Effects of Tillage and Manure on Emergence and Establishment of Russian Wildrye in a Saltgrass Meadow

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Saltgrass [*Distichlis stricta* (Torr.) Rydb.] meadows are found in lowland areas throughout the western United States. Saltgrass meadows are frequently more moist than upland sites and have good production potential if relatively unpalatable saltgrass is replaced by a more palatable species. The electrical conductivity and sodium absorption ratio of saltgrass meadow soils often increase with soil profile depth, while total N and sodium-bicarbonate extractable P decrease. Cultural practices that do not mix the deeper, more saline horizons with the surface should increase seedling germination and establishment. Field studies evaluated the effects of chisel plowing followed by vertical-axis tilling, conventional tilling (moldboard-plowing and discing), and manure (0, 11, 22, 45, and 90 Mg/ha) on soil physical and chemical characteristics as they relate to germination and establishment of Russian wildrye [*Elymus junceus* Fisch.]. Chisel plowing followed by vertical-axis tilling increased seedling emergence by 23% over conventional tillage. Manure increased seedling growth and emergence, but had no effect on stand ratings. The poor physical conditions created on the conventionally tilled plots when the B and C horizons were brought to the surface and organic matter was buried by the plow are believed to have caused the difference in seedling counts between the two tillage treatments.

Saltgrass [*Distichlis stricta* (Torr.) Rydb.] meadows, found on lowland sites throughout the western United States, cover an estimated 500,000 ha in Colorado and Wyoming (Osborn 1974). These meadows are frequently more moist than upland sites and have good production potential if low-value saltgrass is replaced by more palatable species (Ludwig and McGinnies 1978). However, reclaiming salt-affected soils under semiarid conditions without irrigation water is difficult. These lands are usually marginally productive and precipitation is inadequate to leach salts from the root zone. Soil crusting, low fertility, high soluble salt concentrations, high exchangeable sodium, and poor soil structure limit establishment of more desirable species (Ludwig 1976).

Although chemical and organic amendments have been used to rehabilitate dryland saline-sodic soils in the past (Carter et al. 1977, Bower et al. 1951), the quantity of chemicals needed in order to have any ameliorative effect may be uneconomical (Downey 1971, Doering and Willis 1975). Cultural practices such as deep plowing provide an alternative to chemical and organic amendments. Deep plowing increased root penetration, infiltration rates, and yields on saline soils in Canada and North Dakota (Cairns 1967, Sandoval and Richman 1971). However, deep plowing should be avoided on soils that have a highly saline-sodic C horizon that is low in calcium, because of reduced yields when the C horizon is mixed with the A and B horizons (McGinnies and Ludwig 1977). Plowing also may create problems in seedbed preparation by bringing the hard B horizon to the surface (Toogood and Cairns 1978). Therefore, studies were undertaken to identify and evaluate cultural practices that would not bring detrimental subsurface horizons to the surface, and to determine whether manure would help ameliorate the physical and fertility problems associated with saltgrass soils.

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Study Area and Methods

The study area was located along Eastman Creek on a saltgrass meadow at the Central Plains Experimental Range, 19 km northeast of Nunn, Colo. The mean annual precipitation is 31 cm with 85% occurring between May and September. Precipitation for 1981 and 1982 was 29.9 and 41.7 cm, respectively. Summer temperatures range from an average minimum of 9.0°C to an average maximum of 25.5°C. The mean annual temperature is 8.0°C. Annual average wind velocity is 10.3 km/h and the frost-free growing period averages 133 days. Soils on the saltgrass meadow are mostly fine-loamy mixed mesic Ustollic Natrargids of the Avar fine sandy loam series. Soluble salt concentrations and exchangeable sodium increase and fertility decreases with depth (Mueller 1983). The C horizon contains low concentrations of calcium and high concentrations of carbonates, bicarbonates, sulfates, and sodium (McGinnies and Ludwig 1978). Existing dominant species are inland saltgrass, alkali sacaton (*Sporobolus airoides* Torr.), blue grama [*Bouteloua gracilis* (H.B.K.) Lag.], western wheatgrass (*Agropyron smithii* Rydb.), and sedges (*Carex* spp.) (McGinnies et al. 1976).

