 46-0-0). All fertilizer was broadcast on May 22nd, 2014. Soil samples were taken prior to application of the fertilizer. The average pH of the test site was 8.40 as measured from soil samples taken May 22nd, 2014 and 7.96 as measured from samples taken October 28th, 2015. Following the 2015 harvest, the plots were characterized for relative salinity to a depth of 0.75 metres using an EM38, a non-contacting electromagnetic induction meter using the horizontal dipole mode (Figure 2). To assess significance of treatments, soil electrical conductivity and nutrient levels, data were analyzed using the paired means student's t-test within an analysis of variance by the SAS institute, Inc. (2009).

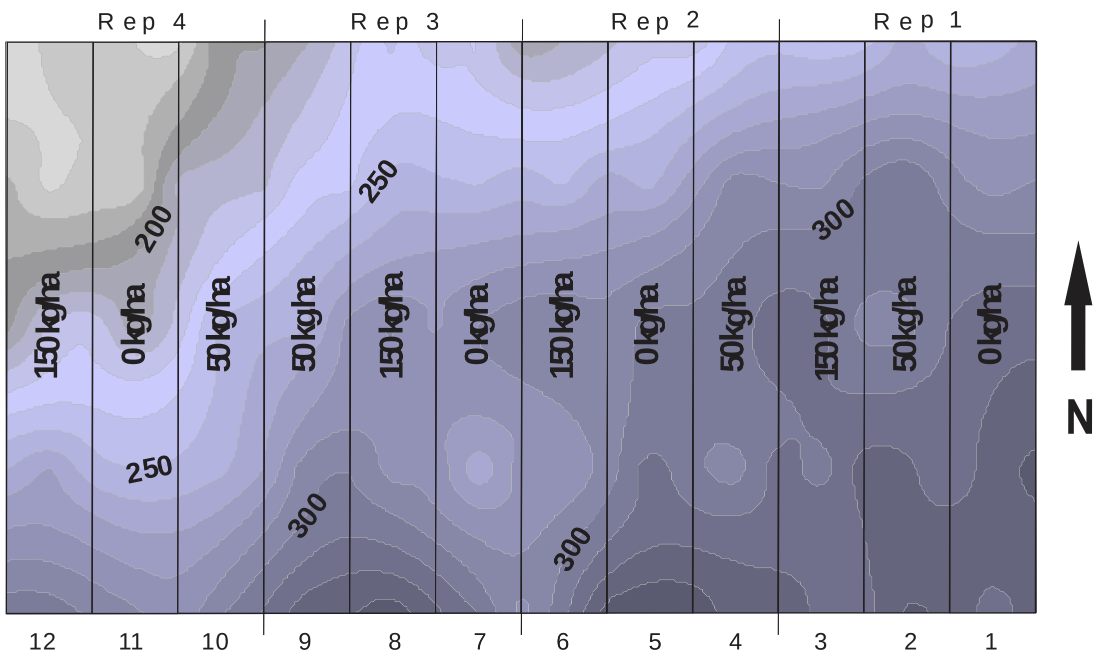

Figure 1. Plot layout and relative salinity map of AC Saltlander green wheatgrass fertility study located at the Swift Current Research and Development Centre (SCRDC) North Farm (SE 32-15-13 W3). Plot dimensions are 1.83 m by 12.20 m. Relative salinity was characterized July 17th, 2015, to a depth of 0.75 metres using an EM38 non contacting electromagnetic induction meter in the horizontal dipole mode.

