Soil-Plant Factors in Early Browning of Russian Wildrye on Natrustoll Soils

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Abstract

The occurrence of early browning in selected areas of a 1979-established Russian wildrye (*Elymus junceus* Fisch.) plot led to a comparison of soil-plant-water relationships in the brown senescing areas, and in adjacent green healthy areas. Although the green areas exhibited better nutrient status and less salinity-sodicity associated problems than the brown areas, the main problem and cause for this premature browning appeared to be water related.

A main objective of the rehabilitation program of the saltgrass meadows soils at the Central Plains Experimental Range (CPER) is to replace the largely unpalatable inland saltgrass [*Distichlis stricta* (Torr.) Rydb.] with better forage grasses and legumes for livestock consumption. These improved forages must be tolerant to drought stress and at the same time tolerant to saline-sodic soil conditions (McGinnies et al. 1976). Russian wildrye (*Elymus junceus* Fisch.) is one such species which is presently being used at the CPER to replace inland saltgrass.

For 2 consecutive seasons (1980, 1981) early browning has been noted in certain areas of a 1979-established Russian wildrye plot (40 m × 6 m). These brown areas varied from entire sub-plots (5 m × 6 m) to parts of a sub-plot (1 m × 0.5 m). In 1981, we sampled 2 contrasting areas to assess soil and plant characteristics of both areas.

Methods and Materials

Study Area

Site description data have been reported by McGinnies et al. (1976). The area is dominated by an Avar sandy loam which is classified as fine, montmorillonitic, mesic, typic Natrustoll. Mean annual precipitation is about 310 mm, most of which occurs between May and September. Frost-free period averages about 133 days per year with an average daily minimum of 9°C and an average daily maximum of 26°C. The study area was conventionally tilled (plowed and disked) and seeded with Vinall Russian wildrye in the spring of 1979.

Soil-Plant Methodology

Soil samples were taken in July 1981 from areas that exhibited green and brown Russian wildrye plants in close proximity (about 3 m apart). These areas were similar in topography and slope. Four matched pair samples were taken: 2 from a large brown area (6 m × 5 m) and 2 from small brown areas (0.5–1.0 m²). Green areas were sampled as closely as possible to the matched brown areas without

sampling transitional areas. A soil coring device was used to obtain entire plants and soil cores 80 cm long and 15 cm in diameter from both areas. Soil cores were subdivided into 10-cm increments and taken to the laboratory for plant and soil analyses. Plant samples were dried at 70°C for 1 day, and plant dry matter production was determined. Root weights were determined for dry matter production at 10-cm increments. All plant materials were ground and wet digested in sulfuric acid (H₂SO₄) for nitrogen (N), phosphorus (P) (Technicon Autoanalyzer), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), iron (Fe), zinc (Zn), copper (Cu), and manganese (Mn) (Atomic adsorption spectrophotometry). Boron (B) was determined on plant tops only (Soltanpour and Workman 1981).

Gravimetric soil moisture was determined on each 10-cm soil increment (Gardner 1965) on freshly collected samples. Percent moisture (weight) was determined at 1/3 bar and 15 bars pressure. Air-dried samples from each 10-cm increment of soil were analyzed for total Kjeldahl N (TKN) (Bremner 1965), organic matter (OM) (Allison 1965) sodium bicarbonate-soluble P (NaHCO₃-P) (Olsen et al., 1954), texture (Day 1965), pH, electrical conductivity (EC), and sodium adsorption ratio (SAR) from saturation extracts (Richards 1954). A *T*-test comparison of the green and brown areas was determined on all soil and plant parameters except for micronutrients.

Results and Discussion

Soil Properties

Composited soil physical and chemical characteristics with depth are shown in Table 1 for green and brown areas. The fact that these areas were within 3 meters of each other demonstrates the wide soil variability that exists (McGinnies et al. 1976). While the 0–10 cm layer classified as sandy loams for both areas, some brown areas had twice as much clay at the lower depths as did the green areas. In some instances as much as 40% clay was found in the brown areas. The green areas at this shallowest depth contained more silt. The textural difference at the 30-cm depth probably greatly influenced plant growth characteristics because of its effect on water movement from above (precipitation), and from below (capillary movement from a shallow water table).

Nutrient availability indices (OM, TKN, NaHCO₃-P) were higher for the green areas. This relationship was not unexpected since the more favorable conditions in the green areas led to more top and root production, and consequently, more cycling and concentration of organic matter. Phosphorus was higher in the green areas for the surface soils. There was generally more mineral P at the lower depths in the brown areas. The slightly higher P values in the surface soil of the green areas probably resulted from

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Table 1. Physical and chemical soil characteristics of green and brown areas of Russian wildrye.