A field study was initiated in the fall of 1980 to compare the effects of chisel plowing followed by tilling with a tiller that mixes the soil horizontally (vertical-axis tillage) with effects of plowing and discing (conventional tillage), both at 5 levels of manure (0, 11, 22, 45, and 90 Mg/ha) on the establishment of Russian wildrye (*Elymus junceus* Fisch. 'Vinall'). Four replicates were established on an area that had been sprayed with 4.6 kg/ha of glyphosate [N(phosphonmethyl) glycine] to control saltgrass in August of 1978 and 1980. The other 4 replicates of the study were located adjacent to the first on an area that was sprayed with glyphosate only in August 1980. Half of each replication was moldboard plowed to a depth of 20 cm in the fall of 1980; the other half was vertical-axis tilled to the same depth in the spring of 1981 after chisel plows, set 0.3 m apart and 20 cm deep, were used to loosen the sod.

Five levels of manure were randomly applied to subplots within each replication of each tillage treatment in the spring of 1981. The manure plots were 2.9-by 4.7-m. The manure was incorporated into the soil with a disc on the conventionally tilled treatments, and with the vertical-axis tiller on the vertical-axis tilled treatment. All plots were cultipacked and then planted on 24 April 1981 to Russian wildrye, in rows 0.3 m apart at 100 live seeds per meter of row, with a double-disc drill equipped with 2-cm depth bands.

Seedlings were counted and height measured 3-4 June and 14-21 July 1981. Stands were rated 24-29 September 1981 and 25 August 1982 on a scale from 0 to 10 with 0 representing no seedling establishment and 10 representing the maximum stand that could be expected on that particular site (McGinnies et al. 1983). Seedling counts and ratings were made on four 0.9-m segments in separate rows within the middle of each subplot.

Soil moisture to a depth of 20 cm was determined gravimetrically on the 0, 22, and 90 Mg/ha manure plots immediately after a heavy rain that fell 18 May 1981. Soil samples were taken on 7 July

1981 from the 0, 22, and 90 Mg/ha manure plots at depth increments of 0 to 10 and 10 to 20 cm. Sodium-bicarbonate extractable phosphorus (Olsen and Dean 1965), total Kjeldahl nitrogen (Bremner 1965), pH, electrical conductivity (EC), sodium adsorption ratio (SAR) (Richards 1954), and texture (Day 1965) were determined on the 0 to 10- and 10 to 20-cm soil samples. On 16 November 1981, soil samples taken from the surface (2 cm) of each treatment were analyzed for texture, $NaHCO_3$-extractable P, pH, EC, and SAR. Soil samples were air dried and passed through a 1-mm screen before analysis. All soil samples and moisture data were taken from the 4 replications which had been previously sprayed in 1978 and 1980.

Weeds were controlled by a single application of 2,4-D [(2,4-dichlorophenoxy)acetic acid)] at 0.37 kg/ha in June 1981, and by a hand-pushed power mower in July and August.

To analyse the plant data a split-split-plot analysis of variance was used, after the variance of the 2 areas were found to be homogeneous. Areas, tillage treatment, and manure rate were main, sub-, and sub-sub-plots, respectively. A randomized block in a split-plot analysis of variance was used to evaluate the soils and moisture data. Conventional linear multiple regression techniques were used where appropriate.

Results and Discussion

It was assumed that the vertical-axis tiller, which mixes soil horizontally but not vertically with its tines, would avoid bringing the deeper salt-affected horizons to the surface. The 0 to 10 cm soil depth on the vertical-axis tilled treatments had significantly ($P\leq0.05$) lower pH and SAR values and significantly ($P\leq0.05$) higher N and P values than the 10 to 20 cm soil depth (Table 1).

Table 1. Effect of tillage and depth on pH, EC, SAR, total N, and NaHCO³-extractable P of soils collected July 7, 1981 at depths of 0 to 10 and 10 to 20 cm.[1]

	Vertical-Axis Tillage		Conventional Tillage	
Soil parameters	Depth (0–10 cm)	Depth (10–20 cm)	Depth (0–10 cm)	Depth (10–20 cm)
pH	7.0 a	7.5 b	7.4 x	7.4 x
EC (dS/m)	1.8 a	1.5 a	1.8 x	1.8 x
SAR	4.0 a	6.4 b	5.0 x	5.3 x
N (ug/g)	1590 b	1029 a	1089 x	1694 y
P (ug/g)	41.1 b	14.0 a	16.7 x	18.9 x

[1]Means within each tillage treatment with same letter are not significantly different ($P\leq0.05$).