Results and Discussion

Soil samples at this site were taken May 22nd, 2014, April 16th, 2015 and October 28th, 2015. Electrical conductivity and pH were measured May 22nd, and October 28th. NO_3-N, PO_4-P and K were measured on all three sampling dates. Soil sampling consisted of three cores taken per plot. Sampling depths were 0-15, 15-30, and 30-60 cm. Table (4a) indicates that there were no differences in the initial level of NO_3-N in the soil profile across plot treatments prior to fertility applications in 2014. Significant differences, however, were noted across replications (Table 5). This is to be expected, considering the inherent variability associated with many salinity sites across the Canadian prairies. As Table (4b) indicates, one year following the fertility application to this site, much of the NO_3-N has been lost, used or tied up by the existing plant roots. Since a typical forage grass crop uses 16 kg of N per tonne of forage produced it can be estimated that 45, 56 and 56 kg/ha of N were removed in the 2014 growing season from the control, 50 kg/ha and 150 kg/ha treatments respectively. During the 2015 season 23, 29 and 33 kg/ha of N would have been removed respectively. The 150 kg/ha treatment shows only a slightly higher level of NO_3-N compared to the 50 kg/ha rate and the control treatment. As Table (5) indicates, the differences across replications had all but disappeared by the spring of 2015, likely owing to volatilization, the mobility of NO_3-N in the soil, the amount used in forage production or tied up in the roots.

The phosphorus levels as shown in Tables (6 and 7) were at ample levels, as would be expected with a severely saline site. Although slight differences were noted in 2014 across treatments, no differences were measured from the soil cores extracted in 2015. The potassium levels as noted in Tables (8 and 9) were high, which also would be expected on a severely saline site. Although some differences were noted across replications, the levels were more than adequate to meet crop requirements.

Table 2a. Average saturated soil paste extract electrical conductivity (EC_e) from samples taken May 22nd 2014 (0-60 cm).

	Conductivity EC_e (dS/m)				
N Applied Kg/ha	Rep 1	Rep 2	Rep 3	Rep 4	Average
0	20.3^{a}	19.8^{a}	18.2^{a}	16.3^{a}	18.7^{a}
50	21.7^{a}	20.4^{a}	17.4^{a}	16.0^{a}	18.9^{a}
150	21.1^{a}	19.2^{a}	17.8^{a}	15.3^{a}	18.4^{a}
RMSE	2.6	3.4	3.2	3.0	3.4
Prob > F	0.79	0.91	0.95	0.93	0.93

Table 2b. Average saturated soil paste extract electrical conductivity (EC_e) from samples taken October 28th 2015 (0-60 cm).

	Conductivity EC_e (dS/m)				
N Applied Kg/ha	Rep 1	Rep 2	Rep 3	Rep 4	Average
0	17.5^{a}	19.1^{a}	19.5^{a}	14.4^{a}	17.6^{a}
50	18.5^{a}	19.8^{a}	18.2^{a}	17.5^{a}	18.5^{a}
150	20.3^{a}	20.0^{a}	19.7^{a}	16.2^{a}	19.0^{a}
RMSE	2.8	3.6	2.6	4.2	3.3
Prob > F	0.53	0.95	0.77	0.68	0.58

* Significance at the 0.05 α error level. Values within each column followed by the same lower case letter do not differ significantly at P $\alpha \leq 0.05$ according to the paired means Student's t – tests.

Table 3. Average saturated soil paste extract electrical conductivity (EC_e) from samples taken May 22nd 2014 and October 28th 2015 (0-60 cm).

	Conductivity EC_e (dS/m)	
Replication	2014	2015
1	21.0^{a}	18.8^{ab}
2	19.8^{ab}	19.6^{a}
3	17.8^{bc}	19.1^{a}
4	15.9^{c}	16.0^{b}
RMSE	2.7	3.1
Prob > F	0.002*	0.08

* Significance at the 0.05 α error level. Values within each column followed by the same lower case letter do not differ significantly at P $\alpha \leq 0.05$ according to the paired means Student's t – tests.

Table 4a. Average soil nitrogen (NO_3-N) levels, from samples taken May 22nd 2014 (0-60 cm).

	NO_3-N (kg/ha)				
N Applied Kg/ha	Rep 1	Rep 2	Rep 3	Rep 4	Average
0	24.6[a]	17.4[a]	24.6[a]	16.6[a]	20.8[a]
50	20.2[a]	19.6[a]	23.0[a]	16.1[a]	19.7[a]
150	22.6[a]	20.5[a]	27.1[a]	19.5[a]	22.4[a]
RMSE	2.2	3.1	2.8	2.5	4.0
Prob > F	0.13	0.49	0.26	0.29	0.26

Table 4b. Average soil nitrogen (NO_3-N) levels, from samples taken April 16th 2015 (0-60 cm).