Parameters	Depth (cm)							
	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80
Green Area								
Organic matter (%)	4.22*	3.60*	1.65*	0.89*	0.72*	0.24	0.21	0.31
Total Kjeldahl nitrogen (%)	0.23*	0.21*	0.10*	0.06*	0.03	—	—	—
NaHCO ₃ -P (μg/g)	16*	14	9	7*	7	6	6	5
pH	7.4	7.4*	7.4*	7.5*	8.0*	7.5*	8.3	8.4
Electrical conductivity (dS/m)	0.88	0.91*	0.81*	1.00*	2.38*	0.91*	0.97*	1.10
Sodium adsorption ratio	0.29	1.81*	0.71*	1.29*	3.15*	3.36*	4.54*	4.36
Sand (%)	55	60	52	49	69	86*	88*	88
Silt (%)	35	28	34*	35*	21*	5*	5*	4
Clay (%)	10	12	14*	16*	10*	9*	7*	8
Brown Area								
Organic matter (%)	1.68	0.76	0.45	0.35	0.28	0.31	—	—
Total Kjeldahl nitrogen (%)	0.11	0.11	0.05	0.01	0.01	—	—	—
NaHCO ₃ -P (μg/g)	12	12	16	20	10	11	10	—
pH	7.4	8.4	8.9	9.2	9.2	9.1	8.8	—
Electrical conductivity (dS/m)	0.96	4.73	14.9	23.9	20.0	28.9	32.5	—
Sodium adsorption ratio	5.00	20.8	60.5	27.8	68.8	40.8	32.0	—
Sand (%)	59	63	62	59	62	61	56	—
Silt (%)	29	27	8	11	12	15	22	—
Clay (%)	12	10	30	30	26	24	22	—

*Denotes significant differences at the 5% level between green and brown means for the same depth.

greater organic matter P mineralization while the lower values below resulted from greater use of mineral P (more growth).

Salinity, sodicity indices in the brown areas indicated severe Na and salt problems. In the undisturbed areas the high Na at the 10-20 cm depth coupled with the transport of clay from above have created a natric horizon. This region (primarily B2nt) is extremely hard and impermeable to water from the top A horizon and from the bottom C horizon. In the plowed area sealing had quickly occurred in the top few centimeters in the brown areas because of the inversion of C horizon (high Na) materials (Mueller 1983). Thus the condition for water intake had deteriorated from that provided initially by the natural soil (Robinson and Franklin 1971). Because of the dispersed nature of the soil and the sealing created by the downward movement of clay, rainfall precipitation in excess of A horizon field capacity resulted in standing water and

subsequent evaporation and lateral run-off to natural drainages. Because the soil water in the C horizon under the brown areas could not be readily replaced by downward percolation, and because capillary movement upward was slow, the soil moisture in the profile was below wilting point to a depth of 50 cm in the brown areas (Fig. 1). In the green area, soil moisture was in the "available" range (between 15 and 1/3 bar suction) below 20 cm; this soil moisture kept the plants growing in the green area. Roots of the green plants extended to at least a depth of 60 cm to make use of this available water. In the brown areas, the high salt content in the soil below 20 cm had the combined effect of creating an estimated osmotic potential of 30 bars (estimated from EC) that further restricted water absorption by the plants.

As shown in Mueller's thesis work (1983) the problem of sealing resulted from plowing bringing the C horizon to the surface. Soil reaction at the C Horizon (pH>9.0) indicated high

Table 2. Dry matter (DM) yield and chemical composition of Russian wildrye roots and tops associated with green and brown plants.

Depth (cm)	N	P	K	Ca	Mg	Na	Fe	Zn	Cu	Mn	B	DM
	—(%)—						—μg/g—					g
Green Area Roots												
0-10	0.94	0.17	0.36	0.34	0.11	0.08*	378	97	20	90		9.1*
10-20	1.05	0.19	0.42	0.28	0.10	0.05*	580	118	20	81		2.6
20-30	0.99	0.20	0.44	0.44	0.10	0.10*	190	114	22	75		1.0
30-40	0.95	0.19	0.44	0.40	0.16	0.12*	272	125	27	72		0.6
40-50	0.49	0.10	0.09	0.18	0.12	0.16	295	118	20	43		0.5
50-60	0.10	0.07	0.18	0.14	0.12	0.20	216	84	21	36		0.4
Brown Area Roots												
0-10	1.16	0.15	0.58	0.33	0.15	0.15	460	95	24	103		5.1
10-20	1.28	0.14	0.37	0.60	0.19*	0.26	505	128	25	100		3.6
20-30	1.11	0.14	0.44	0.35	0.13	0.77	318	110	24	65		1.0
30-40	0.49	0.05	0.14	0.14	0.06	0.42	269	110	18	36		0.1
40-50	—	—	—	—	—	—	—	—	—	—		—
50-60	—	—	—	—	—	—	—	—	—	—		—
Tops												
Green	1.28	0.18	2.30*	0.19	0.19	0.07	434	99	17	87	11	61.4*
Brown	1.22	0.16	1.00	0.17	0.16	0.05	486	99	14	109	10	12.6

*Denotes significant differences at the 5% level between green and brown means for the same depth.