This same trend was observed in a baseline study done on undisturbed sites within the saltgrass area (Mueller 1983). Therefore little vertical mixing of the original soil profile occurred as a result of vertical-axis tillage.

On the conventionally tilled plots, total N in the 0 to 10 cm soil depth was significantly ($P\leq0.05$) lower than total N in the 10 to 20-cm soil depth. There were no significant ($P\leq0.05$) differences between sampling depths for other soil parameters (Table 1), but surface pH and SAR were significantly ($P\leq0.05$) higher on the conventionally tilled plots than on the vertical-axis tilled plots (Table 2). These data indicated that plowing deposited some saline-sodic horizon material on the surface while simultaneously burying the thin topsoil layer, high in organic matter and N. Subsequent discing, which was not as deep as the plowing, thoroughly mixed the saline-sodic material initially deposited on the surface, and thus reduced differences in salinity between depths (the disc penetrated to an average of 15 cm).

Russian wildrye seedlings were taller on the vertical-axis tilled plots. Vertical-axis tillage increased seedling emergence (June 3-4) by 23% over conventional tillage (Table 3). Seedling counts and stand ratings on the vertical-axis tilled plots remained significantly ($P\leq0.05$) higher throughout 1981 and 1982.

Table 2. Effect of tillage on pH, EC, SAR, and texture of surface soils (0–2.0 cm) collected November 16, 1981.[1]

	Tillage	
Soil Parameters	Conventional	Vertical-Axis
pH	7.6 b	7.2 a
EC (dS/m)	1.8 a	0.8 a
SAR	4.4 b	1.1 a
Sand (%)	45.0 a	37.0 a
Silt (%)	26.0 a	35.0 b
Clay (%)	29.0 a	28.0 a

[1]Means with the same letter are not significantly different ($P\leq0.05$).

Table 3. Effect of tillage treatment and manure application rate on seedling heights and stand during 1981 and 1982.[1]

		Tillage	
Plant Measurements	Days After Planting	Conventional	Vertical-axis
Seedling Heights, cm June 3–4, 1981	40–41	6.7 a	8.1 b
Seedlings/m row June–4, 1981	40–41	29.0 a	36.0 b
Seedlings/m row July 14–21, 1981	81–88	22.0 a	28.0 b
Stand Rating (0 = none, 10 = solid) September 15–25, 1981	158–168	3.9 a	5.4 b
Stand Rating (0 = none, 10 = solid) August 25, 1982	439	5.9 a	7.0 b

[1]Means with the same letter are not significantly different ($P\leq0.05$).

Better establishment was expected after vertical-axis tillage than after conventional tillage because plowing was suspected of increasing surface salinity and sodicity to levels that would inhibit either germination or seedling establishment. Although plowing produced average surface pH and SAR values that were significantly ($P\leq0.05$) higher than on the vertical-axis tilled treatments, germination and establishment with conventional tillage was still high. Russian wildrye has been considered to be well adapted to moderately salty lands (Plummer et al. 1955, Rauser and Crowle 1963). However, the range of SAR (0.44 to 11.62) on the conventionally tilled treatments reached levels that could have an adverse effect on soil physical properties (Jayawardane and Beattie 1978) and thus on seedling emergence and survival. Linear multiple regression showed the first seedling count on the conventionally tilled plots to be highly correlated with clay content, SAR, EC, and manure (R=0.84). Clay content and SAR were negatively correlated with seedling counts, whereas EC and manure were positively correlated. There were no significant ($P\leq0.05$) negative correlations between the first seedling count and surface soil parameters on the vertical-axis tilled plots.

Table 4. Regression equation for seedlings/m (S) and seedling ht. (cm) (H) on conventionally tilled and vertical-axis tilled plot as a function of manure application rate (Mg/ha) (M).

Tillage	Regression equation	R^2
Conventional	S = 26.88 + 0.05 M	.63
	H = 5.67 + 0.03 M	.97
Vertical-axis	S = 33.09 + 0.07 M	.95
	H = 6.72 + 0.46 Logan (M+1)	.92

Past studies have shown that the combination of montmorrillonite clay, high Na, and low organic matter can result in poor soil physical properties (Richards 1954, Lemos and Lutz 1957). Frequent and severe crusting as well as rough, cloddy seedbed were observed in areas where seedling stands were poor. Therefore, the poor physical conditions on the conventionally tilled plots, created when the sodic B and C horizons were brought to the surface and the A horizon with its high organic matter content was buried, are believed to have resulted in the difference in seedling counts between the two tillage treatments.