	NO_3-N (kg/ha)				
N Applied Kg/ha	Rep 1	Rep 2	Rep 3	Rep 4	Average
0	13.7[a]	15.4[a]	16.8[a]	14.7[a]	15.1[a]
50	12.6[a]	18.5[a]	13.7[a]	13.7[a]	14.6[a]
150	24.0[a]	21.5[a]	14.1[a]	12.7[a]	18.1[a]
RMSE	11.4	11.0	6.5	2.7	8.1
Prob > F	0.45	0.80	0.83	0.70	0.53

* Significance at the 0.05 α error level. Values within each column followed by the same lower case letter do not differ significantly at P $\alpha \leq 0.05$ according to the paired means Student's t – tests.

Table 5. Average soil nitrogen (NO_3-N) levels, from samples taken May 22nd 2014 and April 16th 2015 (0-60 cm).

	NO_3-N (kg/ha)	
Replication	2014	2015
1	22.5[a]	16.8[a]
2	19.2[b]	18.5[a]
3	24.9[a]	14.9[a]
4	17.4[b]	13.7[a]
RMSE	2.9	8.1
Prob > F	0.0001**	0.62

* Significance at the 0.05 α error level. Values within each column followed by the same lower case letter do not differ significantly at P $\alpha \leq 0.05$ according to the paired means Student's t – tests.

Table 6. Average soil phosphorus (P_2O_5) levels in kg/ha, from samples taken May 22nd 2014 and April 16th 2015 (0-60 cm).

	P_2O_5 kg/ha	
Replication	2014	2015
0	451.3[a]	403.7[a]
50	384.9[ab]	381.7[a]
150	346.4[b]	380.3[a]
RMSE	95.8	69.1
Prob > F	0.04*	0.65

* Significance at the 0.05 α error level. Values within each column followed by the same lower case letter do not differ significantly at P α ≤ 0.05 according to the paired means Student's t – tests.

Table 7. Average soil phosphorus (P_2O_5) levels in kg/ha, from samples taken May 22nd 2014 and April 16th 2015 (0-60 cm).

	P_2O_5 kg/ha	
Replication	2014	2015
1	360.6[a]	364.2[a]
2	427.4[a]	371.3[a]
3	399.5[a]	406.9[a]
4	389.3[a]	411.8[a]
RMSE	104.6	67.5
Prob > F	0.60	0.34

* Significance at the 0.05 α error level. Values within each column followed by the same lower case letter do not differ significantly at P α ≤ 0.05 according to the paired means Student's t – tests.

Table 8. Average soil potassium levels (K_2O) in kg/ha, from samples taken May 22nd 2014 and April 16th 2015 (0-60 cm).

	K_2O (kg/ha)	
Replication	2014	2015
0	2671.3[a]	2775.7[a]
50	2737.1[a]	2876.8[a]
150	2846.7[a]	2800.9[a]
RMSE	399.2	467.1
Prob > F	0.56	0.86

* Significance at the 0.05 α error level. Values within each column followed by the same lower case letter do not differ significantly at P α ≤ 0.05 according to the paired means Student's t – tests.

Table 9. Average soil potassium levels (K_2O) in kg/ha, from samples taken May 22nd 2014 and April 16th 2015 (0-60 cm).

	K_2O (kg/ha)	
Replication	2014	2015
1	2551.9[b]	2565.4[b]
2	2643.7[b]	2657.2[b]
3	2783.3[ab]	2940.3[ab]
4	3027.9[a]	3108.2[a]
RMSE	366.1	417.1
Prob > F	0.05*	0.03*

* Significance at the 0.05 α error level. Values within each column followed by the same lower case letter do not differ significantly at P $\alpha \leq 0.05$ according to the paired means Student's t – tests.