SOIL WATER (%)

Fig. 1. Soil water relationships with depth in green and brown areas.

concentrations of carbonates and bicarbonates with the typical salt being primarily sodium sulfate (Na_2SO_4), sodium chloride (NaCl), and sodium bicarbonate-carbonate ($\text{NaHCO}_3\text{-Na}_2\text{CO}_3$) (McGinnies and Ludwig 1978). This predominance of Na_2CO_3 over CaCO_3 ($\text{pH} > 9.5$ in many instances) makes deep-plowing a questionable practice since the resultant seedbed is more apt to seal, crust, puddle, and provide greater osmotic stress (Toogood and Cairns 1978).

Plant Properties

The Russian wildrye plant data for both areas are given in Table 2. The most striking difference in areas was reflected by the five-fold increase in dry matter production in the green area over the brown area. Nutrient content in the tops at both areas did not suggest any major differences except maybe with respect to potassium (K), which could have been physically leached in the brown plants (Tukey 1970), and to manganese (Mn), which probably was still within acceptable limits of sufficiency (Epstein 1972). Specific toxic ions such as Na and B did not accumulate in large quantities in tops of the senescing Russian wildrye. Low sodium values in tops could be partially attributed to leaching and to specific uptake characteristics of Russian wildrye which appeared to possess an exclusion mechanism for Na (Bowman and McGinnies, 1981).

Root data showed green area root penetration of 60 cm while penetration in the brown area was only about one-half of that. Differences in root biomass, however, were not as dramatic as those found in the tops (14.2 g versus 9.8 g). Since the soil coring device was 15 cm in diameter, roots outside of this area were not included in our sampling. Thus, some roots were not accounted for and this loss would possibly be greater for the green area than for the brown (more superficial lateral roots).

Root chemical composition in the 2 areas primarily showed uptake differences with respect to Na. Brown area roots exhibited nearly 0.8% Na at the 30-40 cm depth, but this amount became less at the surface horizons. Green area roots had substantially less Na uptake. The K-Ca data suggested much greater resistance for Ca

movement to the tops than for K, but this phenomenon occurred in both areas. While the $36 \mu\text{g Mn/g}$ appeared low, greater uptake at the surface soils resulted in adequate amounts of Mn in the plant tops. High Fe values suggested some soil contamination.

Soil-plant interactions

Saline-sodic soils show unique relationships with respect to horizon stratifications and to Na and Ca relationships (Richards, 1954). This Na to Ca relationship was also expressed in the Russian wildrye plants (Fig. 2). At the 40-cm depth, roots in the brown

Fig. 2. Na/Ca ratios of Russian wildrye roots as a function of depth in green and brown areas.

areas showed a 10-fold increase in the Na/Ca ratio over the green area roots. However, this relationship did not appear to affect the plant tops. This ratio narrowed at the lower depths since both SAR and EC increased in the green areas.

Various plant nutrient ratios were correlated with soil SAR. Plant Na/Ca ratio was not significant, but both $\text{Na}/\text{Ca}^{1/2}$, and $\text{Na}/[\text{Ca} + \text{Mg}]^{1/2}$ ratios were significant with SAR. Using plant K values did not improve correlations with soil SAR.

Conclusions

Russian wildrye did not show any excessive nutrient concentrations associated with salinity, sodicity, or boron. The roots did show some high Na concentrations in the brown areas. While salinity and sodicity contributed to the early browning noted in the field, it appeared that the main mechanisms affecting these changes were related to moisture availability. It can be postulated that in the brown areas, moisture was quickly lost to evapotranspiration because of the shallow or sparse nature of A horizon material and the impervious nature of the sealed lower horizon. This condition probably led to shallow and sparse rooting which in turn resulted in quick desiccation under relatively short dry spells (1-2 weeks without added precipitation). Field observations indicate that the movement of water in the unrestricted zones of the green areas (presence of greater water storage capacity) resulted in completion of the life-cycle and production of seed heads in Russian wildrye. Restricted water movement in the brown areas resulted in failure or significant delay of plants to complete their life-cycle and produce seed heads as was also noted by Dodd and Coupland (1966).

Although field testing to alleviate this problem is still in progress, it would appear that any cultural practice that improves or maintains water storage capacity (mulching, manuring, minimal disturbance of C horizon material) would help to solve this problem.

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