The vertical-axis tiller broke clods into smaller aggregates and produced a smoother, more level seedbed than a disc and harrow. This may have also contributed to the higher seedling count on the vertical-axis tilled plots by providing better contact between seed and soil and a more uniform planting depth. However, both vertical-axis tilling and/or discing and harrowing can result in a poor seedbed when saline-sodic horizons are brought to the surface. Toogood and Cairns (1978) have also reported that plowing created problems in seedbed preparation on Solonetzic soils by bringing the hard B horizon to the surface.

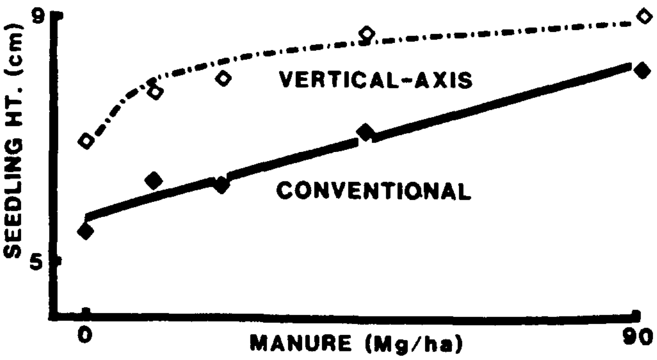

Fig. 1. *Relationship between seedling and manure on the vertical-axis and conventionally tilled plots during June 1981.*

Vertical-axis tilling failed to bury most weed seeds deeply enough to prevent their germination and emergence, resulting in abundant weed growth, predominately summer-cypress [*Kochia scoparia* (L.) Schrad.] and lambsquarter (*Chenopodium album* L.). Better weed control would have probably resulted in even greater differences between the two tillage treatments.

Regression analysis showed a positive effect of manure on early-June seedling heights and emergence (Fig. 1 and Fig. 2). The effect

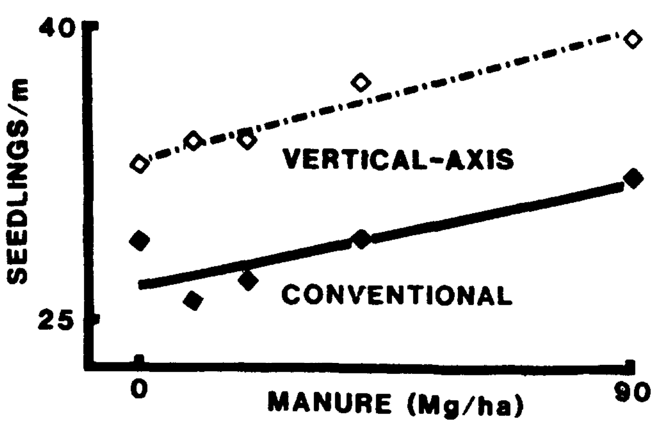

Fig. 2. *Relationships between seedlings/m and manure on the vertical-axis and conventionally tilled plots during June 1981.*

of manure on seedling heights within the vertical-axis tilled plots decreased at application rates above 11 Mg/ha. Seedling heights on the conventionally-tilled plots and seedlings/m on both tillage treatments increased linearly throughout the manure application rates used in the study. Reasons for responses of Russian wildrye to manure cannot be definitively determined from the data. Although nitrogen and phosphorus levels were significantly ($P \leq 0.05$) higher than the control on the 90 Mg/ha manure plots, regression analysis did not show any significant positive correlations between these soil parameters and seedling heights or seedling counts. Vertical-axis tilled plots had higher soil water content than conventional-tilled plots at ($P \leq 0.10$) but there was no difference in soil water content between manure treatments.

The vertical-axis tiller produced a better seedbed than conventional tillage methods by breaking the soil into smaller aggregates, not bringing saline horizons to the surface, leaving organic matter on the surface, and reducing the severity and frequency of soil crusting.

To avoid bringing the B or C horizon to the surface, chisel plowing followed by vertical-axis tilling is recommended on areas that have a shallow A horizon (less than 20 cm). If the A horizon is deep (greater than 20 cm) moldboard plowing followed by vertical-axis tilling is recommended, because moldboard plowing controls the weeds better than chisel plowing. Russian wildrye emergence and establishment were improved by using a vertical-axis tiller on the saltgrass meadow. Although the vertical-axis tiller did not control weeds as well as conventional tillage, it produced a better seedbed.

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