The plots were harvested for biomass on July 9th, 2014 and July 17th, 2015. Four sub-plots, measuring 2 feet by 2 feet (61 centimetres by 61 centimetres) in size, were hand harvested in each plot. The foxtail barley and green wheatgrass biomasses were separated, oven-dried and weighed. Growing conditions were generally favorable with 189 mm of precipitation recorded for April, May and June. The total precipitation recorded at the SCRDC met site for 2014 was 456 mm. Although above-ground biomass increased significantly with the application of the urea, there were no differences between the 50 kg/ha and the 150 kg/ha applications (Figure 3 and Table 10). The control treatment averaged 281 g/m^2 and the 50 and 150 kg/ha treatments averaged 349 and 348 g/m^2 respectively. The foxtail barley yield in the sward showed no differences between treatments. The percentage biomass of foxtail barley in the stand was 3.6%, 2.3% and 4.2% for the control, 50 kg/ha and 150 kg/ha treatments respectively (Table 11).

In 2015, however, differences were noted between all three treatments. Precipitation wise, it was a very challenging year as only 39 mm of precipitation was recorded during the months of April, May and June, most of that being recorded during the last few days of June. The total moisture received for the year was 356 mm. The biomass for the control treatment was 141 g/m^2, the 50 kg/ha treatment biomass totalled 182 g/m^2 and the 150 kg/ha treatment averaged 208 g/m^2 (Figure 4 and Table 10). Even though the differences were only significant between the 150 kg/ha and the control treatment, a trend toward an increase in above-ground biomass yield was observed with each nitrogen application. As expected, during a period of drought, the foxtail barley portion of the biomass increased. Although the differences were not significant, the trend was for a lower foxtail barley yield as the rate of nitrogen was increased (Figure 4 and Table 10). The percentage of foxtail barley in the stand ranged from 27.5 for the control treatment, 18.0 for the 50 kg/ha treatment and 14.9 for the 150 kg/ha treatment (Table 11).

Table 10. Mean 2014 and 2015 above-ground biomass of AC Saltlander green wheatgrass (GWG) and foxtail barley (FTB) under three different nitrogen application treatments at Swift Current Research and Development Centre, North Farm.

	Above-ground biomass (g/m^2)			
N Applied Kg/ha	GWG 2014	FTB 2014	GWG 2015	FTB 2015
0	281.0[a]	9.3[a]	140.5[a]	50.1[a]
50	348.6[b]	7.7[a]	181.8[ab]	42.0[a]
150	348.2[b]	13.3[a]	208.3[b]	38.7[a]
RMSE	58.3	19.0	66.7	44.7
Prob > F	0.002*	0.69	0.02*	0.76

* Significance at the 0.05 α error level. Values within each column followed by the same lower case letter do not differ significantly at P α ≤ 0.05 according to the paired means Student's t – tests.

The question that still needs to be answered is, is it economical to apply fertilizer to a mature forage stand on a severely saline site? In 2014, the price of a tonne of hay hovered around $100. When converting the biomass yields from g/m^2 to kg/ha, the treatment with only P_2O_5 applied, produced on average $309.10/ha. The 50 kg/ha application produced $383.46 worth of feed while the 150 kg/ha application produced $383.02/ha. If the producer was fortunate enough to purchase his fertilizer in the fall of 2014, the cost was $520 per tonne for the 46-0-0 and $620 for the 11-52-00. When the cost of the nitrogen is subtracted, the 50 kg/ha treatment produced the highest return, while the 150 kg/ha treatment produced the lowest return per hectare. In 2015, however, due to the drought in southern Saskatchewan, feed prices increased to about $154/tonne. Despite the low yields, the returns per hectare were still significant. Combining the returns from both seasons, the 50 kg/ha is the highest with a return of $637.74/ha, the 150 kg/ha application return was $626.73, while the control treatment returned $525.47/ha.

If the producer purchased the urea in the spring of 2014, however, at a cost of $795 per tonne, results indicate only the 50 kg/ha application was economical after the first harvest (Table 12). Two harvests following the fertilizer application, both treatments exceeded the control. The 50 kg/ha treatment, however had a higher return than the 150 kg/ha. The cost of the 11-52-0 was $830 per tonne in April of 2014.

Table 12. Average revenue in $ per hectare. Net revenue expressed as the revenue minus the cost of the nitrogen fertilizer. 2014 feed price = $110/tonne, 2015 feed price = $154/tonne.

Fertilizer purchased in the fall of 2013 ($520/tonne)					
N Applied Kg/ha	Cost of N $/ha	2014 Revenue $/ha	**2014 Net $/ha**	2015 Revenue $/ha	**2 Year Net $/ha**
0	0.00	$309.10	**$309.10**	$216.37	**$525.47**
50	$25.69	$383.46	**$357.77**	$297.97	**$655.74**
150	$77.07	$383.02	**$305.95**	$320.78	**$626.73**
Fertilizer purchased in the spring of 2014 ($795/tonne)					
0	$0.00	$309.10	**$309.10**	$216.37	**$525.47**
50	$39.28	$383.46	**$344.18**	$297.97	**$642.15**
150	$117.83	$383.02	**$265.19**	$320.78	**$585.97**

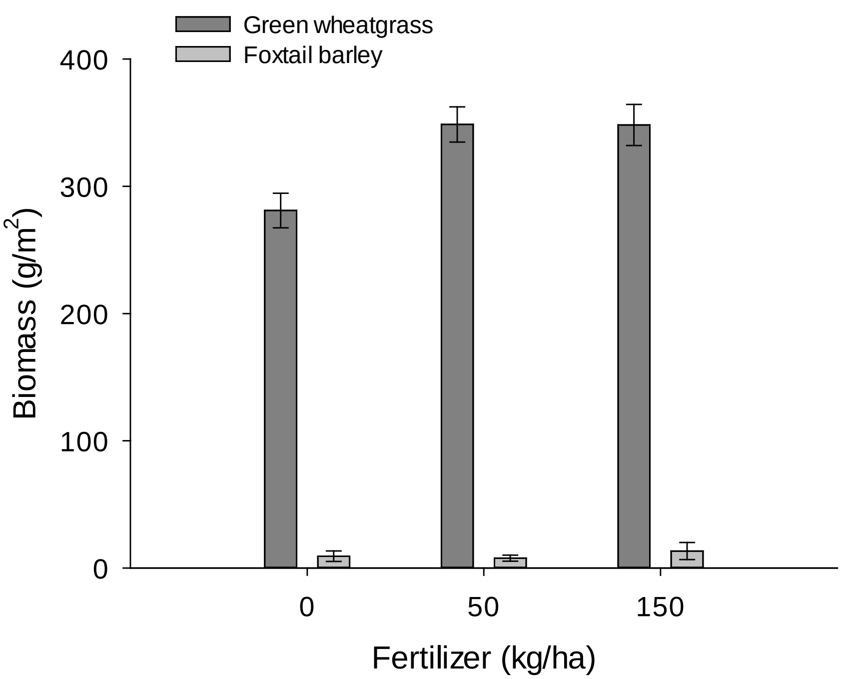

Figure 3. Mean 2014 above-ground biomass of AC Saltlander green wheatgrass and foxtail barley under three different nitrogen application treatments at Swift Current Research and Development Centre North Farm.

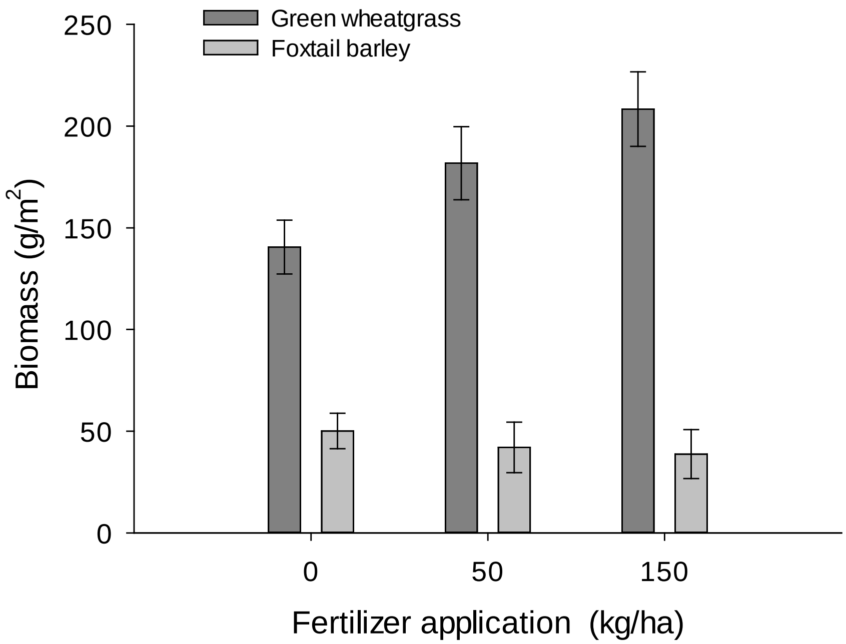

Figure 4. Mean 2014 above-ground biomass of AC Saltlander green wheatgrass and foxtail barley under three different nitrogen application treatments at Swift Current Research and Development Centre North Farm.

Table 11. Average foxtail barley yield expressed as a percentage of the total biomass of AC Saltlander green wheatgrass and foxtail barley combined.

	Percent of total yield	
N Applied kg/ha	2014	2015
0	9.3[a]	27.5[a]
50	7.7[a]	18.0[a]
150	13.3[a]	14.9[a]
RMSE	6.8	19.4
Prob > F	0.71	0.17

* Significance at the 0.05 α error level. Values within each column followed by the same lower case letter do not differ significantly at P α ≤ 0.05 according to the paired means Student's t – tests.

Conclusions

From these preliminary results, it appears that yields can be increased with the addition of nitrogen fertilizer, even on a severely saline site. Whether it is economical to do so would depend on the price of the fertilizer and the price of the forage produced. If fertilizer prices are high and forage prices are low, it may not be economical to fertilize. On fields where the salinity is high, money for fertilizer may be better spent on a less saline site with the possibility of higher returns. Another factor to consider, however, is that it appears the addition of the fertilizer seems to allow the forage to better compete with foxtail barley, which seems ever present on these sites. Fertilizing may also be an option to extend the life of the stand as a productive sward, especially since breaking the stand may result in difficulty in re-establishing forages. Future harvests on this site may yet reach a conclusion regarding the best rate of fertilization, as the higher rate may continue to produce residual returns with higher biomass. Future research may examine the impacts of the lower application rate (50 kg/ha) on an annual basis, as this may in fact show the best rate of return on a well-established forage on a saline site. Other options may include the use of “Super U” or other forms of slow release nitrogen products to limit volatilization.

References

Bresler, E., B.L. McNeal and D.L. Carter. 1982. Saline and Sodic Soils. Advanced series in agricultural sciences number 10. Springer-Verlag, Berlin, Germany. 236 pp.

Hendry, M.J. and B.D Buckland. 1990. Causes of soil salinization:1. A basin in southern Alberta, Cananda. Ground Water 28:389-393.

McKenzie, R.C. 1998. Tolerance of plants to soil salinity. Pages 262-304 in Soil and Water Program, 1987. Alberta Special Crops and Horticultural Research Centre Pamphlet 88-10. Alberta Agriculture, Brooks, AB.

SAS Institute Inc. 2009. JMP (Version 9.0.0) Statistical Discovery Software. SAS Institute, Inc., Cary, NC.

Shannon, M.C., C.M. Grieve and L.E. Francois. 1994. Whole plant response to salinity. Pages 192-244 in R. E. Wilkinson, ed. Handbook of plant environment interactions. Marcel Dekker Inc., New York, NY.

Springer, B. 1999. Rejuvenation of Tame Forages in Southern Saskatchewan, Grazing and Pasture Technology Program, Saskatchewan Ministry of Agriculture.

Steppuhn, H. and K.H. Asay. 2005. Emergence, height, and yield of tall, NewHy, and green wheatgrass forage crops grown in saline root zones. Can J. Plant Sci. 85:863-875.

Steppuhn, H., P.G. Jefferson, A.D. Iwaasa, and J.G. Mcleod. 2006. AC Saltlander Green Wheatgrass. Can J. Plant Sci. 86:1161-1164.